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POST-IRRADIATION EXAMINATION OF CHEMICALLY NICKEL-PLATED FUEL ELEMENTS FROM PT-IP-263-A (RM-414)

AUTHOR

W. J. Gruber

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April 17, 1961

W. J. Gruber

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POST-IRRADIATION EXAMINATION OF CHEMICALLY NICKEL-PLATED FUEL ELEMENTS FROM PT-IP-263-A (RM-414)

INTRODUCTION

Two chemically nickel-plated, internally and externally cooled, Hanford production fuel elements, which were irradiated to approximately 800 MWD/T as part of PT-IP-263-A, were transferred to the Radiometallurgy Laboratory in December, 1960. The elements were selected for detailed examination because one had incurred a hot spot during irradiation and the other contained some unusual cracks in the nickel plate. Prior to irradiation, both fuel elements had been baked at 300C to heat-treat the nickel plate.

Also, the nickel plate of several unirradiated elements was damaged by scraping, marring, scratching and punching. The elements were exposed for six weeks to 105C basin water, which was approximately the length of time the irradiated elements were in 105C basin prior to transfer. Two unirradiated elements were submitted for comparison with irradiated pieces.

The examination was requested by Process Engineering, Fuels Preparation Department; and Process and Reactor Development, Irradiation Processing Department, to determine the effects of irradiation on elements with improved nickel plating and to aid in evaluating the nickel-plated fuel element program.

[redacted]

SUMMARY AND CONCLUSIONS

The "hot spot" was the result of misalignment during irradiation. Annealing of the nickel indicated the maximum surface temperature was about 300C. The presence of the nickel plate prevented damage to the element as no corrosion of the aluminum was observed, and the nickel plate and Ni-Al bond were in excellent condition in the heated area.

The cause of the unusual cracking in the nickel plate of the second element was not determined. None of the cracks propagated into the aluminum and no serious aluminum corrosion occurred under the cracks. The cracking of the plate has occurred only in areas where normal temperatures were prevalent and none have been observed in areas where surface heating was detected.

Severe pitting of the aluminum cladding of both elements was observed. Corrosion had penetrated to the Al-Si in one of the elements. Comparison of irradiated and unirradiated cladding revealed that the corrosion attack was identical. Therefore, the observed pitting in the irradiated elements probably was the result of mechanical damage to the nickel plate during discharge and/or subsequent handling with basin tongs, and corrosion occurred while the elements were standing in basin water.

The nickel plate on elements from PT-IP-263-A was superior to that seen on elements from a previous irradiation, PT-IP-207-A. Bond strength was improved. Also, corrosion of the aluminum under cracks in the nickel may have been minimized by an intermediate layer in the plate of PT-IP-263-A elements. The intermediate layer did not exist in the plate of PT-IP-207-A elements.

DETAILS

A. Visual Examination and Sample Procurement

Visual examination of the irradiated elements disclosed that the surfaces were peppered with numerous pits. The element containing the hot spot, piece number 13A, displayed the least number of pits. There were fewer pits per unit area in the "hot spot" than in the remainder of the element, which indicates that further heat treatment studies may produce a plate with superior protective qualities. Evidence of misalignment was seen in the uneven flow patterns at both ends of the element (Figure 1).

Unusual cracking of the nickel plate was observed at two locations on the second element, piece number 65A. A maze of cracks were seen on the surface of a slightly bulged area near the midpoint outside of the ribs. Cracks, oriented along circumferential lines, emanated from an area about two and one-half inches long which lay between and parallel to the ribs. The cracks ranged from approximately one-eighth to one-fourth inch in length (Figure 2). The element was cut to obtain a longitudinal section that intersected several of the oriented cracks. An additional sample, containing a heavily pitted area, was removed.

The overheated element was sectioned to remove a wafer from the midpoint of the hot spot. The wafer was then sectioned to remove a quadrant that contained cladding extending from the maximum temperature zone to the normal surface outside the hot spot.

Pitting of the cladding of unirradiated elements occurred profusely where the nickel plate had been damaged (Figure 3). One pit was apart from the obviously damaged plate and resembled the pitting in the irradiated cladding. This pit was isolated for metallographic examination.

