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TITLE

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

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

By

M. A. Clinton

July 10, 1961

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INTRODUCTION

Irradiation of the initial test in this program involving ten tubes of alternately charged nickel-plated C-64 alloy clad test elements and X-8001 alloy control elements has been successfully completed. The test indicated[1] that the nickel-plate spalling problem has been resolved as no significant spalling or flaking was observed during the post-irradiation examination. The second test in this program will be to verify the performance of nickel-plate with a pilot loading (up to 100 charges) of fuel elements which have been nickel-plated on a production basis.

OBJECTIVE

The objectives of this test are to demonstrate with a larger scale test that nickel-plate performs satisfactorily and that reducing the nominal plate thickness from .6 mil to .2 mil will not affect the performance of the nickel-plate fuel element.

TEST SUMMARY

This test authorizes the irradiation of up to 100 columns of OIIN, chemically nickel-plated, C-64 alloy jacketed fuel elements to 200 per cent of normal goal exposure to extend the evaluation of nickel-plated fuel elements on a pilot scale at DR Reactor. Seventy columns will be plated to a nominal thickness of .6 mil and thirty columns to a nominal .2 mil thickness. Twenty measured columns, ten representing each plate thickness, will be charged to monitor the irradiation performance. Effluent samples will be obtained during the course of the test from a pair of tubes, each tube containing a measured monitor charge representing each plate thickness.

BASIS AND JUSTIFICATION

The incentives and the highlights of the nickel-plate development and testing program have been covered in HW-68793[2]. The application of a thin coating of nickel on the coolant contacting surfaces of aluminum-jacketed fuel elements to provide additional corrosion resistance is attractive. Potential benefits of a nickel coating include a corrosion-resistance coating to protect against severe localized temperature conditions, reduction of mechanical damage to both fuel element jackets and process tube ribs, improved fuel element alignment (by reducing friction between fuel elements and process tube ribs) and probably lower over-all surface temperatures due to reduction in corrosion product film. Upon demonstration of improved corrosion resistance, utilization of a .2 mil thick plate on C-64 aluminum alloy could permit a decrease in can wall thickness and an accompanying increase in uranium volume and/or an increase in coolant flow annulus.

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(1) HW-69285, "Post-Irradiation Examination of Chemically Nickel-Plated Fuel Elements from PT-IP-263-A (RM-414)", By. W. J. Gruber, dated 4-17-61. Secret.

(2) HW-68793, "Incentives For Nickel Plating Aluminum Jacketed Fuel Elements", G. F. Jacky, dated 3-20-61, Secret.

While the major problems have included producing an adherent continuous plate of uniform thickness and evaluation of the possible reactor effluent contamination by radioactive nickel, cobalt and phosphorous, the test results to date have been encouraging and are summarized briefly below:

1. Satisfactory adhesion (probably 100 per cent) of 0.5 mil thick chemically deposited nickel-plate can be achieved as demonstrated by the irradiation performance of 136 nickel-plated fuel elements from eight charges exposed to a nominal 800 MWD/T[3].

2. Reactor effluent contamination fron nickel-plated fuel elements may be tolerable, based on data from four tubes irradiated to approximately 400 MWD/T at C Reactor[4]; however, these results are not extrapolatable to full reactor usage and further testing will be required.

3. Nickel-plate affords a high degree of corrosion protection in hot-spot areas[5]. Thirty-five of the 136 fuel elements[6] from charges which were irradiated to 800 MWD/T exhibited hot-spot corrosion patterns with no evidence of apparent aluminum corrosion. This observation was supported by the fact that weight loss of the nickel-plated elements was practically nil (six to fifteen fold less than the X-8001 jacketed control elements) in the region of maximum corrosion in the reactor.

4. Aluminum, in reactor process water, does not corrode at an accelerated rate at the site of discontinuities (pinholes or hairline cracks) in the nickel-plate provided the adhesion of the plate is good; and even if a portion of the plate should slough, restriction of coolant flow passage is highly unlikely as shown by ex-reactor fuel-tube flow tests[7]; however, this may only be true for chemically deposited plate.

5. Aluminum components, plated on both external and internal surfaces, may be employed for Al-Si dip canning to provide a corrosion resistant layer of nickel on both the internal and external surfaces of the aluminum jacket. The internal plate virtually eliminates Al-Si penetration of the aluminum can wall during canning; hence, a more accurate pre-determination of residual can wall thickness is permitted[8].

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(3) HW-64419 C, "PT-IP-263-A-FP, Evaluation of Chemically Nickel Plated Fuel Elements", By R. E. Hall and M. A. Clinton, dated 4-20-60, Secret.

(4) HW-58179-C, "Irradiation Summary Report PT-IP-207-A-3-FP, Evaluation of Effluent Contamination Problems Associated With Nickel Coated Fuel Elements", R. E. Hall and R. B. Hall, dated 11-16-59, Secret.

