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POST IRRADIATION EXAMINATION OF A NICKEL PLATED FUEL ELEMENT FROM PT-IP-207-A

(RM-306)

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W. J. Gruber

October 30, 1959

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POST IRRADIATION EXAMINATION OF A NICKEL PLATED FUEL ELEMENT FROM PT-IP-207-A (RM-306)

INTRODUCTION

A .0005 inch thick chemically nickel plated, C-64 aluminum clad, natural uranium, internally and externally cooled, Hanford production fuel element, which had incurred a "side hot spot" during irradiation, was shipped to the Radiometallurgy Laboratory in June, 1959 for post irradiation examination. The slug was irradiated to approximately 400 MWD/T in C Reactor as part of PT-IP-207-A.

The examination was requested by personnel from Process Engineering, Fuels Preparation Department and Process and Reactor Development, Irradiation Preparation Department to determine the irradiation behavior of nickel plated fuel elements and to aid in evaluating the nickel plated fuel element program.

SUMMARY AND CONCLUSIONS

The presence of the nickel plate probably averted a "side hot spot" failure. Al-Si spheroidization and Ni-Al diffusion indicated that the maximum surface temperature was 325-350°C for at least one hundred hours, however no sloughing of the nickel was seen in the "hot spot".

Sloughing of the nickel plate, associated with poor nickel bonding, was observed near the cap end of the slug. The condition may have been aggravated by the formation of hydrogen gas originating from the diffusion of atomic hydrogen through and/or from the nickel plate into the voids between the nickel and aluminum in poorly bonded areas. Observations prompted the establishing of tests of other nickel plated slugs from PT-IP-207-A to determine whether or not hydrogen gas was being trapped under the plate. These tests are currently in progress.

The aluminum canwall was attacked intergranularly in a few localized areas near the cap end of the slug. The attack was observed only where a crack in the nickel plate coincided with an unbonded area of the nickel and aluminum. There was no undercutting of the plate by corrosion to cause sloughing of the nickel.

DETAILS

The slug selected for examination was #10 of the 20Q series and was irradiated in tube 1675C.

Visual examination of the slug showed the nickel plate to be intact over the entire surface of the slug with the exception of approximately one fourth inch of the sidewall at the cap end and the weld at the base end of the slug. Some isolated areas

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were devoid of nickel but these were associated with mechanical damage received after discharge. A "hot spot" was observed which was approximately one and one-fourth inches wide and extended from one-half inch from the cap end to the mid-point of the slug. Orientation of the "hot spot" was not possible as rib marks were not visable. The deposition film was missing from the heated area, and the edge of the "hot spot" was outlined by dark surface discoloration of the nickel. Near the cap end of the slug several bumps about the size of a pin head were seen and appeared to be small blisters in the nickel. (Figure I.)

The slug was sectioned to remove a wafer from the maximum temperature zone of the hot spot. Also, three canwall samples were removed from the slug, (1) a sample containing a corrosion pit from the non heated area at the midpoint of the slug opposite the hot spot, (2) a sample from the "hot spot", and (3) a sample from the proximity of the cap end containing nickel void areas and three of the small blisters. After metallographic preparation, the canwall samples were immersed in a solution of 10% ammonium persulphate-10% sodium cyanide in water to etch the nickel.

The sample from the "hot spot" was three-eighths inches wide and included approximately one circumferential inch of the canwall extending from the center to the fringe of the "hot spot". At least three intermediate phases were seen between the nickel and aluminum. The extent of diffusion decreased as the least heated end of the sample was approached and beyond .75 inches from the center of the "hot spot" no intermediate phases were observed. Extrapolating the preceeding observations, significant Ni-Al diffusion probably occurred over all the area outlined by the dark fringe around the "hot spot". The laminar structure, normally seen in chemplated nickel, had been annealed out of the sample. There was no separation of the nickel from either the aluminum or the diffusion product nor was there any water penetration of the nickel plate, although cracks or pores were present in the plate. Advanced spheroidization of the Al-Si was observed in the maximum heated area of the canwall. (Figure II.)

The one half inch thick wafer, which was removed one and three fourths inches from the cap end of the slug near the center of the "hot spot", was cathodic vacuum etched. Examination of the uranium showed a uniform structure across the section with no evidence of over-heating. The Al-Si bond was intact in both the interior and exterior jacketing. (Figure IV.)

