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PT-IP-263-A-FP
EVALUATION OF CHEMICALLY NICKEL PLATED
FUEL ELEMENTS

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AUTHOR

R. E. HALL
M. A. CLINTON

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EVALUATION OF CHEMICALLY NICKEL PLATED FUEL ELEMENTS

by

R. E. Hall

&

M. A. Clinton

April 20, 1960

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EVALUATION OF CHEMICALLY NICKEL PLATED FUEL ELEMENTS

OBJECTIVE

The objective of this test is to determine, through in-reactor testing, the resistance to corrosion of nickel plated fuel elements, plated by a chemical deposition technique.

TEST SUMMARY

This program may eventually be composed of the following portions, the first of which is authorized by this test:

1. Irradiate ten columns of 0.5 mil chemically nickel-plated C-64 OIIN fuel elements having various heat treatments, each alternated with X-8001 control pieces. Two columns will be exposed to 400 MWD/T and eight to 800 MWD/T.
2. Should results from the above test be encouraging, separate authorization for the following tests may be requested:
 - a. Irradiate four columns of nickel-plated fuel and four of X-8001 clad fuel, both groups having purposely cocked pieces, until two ruptures are sustained in each group or until a factor of improvements of 40 is demonstrated at the 95% confidence level, unless the nickel-plated elements fail first.
 - b. Irradiate five columns of chemically nickel-plated C-64 clad OIIN fuel elements, alternating 0.2 mil and 0.5 mil plate, heat treated at 300°C for six hours. Two columns will be discharged at 400 MWD/T and three columns at 800 MWD/T exposure.
 - c. Irradiate approximately thirty columns of nickel-plated, C-64 alloy clad fuel elements to 200 per cent of normal goal exposure to extend the evaluation of nickel-plated fuel elements on a pilot scale.

BASIS AND JUSTIFICATION

Application of a nickel corrosion barrier to fuel elements appears feasible as a means of extending the useful range of the AlSi aluminum cladding process. The nickel plate has been found to be extremely resistant to corrosive attack in caustic (NaOH) and in boiling water near a pH of 7.0, and is used fairly extensively where corrosion resistance or cleanliness are required and stainless steel is either uneconomic or unacceptable. Two primary processes have been developed for this purpose, electroplating and chemplating, both of which will deposit thin plates on aluminum. Both of these processes have inherent inadequacies; however, both could be adapted for plating of HAP0 fuel elements. The chemplate is more brittle than the electroplate and contains up to 10% of phosphorous; however, the process provides excellent plate thickness control down to 0.0001" plates and is insensitive to irregularities, even pits, i.e., uniform plates could be applied to most geometries, including fuel elements, and the plate would cover minor pits and cracks in the weld area provided they

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are not excessively deep. This process, as an example, has been utilized to plate interior threads on bolts and insides of tubing. Plate thicknesses in the range of 0.5 mils are desirable to achieve adequate assurance of pore free plates.

The results of several preliminary tests which were recently completed include:⁽⁴⁾

1. In-reactor tests to evaluate effluent activity levels,
2. Ex-reactor tests to evaluate the corrosive properties of perfect and defected nickel plate, the effects⁽³⁾ of heat treatment after plating, and plate adherence tests utilizing hydrogen absorption, and
3. Radiometallurgy examination of fuel elements from in-reactor testing.⁽²⁾

The in-reactor tests indicated that effluent contamination will probably not be a problem for nickel plated elements and certainly should not restrict further testing. Since the test material lost its plating during irradiation, however, and since the test was shorter than desired, it will be necessary to again measure effluent activities prior to large scale use of nickel plated elements.

To improve nickel-aluminum adherence, post-plating heat treatment was investigated. It was assumed a nickel-aluminum diffusion bond could be formed with satisfactory mechanical strength and stability in an irradiation field, as demonstrated by experience with hot-press canned fuel elements. Comparatively, (in the electrolytic hydrogen blistering test) unbaked samples average about 40 per cent of surface area blistered, with some as high as 100 per cent. Samples of the same material baked for three hours at 300°C did not blister at all. Consistent improvement from baking is realized only if the plate has good adherence in the as-plated conditions, as determined by bend testing.