(5) HW-69285, "Post-Irradiation Examination Of Chemically Nickel-Plated Fuel Elements From PT-IP-263-A (RM-414)", By W. J. Gruber, dated 4-17-61, Secret.

(6) Personal communication with K. E. Fields.

(7) HW-63636, "Interim Evaluation of Nickel-Plate On Aluminum-Jacketed Fuel Elements", (pages 4 and 11), by G. F. Jacky, dated 2-8-60, Secret.

(8) Personal communication with G. F. Jacky.

In conclusion, it is believed that nickel-plate has a high potential for achieving the benefits cited above.

TEST DETAILS

1. Reactor

DR Reactor is chosen to conduct this test.

2. Material

A. Fuel Elements

Details of fuel element fabrication, plating, and testing are presented in HW-70349[9] and HW-64419-D[10]. All fuel elements will be normal production OIIN fuel elements, jacketed in C-64 aluminum alloy. After canning, the elements will be nickel-plated by a chemical deposition process, examined and tested for plate quality, and assembled into charges as noted below.

1) Up to 70 columns of nominal .6 mil thick nickel-plate and up to 30 columns of nominal .2 mil thick nickel-plate will be required. These include twenty measured and serially numbered monitor columns, ten of each plate thickness.

2) Fuel columns will consist of 32 fuel elements.

3) Existing downstream dummy patterns and seating methods will be employed.

4) Use of water-mixer elements is being considered and will be used at the discretion of the test author with the concurrance of the Manager, DR Processing Operation.

B. Pre-Irradiation Measurements

Pieces utilized in the monitor columns will:

1) Contain identification numbers and letters which are adequate to identify the vendor, plate thickness, plating lot, and position in the column.

2) Have O. D. (three locations on all pieces), warp-ellipticity for all pieces, and weight and I.D. (three locations) on all odd numbered pieces measured and recorded.

3) Have inked position numbers on the side near the female end which will relate to the piece numbers stamped in the base end (male-end).

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(9) HW-70349, "Nickel-Plated Fuel Elements for 100 Tube Test in 105-DR, (Supplement A to PT-IP-263-A-FP)", by G. F. Jacky, dated 8-1-61, Conf. Undoc.

(10) HW-64419 D, "Design of Supplement A to PT-IP-263-A-FP, Evaluation of Chemically Nickel-Plated Fuel Elements" by W. H. Hodgson, dated 7-10-60, Secret.

[redacted]

3. Irradiation

A. Charging

1) Monitor columns - will be charged in numerical order with piece number one downstream. Each column shall have the fuel identification number (series number) recorded opposite the tube number on the front face sequence sheets.

2) Lot-Charge Material - will require no special charging order; however, it will be required that all pieces in a column consist of the same nominal plate thickness. Record the fuel lot number opposite the tube number on the front face sequence sheet and identify as .6 or .2 mil plate.

3) Channel locations which will provide similar irradiation conditions for all tubes will be selected by the assigned Process Engineer and Physicist with the concurrance of the test author. Locations which will provide maximum operating severity with minimum attendent control problems will be given first consideration. Two tube channels, 1272-DR and 1278-DR are equipped to provide effluent samples and will be selected on this basis. Each will be charged with a monitor column representing a different plate thickness.

4) If water mixer elements are not used, the tubes selected for the 20 monitor columns will be probologged before and after irradiation of the test material to evaluate the tube damage caused by the local high water temperatures.

5) Charging will be followed by a representative of Research and Engineering.

B. Irradiation

During irradiation, daily temperature and flow data shall be recorded for all monitor charges. No special data will be required for material which is lot charged.

Effluent samples will be required routinely from tubes 1272 and 1278. Procedures for handling the samples will be supplied by Radiological Engineering.

C. Goal Exposure

All nickel plated fuel charges will be irradiated to 200 per cent of the normal goal exposures in effect during the irradiation period.

D. Discharge

1) All twenty monitor columns will require special pickup and immediate shipment to the 105-C Metal Examination Facility for post-irradiation examination and measurement. If circumstances will not permit either

immediate transfer to the 105-C MEF or examination after reaching C, then a visual examination of selected columns should be accomplished at the 105-DR fuel element viewing facility as soon after discharge as possible. Extensive pitting has been observed[11] during post-irradiation examination on some of the nickel plated elements at discontinuities in the plate, and although it is believed that this has been caused by a lack of corrosion inhibitor (sodium dichromate) in the discharge basin water coupled with the time delay prior to visual examination, the best way to verify this conclusion is to obtain an immediate visual examination.

2) Monitor columns may be combined during special pickup to the following extent:

   a. No more than four charges (128 pieces) are to be combined in one bucket if the fuel elements from the four tubes are mixed.

   b. As many tubes as a bucket will hold may be combined if the columns are segregated and the fuel pieces are stacked such that all pieces from a individual column are together.