B. Metallographic Examination

The cause of the cracking in the nickel plate was not determined. Probably it resulted from an external occurrence as there were no abnormal conditions in the element at the site of the cracks. The cracks in the plate did not propagate into the aluminum, and corrosion of the aluminum under the cracks was negligible. None of the corrosion pockets associated with the examined cracks was greater than 0.001 inch in depth or width (Figure 4). The appearance of the etched nickel plate differed from that seen in an earlier irradiation, PT-IP-207-A (RM-306). The plate from PT-IP-263-A which had the 300C pre-irradiation anneal did not display a fine laminar structure. An intermediate layer including approximately ten per cent of the total thickness was seen in the nickel at the Ni-Al interface. The presence of the intermediate layer had two obvious beneficial effects. The previously described cracks narrowed to a thin line in the layer adjacent to the aluminum which may account for the absence of corrosion under the cracks. Also, the nickel to aluminum bond was more tenacious than that seen in PT-IP-207-A plating. The difference in bond strength was readily seen when pitted areas from PT-IP-263-A and PT-IP-207-A cladding were compared (Figure 5).

Eight corrosion pits in irradiated cladding were examined and compared to a similar pit in unirradiated cladding. Corrosion in both irradiated and unirradiated cladding was similar in appearance and identical in mode of attack. It was surprising to see intergranular attack in the unirradiated cladding (Figure 6). All pits appear to have resulted from mechanical damage to the protective nickel plate which exposed the aluminum to water (Figure 7). Probably the reason there was less pitting in the unirradiated elements was that they never experienced the rigors of discharging and subsequent handling with basin tongs. The corrosion in the irradiated elements probably occurred after, not during, irradiation since the mode of attack in unirradiated and irradiated cladding was identical. No undercutting by corrosion or sloughing of the nickel plate was observed in any of the examined samples. There was evidence that some of the pits penetrated the aluminum cladding, although none was actually seen during examination. "Water trails" in the Al-Si were detected at several locations; however, no reaction with the uranium fuel was observed (Figure 7).

The nickel in the maximum temperature zone of the hot spot was in excellent condition as was the Ni-Al bond. Spheroidization of the Al-Si was also seen. The plate in the high temperature zone was annealed so that the etched nickel appeared homogeneous. As the cooler areas were approached traces of the intermediate layer were visible and spheroidization of the Al-Si decreased comparably (Figure 8). It would require temperatures of about 300C for an extended period of time to produce the observed annealing.

W. J. Gruber, Engineer
Radiometallurgy Laboratory
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FIGURE 1

PIECE NUMBER 13-A AS RECEIVED

A1367 Hot Spot 0.7x

A1362 1.2x A1363 1.3x

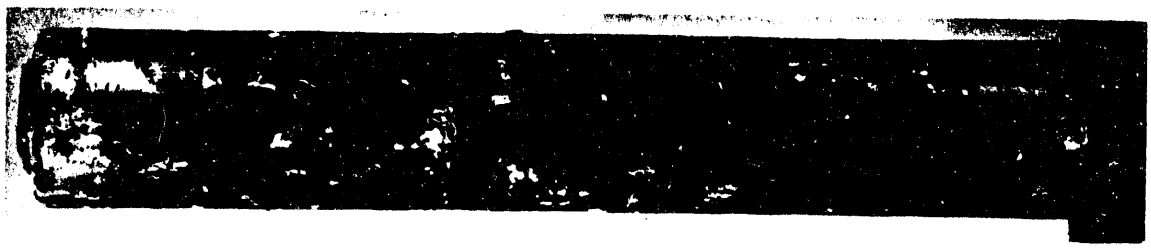
Male and female ends of element.

A2194 1.2x

Enlargement of hot spot.

FIGURE 2

PIECE NUMBER 65A AS RECEIVED



A1356 0.7x

Cracked nickel plate between ribs.