The canwall sample from the nickel void and blistered area was removed one half inch from the cap end of the slug and contained a portion of the fringe of the "hot spot". The nickel plate near the cap end of the slug was poorly bonded and in many locations was completely missing. In the portion of the sample which lay in the fringe of the hot spot, several isolated spots of intergranular attack in the C-64 aluminum were noted. However, the intergranular attack was observed only where poor bonding of the nickel plate coincided with a crack in the plate. Many locations were seen where there was either poor bonding or cracking of the plate, but no intergranular attack was present. In some of the unbonded spots, the nickel and aluminum were separated by voids up to one and two mills thick. There was no corrosion in these spots but it appeared that the nickel had been forced away from the aluminum. In other locations where more separation was present the nickel had cracked and corrosion of the aluminum had occurred. A cross section of one of the blisters showed the nickel to be cracked and aluminum corrosion present, but all of the dome shaped void was not filled with corrosion product. (Figure III.) In order to explain the sloughing of the nickel plating from some of the fuel elements from PT-IP-207-A it had been theorized that the plating had been forced away from the aluminum by hydrogen gas pressure originating from atomic hydrogen that diffused from the nickel into voids between the aluminum and nickel plate. The examination of the canwall from this slug tended to support the theory strongly enough to pursue the question further and a test was devised and is currently in progress to determine whether or not hydrogen gas had been trapped under the plating of other slugs from PT-IP-207-A.

The third canwall sample was approximately one-half inch square and contained a pit from a non-heated area at the midpoint of the slug from the side opposite the "hot spot". The sample was mounted so that a transverse section of the pit was visible. The corrosion of the aluminum originated at an .010 inch wide break in the nickel plate. The area of corrosion was evenly dispersed from the break and was in the shape of a crude oval .040 inches wide and .010 deep The aluminum attack was not typical of in-reactor corrosion and the nickel plate had been shattered at the break, indicating mechanical damage. The nickel plate was well bonded over the remainder of the sample. The nickel plate probably was damaged after discharge and the subsequent corrosion occurred while the slug was standing in the basin. (Figure IV.)

The maximum temperature was determined primarily from the observations made of the uranium and the Ni-Al diffusion. No grain growth was noted in the uranium in the "hot spot" area so the upper temperature limit was approximately 450°C. Allowing for the temperature drop to the Ni-Al interface the maximum temperature at the surface of the aluminum would be 325-350°C. The temperature may have been lower than 350°C but probably was not any higher. Extrapolating limited data on diffusion in nickel plated aluminum canwall, it would require at least one hundred hours at 350°C to produce the amount of diffusion observed.

Intergranular corrosion of the aluminum penetrated 30% of the canwall thickness where water entered the nickel plate in the poorly bonded area at the fringe of the "hot spot". Had the aluminum not been protected by the nickel plate at the center of the "hot spot" where temperatures were much higher, water probably would have penetrated the canwall and caused a rupture.

Radiation readings of 500 mr/hr were obtained from the slug through a 6.2 density lead oxide viewing window, ten and one-half inches thick. Readings from non-plated slugs with comparable neutron exposures and decay times are less by about a factor of ten.

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The data from which the report originated may be seen in Personal Notes, by W. J. Gruber, HWN-163.

W. J. Gruber, Engineer
Radiometallurgy Laboratory
MATERIALS DEVELOPMENT OPERATION

WJG:lr

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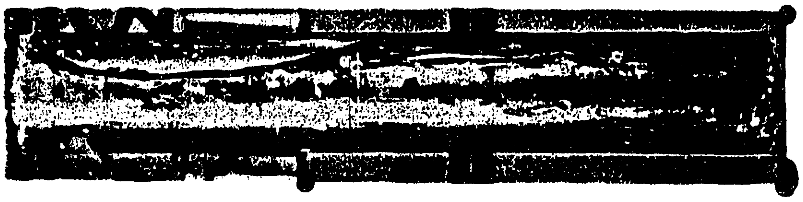
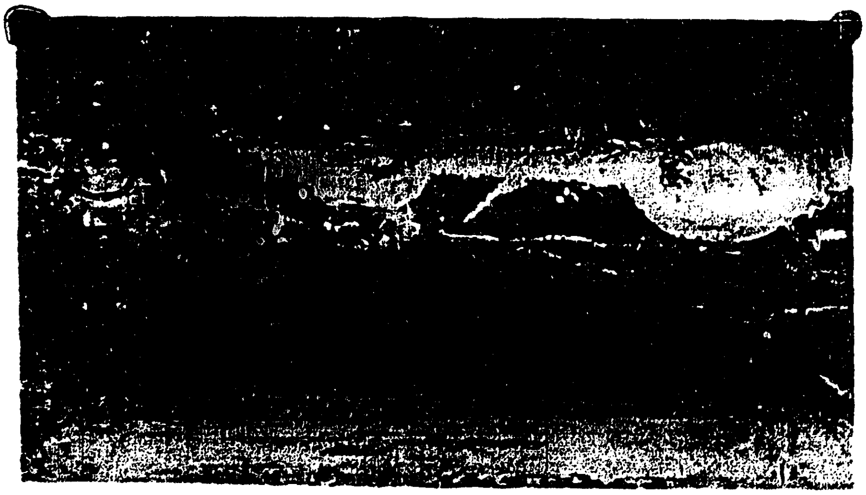
Neg. #12024 .4X