3) All columns, monitor and lot charged, may be discharged before reaching goal discharge exposures after two failures have occurred providing all of the monitor columns can be specially picked up. If a failure should occur, it will be important to obtain the ruptured piece and all other pieces from the column; and to examine them prior to starting up from the rupture outage if at all possible.

E. Operating Conditions and Limits

Operating limits in current Process Standards will apply to this material. Since the fuel elements are of the OII size, a slight flow decrease (on an individual tube basis) may be noted and tube outlet temperatures may run two to three degrees higher than surrounding tubes; however, they should be well within normal TAI limits. For this reason, it is suggested that data from the test columns should not be used in calculating OSI and/or the power of the 10 high power tubes.

4. General

A. Duration and Further Testing

Irradiation of this material will require about six months. Further testing is planned; however, it will be authorized by a new production test. This test authorization will terminate on 4-20-62.

The next test will be a small scale test (10 alternated charges) using fuel elements canned in nickel plated aluminum components as opposed to

(11) HW-68793, "Incentives For Nickel Plating Aluminum Jacketed Fuel Elements", G. F. Jacky, dated 3-20-61, Secret, (See page 17).

the material in this test which was plated after canning. Nickel plating of both the internal and external surfaces of the aluminum components prior to canning offers the following potential advantages:

1) Increased corrosion resistance by virtue of a double layer of nickel, which should minimize the effect of discontinuities in any one layer.

2) Minimization or elimination of AlSi penetration and wash-out of the aluminum canwall during canning; thus, permitting a reduction in initial canwall thickness and concomitant increase in uranium volume.

3) If effluent activity problems appear, then etching off the outer nickel coating could be accomplished after canning and all benefits under item 2 above and half of those under 1 retained.

B. Schedule

The fuel elements have been fabricated, plated, tested, and are currently receiving pre-irradiation measurements. The material will be ready for shipment to DR Reactor about August 1, and will be charged during the next scheduled block discharge, which current schedules indicate will occur about 8-14-61.

C. Post-Irradiation Examination*

1) All fuel elements will be weaseled and visually inspected for surface conditions, particularily sloughing, flaking, spalling, and/or cracking of the nickel coating.

2) All fuel elements will be measured for O.D., warp, ellipticity, and bumping.

3) Odd numbered pieces will be weighed and measured for ID.

4) Pieces will be cleaned with a special cleaning solution to prevent plate damage. The pieces will be re-weighed and re-visualled after cleaning to determine plate condition.

5) Elements having unusual measurements and/or corrosion patterns shall be set aside for further examination.

6) Photographs will be taken of elements showing unusual surface conditions (discontinuities in the plate, severe dimensional distortions, severe hot-spots, etc.).

7) Selected elements may be sent to the Radiometallurgy Laboratory for further destructive examination upon request of the test author.

D. Costs

All incremental costs incurred as a direct result of this test may be charged to XXXX-5R24-XXX.73. Outage time and manhours will be required for the following:

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* Monitor Columns

[redacted]

1) Charging twenty monitor columns.

2) Discharging and special pickup of twenty monitor columns.

3) Probologging 20 tubes before and after irradiation if water mixer elements are not used.

4) Rupture removal time for up to two ruptures may be required and tube removal may be required if less than predicted performance is experienced.

E. Hazards

1) Flaking or sloughing of the nickel plate has potential to cause a panellit scram, and even though previous testing, both in and out of reactor, indicates that this has a small probability of occurrance; it is recommended that panellit pressures for these test columns be kept slightly lower than normal at the discretion of the Process Engineer.

2) There is a slight possibility of incurring a tube leak due to accelerated tube corrosion. Postulating conditions of severe fuel-tube eccentricity or misalignment and/or unusual fuel dimensional distortions coupled with the assumption that the nickel-coating resists the corrosion conditions created, then it is conceivable that the tube wall could fail by a mechanism similar to that of the hot-spot rupture.

RESPONSIBILITIES

Fuels Preparation Department

Responsibilities assigned to the Fuels Preparation Department are authorized by HW-64419 E; which in brief, authorizes fabrication of the test material and assigns responsibilities within Fuels Preparation necessary to carrying out this production test.

Irradiation Processing Department

Research and Engineering Section

Process and Reactor Development Subsection - shall be responsible for coordination of the test, analysis of operating data, reporting of in-reactor performance, and for provision of bases for operating limits. Radiological Engineering shall be responsible for making arrangements to acquire and analyze effluent samples and to report results.

Process Technology Subsection - shall 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.

[redacted]

Operational Physics Subsection - shall be responsible for providing assistance in selecting test channel locations, and for reactivity adjustments as required by this test.

Component Testing Unit - shall be responsible for post-irradiation fuel element examination and measurements.

Manufacturing Section

D-DR Reactor Operation

DR Processing Operation - shall be responsible for scheduling, for operational safety and production continuity of the reactor, for charging the test material, for taking effluent samples, and for collection of operating data.

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

M. A. Clinton

M. A. Clinton, Engineer
Reactor Fuels Unit
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

MA Clinton/bc

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