A1360 1.1x

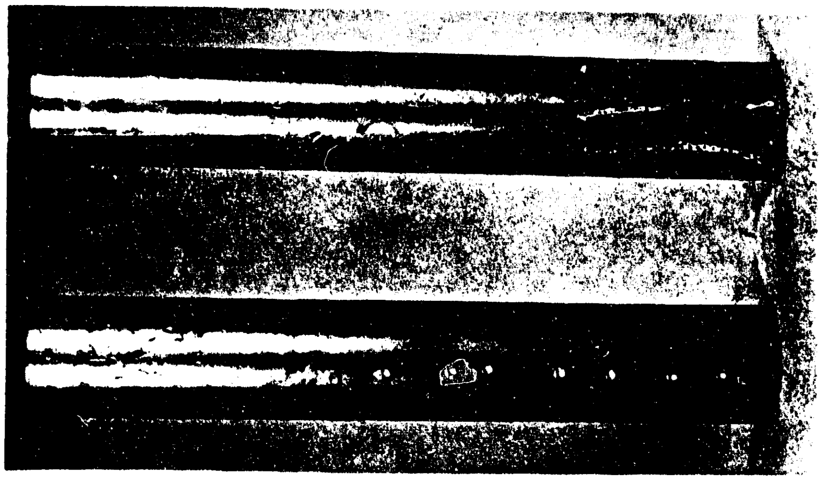
Enlargement of area between ribs.

A1361 1.5x

Enlargement of cracked area near one rib.

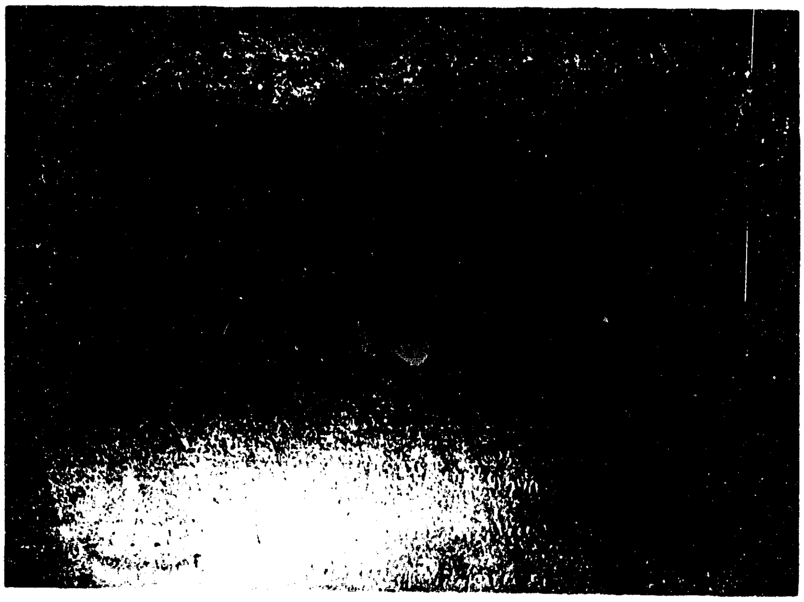
FIGURE 3

UNIRRADIATED ELEMENTS AS RECEIVED



A1668 0.4x

The purposely damaged nickel plate and associated corrosion are plainly visible.

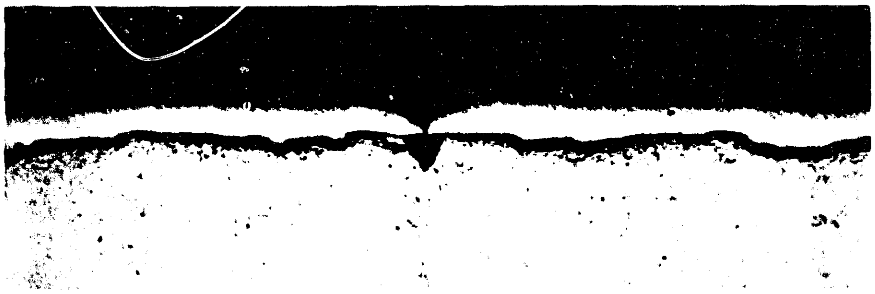


A1669 5x

Enlarged view of a pit in the cladding with no obvious mechanical damage.

FIGURE 4

METALLOGRAPHY OF CRACKED NICKEL PLATE FROM BETWEEN THE RIBS OF PIECE 65A



A1539 As Polished 250x

A1571 Nickel Plate Etched 500x

A1572 Nickel Plate Etched 1000x

Variation in the composition of the nickel in the initial and final plating process was revealed by the etch. The variation appears as a thin layer at the Ni-Al interface.