Neg. #12022 .4X

The fuel element as received. In the second view the slug was rotated 90°. The outline of the hot spot has been inked. Cap end of the slug is to the left.



Neg. #12093 3X

Photomacrograph of the fringe of the hot spot at the cap end of the slug. A group of blisters in the nickel has been encircled.

FIGURE 1

As Received Photography

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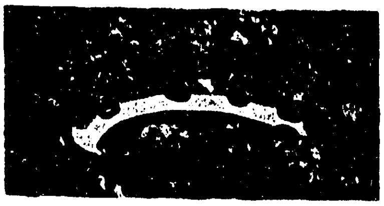
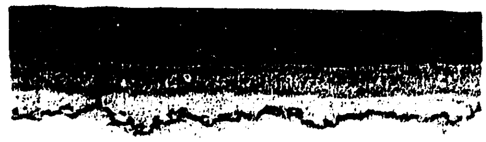


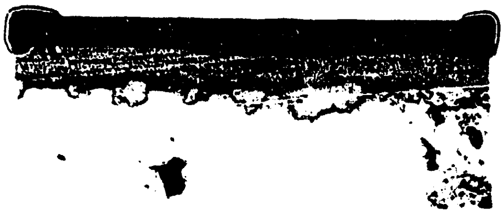
Neg. #12262 1.5X

Canwall from the hot spot. The maximum temperature zone is at the extreme right of the sample. The areas from which photomicrographs were obtained were indexed.

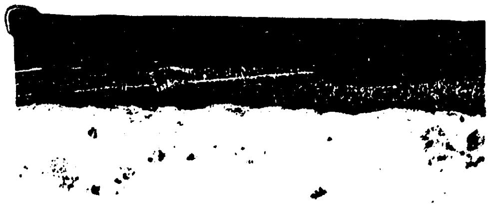
Neg. #12310 Area 1 400X



Neg. #12309 Area 2 400X

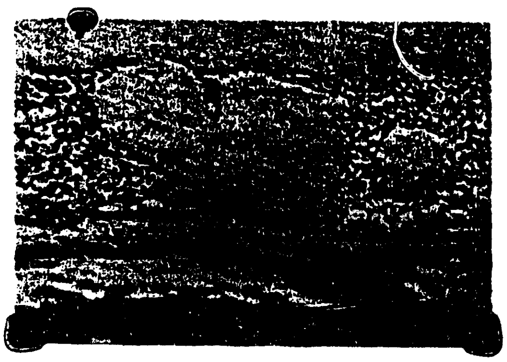


Neg. #12308 Area 3 400X



Neg. #12306 Area 4 400X

The photomicrographs of the etched nickel plate above show the Ni-Al diffusion in the "hot spot" area.



Neg. #12311 Area 5 [illegible]