Examination of irradiated nickel-plated fuel elements and ex-reactor tests did not indicate that nickel spalling was due to corrosion of the underlying aluminum or to generation of cracks in the nickel plate as a result of thermal cycling. Spalling preferentially occurred in high-flux regions and was notably reduced or absent in regions of maximum surface temperature. Metallographic sections of slightly separated nickel plate and aluminum substrate did not reveal corrosion undercutting of the nickel. An ex-reactor test, attempting to reproduce the observed extensive nickel spalling through severe thermal cycling, was not successful.

Test results for improving nickel adherence are encouraging, indicating nickel-plating of aluminum-jacketed fuel elements has a high potential for achieving the benefits cited earlier. This test therefore will attempt to evaluate these gains.

TEST DETAILS

A. Fuel Elements

All fuel elements utilized in this test will be normal production OIIN fuel elements which will have passed all normal quality controls and

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have been processed within Process Standards. All test elements shall be C-64 clad while the controls are to be X-8001 clad. After cladding the test elements shall be plated with 0.0005" of Nickel by a chemical deposition process and after visual examination assembled into charges as noted below.

B. Pre-Irradiation Measurement

All pieces utilized for this test shall be weighed and measured in order that weight loss, warp, and diameter change may be obtained after irradiation. In addition all columns shall be numbered in ink with column and position numbers, which shall relate to piece numbers stamped in the end of each piece.

C. Charges

The following charges shall be required for the test for irradiation to the goal specified. All columns shall be charged in order with piece number 1 downstream.

Since it is desirable to attain worst case conditions for this test, tubes with residual walls above 55 mils and tube factors above 1.2 are requested. Probologging will attempt to evaluate tube damage caused by the nickel-aluminum galvanic couple (if it is a problem), and local high water temperatures. To attain desired irradiation conditions and tubes, discharge of green metal is authorized at the discretion of the test author.

<u>Charge No.</u>	<u>Test*</u>	<u>Fuel Element</u>	<u>Number Charge</u>	<u>Cocked Pieces</u>	<u>Probolog**</u>	<u>Goal</u>
1	1	OIIN, alternated nickel-plate on C-64 heat treated at 300°C for three hours and unplated X-8001	34	None	Yes	400
2-5	1	OIIN, alternated nickel-plate on C-64 heat treated at 300°C for three hours and unplated X-8001	34	None	Yes	800
6	1	OIIN, alternated nickel-plate on C-64 heat treated at 300°C for six hours and unplated X-8001	34	None	Yes	400
7-10	1	OIIN, alternated nickel-plate on C-64 heat treated at 300°C for six hours and unplated X-8001	34	None	Yes	800

* Refers to test summary section

** Tube to be probologged before and after irradiation

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D. Irradiation

During irradiation, daily temperature and weekly flow data shall be recorded for all tubes.

E. Discharge

All columns in this test shall be irradiated to the goal shown and discharged for special pickup. Should a rupture occur in any column of this test, it is desirable to recover all fuel elements from the rupture tube for examination. Any column which has attained its test objective and from which no further data are to be gained may be discharged early at the discretion of the test author.

F. Post-Irradiation Examination

Columns 1-10 shall be visually examined, weighed and measured (before cleaning) and re-weighed after cleaning to determine conditions of the plate, corrosion and slug stability. If possible a special cleaning solution will be utilized to prevent plate damage. Selected elements may also be photographed at the request of the test author.