FIGURE 5

COMPARISON OF BOND AT NI-AL INTERFACE IN PITTED AREAS. PLATE FROM PT-IP-207A IS SHOWN, AND ALSO FROM PT-IP-263A.

12608 As Polished 150x

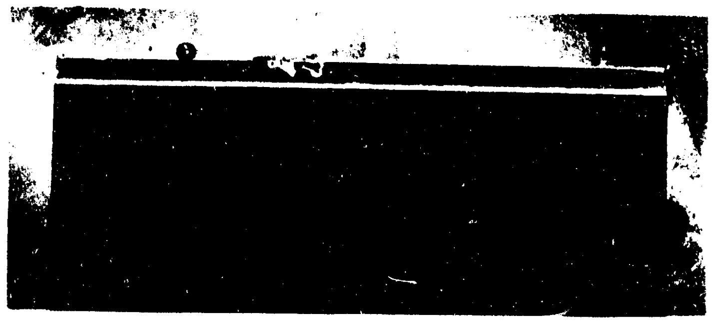
12609 As Polished 150x
Plate above is PT-IP-207A material.

A1534 As Polished 250x

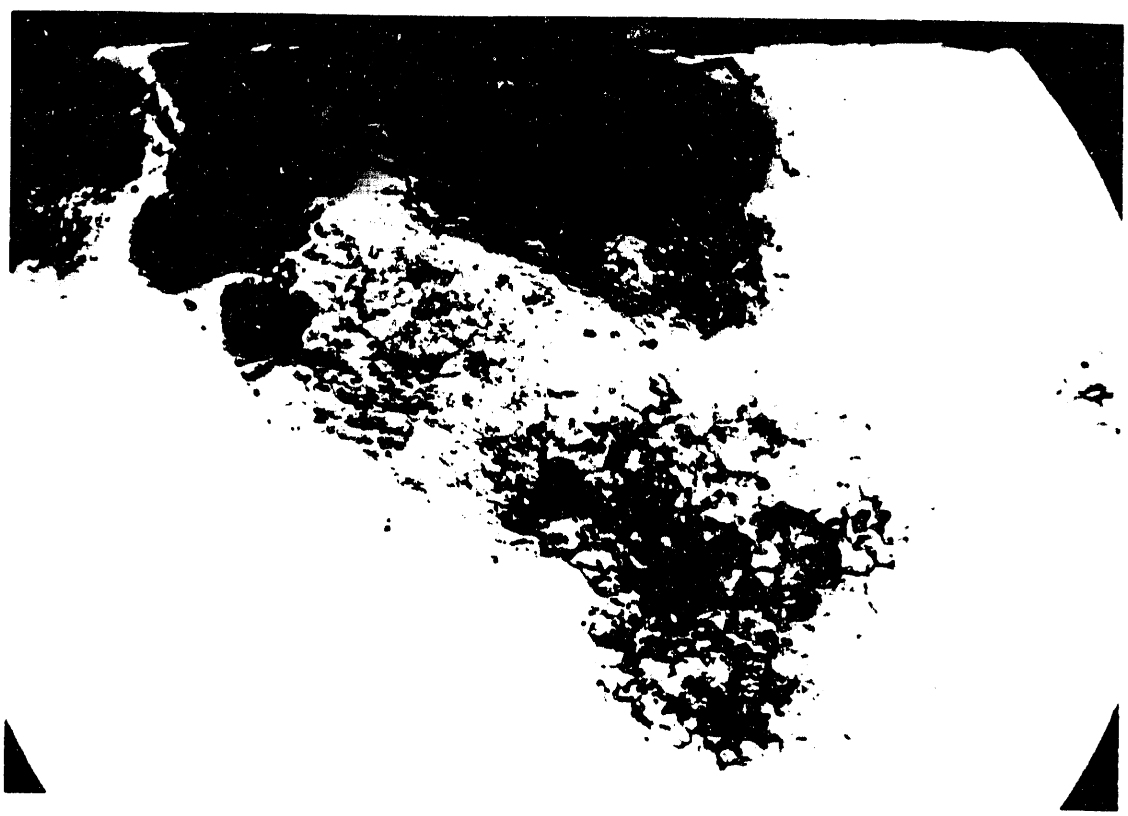
A1537 As Polished 250x
Plate above is PT-IP-263A material.