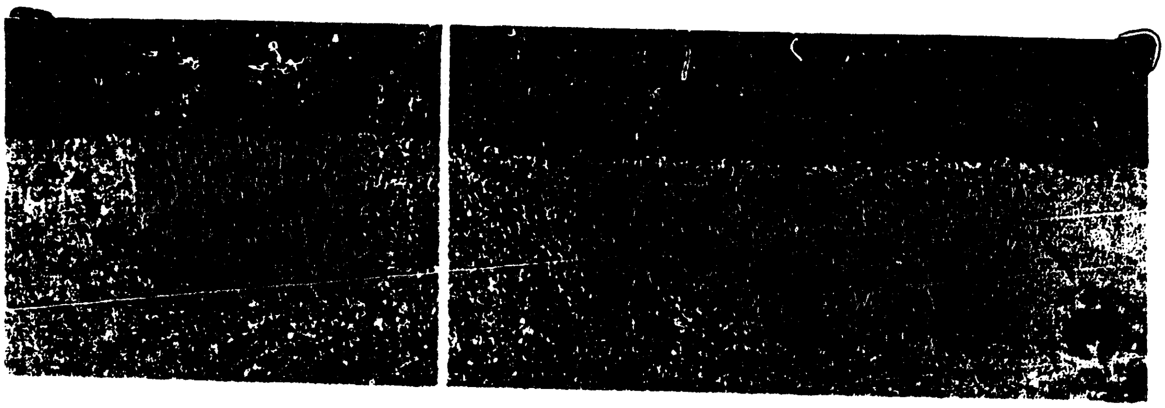
[illegible]ation [illegible] the [illegible] [illegible] [illegible].

[illegible] D

M[illegible]y [illegible] in the "Hot Spot"

Neg. #12609 150X Neg. #12605 150X

Two areas where poor bonding coincided with a fault in the plate and intergranular attack of the aluminum occurred. These areas were located at the edge of the "hot spot". Maximum penetration observed was .013 inches.

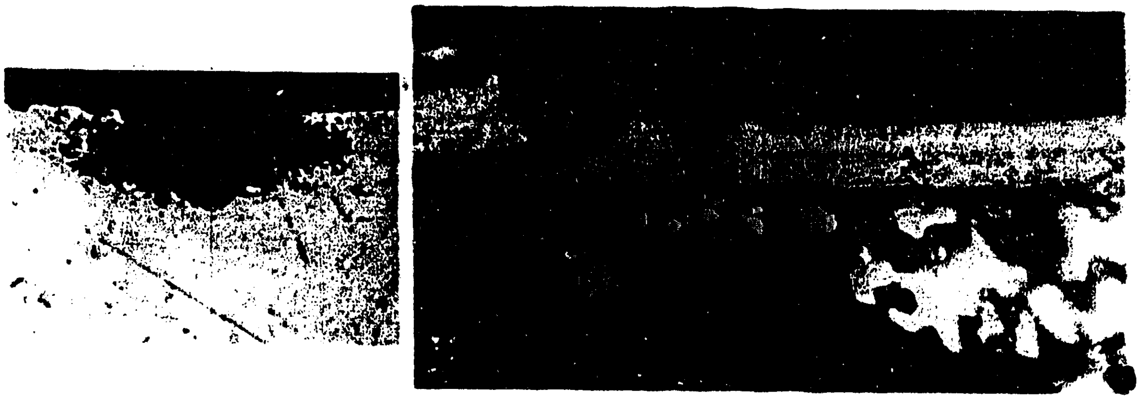


Neg. #12458 600X Neg. #12457 600X

The two photomicrographs show a crack in the nickel and an unbonded area with no attack of the aluminum in either case. The laminar structure, typical of etched electroplated nickel, is seen in the photomicrographs.

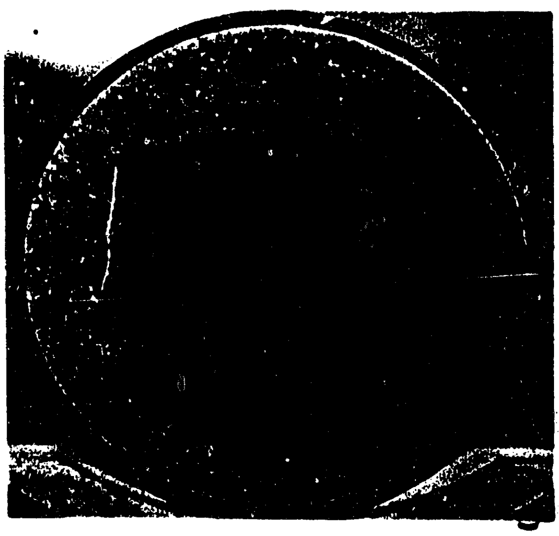
FIGURE III

Metallography of the Plating at the Fringe of the "Hot Spot"



Neg. #12149 60X Neg. 1[illegible]169 600X

Photomicrographs of the pit from a non heated area of the can. The photo on the right shows the broken plate at the edge of the pit.



Macro photograph of the wafer sectioned from the "hot spot". Note annealing is not evident.

Neg. #12459 2X

FIGURE IV

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