G. Costs

All incremental costs incurred as a direct result of this test may be charged to XXXX-5320-XXX.04. Outage time and outage manhours which will be required to charge this test are indicated below for scheduling purposes:

<u>Job</u>	<u>Outage Time</u>	<u>Manpower</u>	<u>Total Outage Time</u>
1. Discharge with solid aluminum, flush for probolog.	1/4 hr/tube	3/4 mh/tube	2.5 hrs.
2. Probolog for charges 1-10.	1/8 hr/tube	1/8 mh/tube	1 hr.
3. Charge Columns 1-10.	1/8 hr/tube	1/2 mh/tube	1 hr.
4. Discharge for special pickup columns 1-10.	1/4 hr/tube	1 mh/tube	2.5 hrs.
5. Probolog tubes 1-10.	1/8 hr/tube	1/8 mh/tube	1 hr.
6. Return all tubes to normal	1/8 hr/tube	1/8 mh/tube	1 hr.
7. In addition rupture removal time for up to two ruptures may be required, and tube removal may be required if damage is encountered if less than predicted performance is experienced.			9 hrs.*

* This time assumes no overlapping of work and presumes that all work is chargeable outage time, and is therefore conservatively high.

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H. Hazards

This test will not be charged until it has been shown out-of-reactor that difficulties in nickel to aluminum bonding experience in PT-207-A⁽¹⁾ have been corrected; however, there still exists the possibility that nickel flaking will occur in-reactor. The two columns scheduled for discharge at 400 MWD/T will assist in evaluating the performance of this material in this respect. The potential, though reduced materially, still exists for a reactor scram caused by film flaking; so, it is recommended that panellit pressures for these columns be kept slightly lower than normal at the discretion of the Process Engineer.

RESPONSIBILITIES

Fuels Preparation Department

Manufacturing Operation

The Manufacturing Operation shall be responsible for canning all pieces by the "F" process, for normal quality control, and for pre-irradiation measurements and marking.

Engineering Operation

The Engineering Operation shall be responsible for liaison in the 300 Area portion of this test and for providing technical assistance. They shall also arrange for nickel plating of the test elements.

Irradiation Processing Department

Research and Engineering Section

Process Technology Subsection shall be responsible for assistance in scheduling, assistance in charging of the test, and for forwarding of operating data to the author.

Process and Reactor Development Subsection shall be responsible for coordination of the test, data analysis, and reporting of irradiation experience.

Testing Subsection shall be responsible for obtaining post-irradiation examination data.

Operational Physics Subsection shall be responsible for adjustments in reactivity as required by this test.

D-DR Reactor Operation

DR Processing Operation will be responsible for planning, scheduling the operational safety and production continuity of the reactor except as specified by this test, and for collection of routine operating data for the test.

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D-DR Maintenance Operation shall be responsible for all maintenance work required by this test.

Reactor Fuels Unit
Process and Reactor Development Subsection
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

Reactor Fuels Unit
Process and Reactor Development Subsection
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

RE Hall:MA Clinton:klm

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APPROVALS

<u>AWA</u> <u>J. H. Brown</u>	J. H. Brown, Manager Process and Reactor Development Subsection IRRADIATION PROCESSING DEPARTMENT
<u>R. W. Reid</u>	R. W. Reid, Manager Process Technology Subsection IRRADIATION PROCESSING DEPARTMENT
<u>G. C. Fullmer</u>	G. C. Fullmer, Manager Operational Physics Subsection IRRADIATION PROCESSING DEPARTMENT
<u>C. G. Lewis</u>	C. G. Lewis, Manager Testing Subsection IRRADIATION PROCESSING DEPARTMENT
<u>O. H. Greager</u>	O. H. Greager, Manager Research and Engineering Section IRRADIATION PROCESSING DEPARTMENT
<u>W. D. Richmond</u>	W. D. Richmond, Manager D-DR Reactor Operation IRRADIATION PROCESSING DEPARTMENT
<u>C. A. Priode</u>	C. A. Priode, Manager Production Operation IRRADIATION PROCESSING DEPARTMENT
<u>R. L. Dickeman</u>	R. L. Dickeman, Manager Manufacturing Section IRRADIATION PROCESSING DEPARTMENT

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