FIGURE 6

PITS IN UNIRRADIATED CLADDING



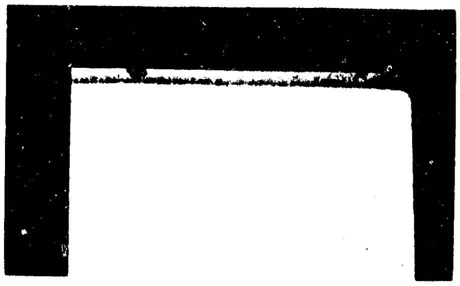
A1858 3x



A1742 As Polished 100x

FIGURE 7

PITS IN IRRADIATED CLADDING



A1859 1.5x

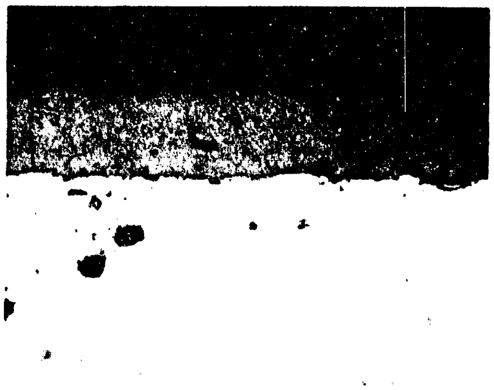
A1532 As Polished 250x

The pit above is typical of the corrosion in irradiated cladding.

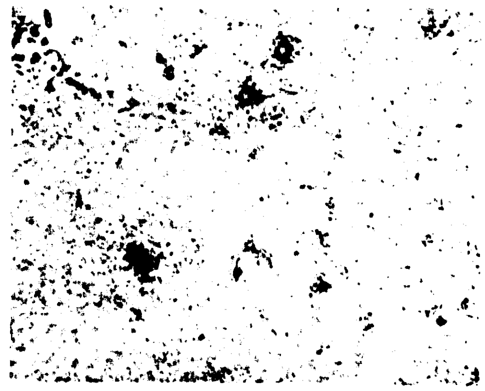
A1574 "Water trail" in Al-Si. 250x

FIGURE 8

NICKEL PLATE AND AL-SI IN HOT AREA



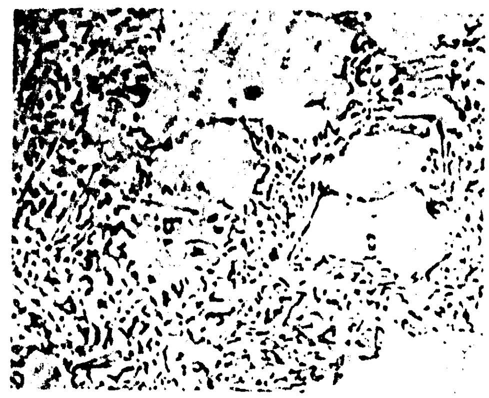
A2127 750x



A2129 750x

Plate and Al-Si in center of "hot spot".

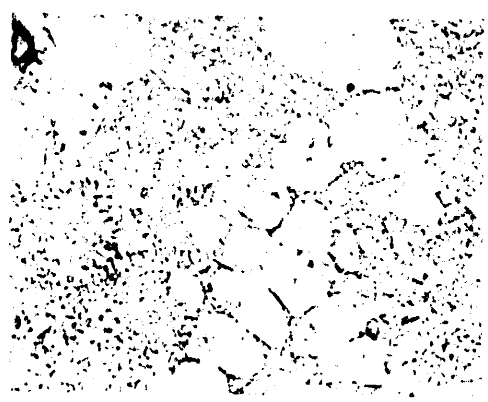
A2131 750x



A2130 750x

Plate and Al-Si at edge of "hot spot".

A2135 750x



A2132 750x

Plate and Al-Si about three-eighths inch from edge of "hot spot".

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