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# SAXTON PLUTONIUM PROJECT
# QUARTERLY PROGRESS REPORT FOR THE PERIOD
# ENDING MARCH 31, 1973

MASTER

by

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May 1973

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# SECTION 1

# INTRODUCTION AND SUMMARY

## 1.1 SCOPE

This quarterly report covers work completed on the Saxton Plutonium Project during the period January through March 1973.

## 1.2 OBJECTIVES

The overall objective of the Saxton Plutonium Project is to develop information concerning the utilization of plutonium enriched fuels in pressurized water reactor systems. The program includes design, fabrication, operation, and post-irradiation examination of a partial plutonium core. The in-pile performance of the fuel will be evaluated and compared with analytical predictions.

## 1.3 PROJECT ADMINISTRATION

Quarterly reports for the periods ending September 30 and December 31, 1972, were issued.

## 1.4 SUMMARY OF PROGRESS DURING THE PERIOD

Destructive evaluations of eight Core 3 end-of-life fuel rods were almost completed. All scoped metallography, including alpha and beta-gamma autoradiography, was finished. Burst tests were completed, and tensile tests were initiated. The last of the clad hydrogen, Mn-54, and standard burnup samples were prepared and shipped to the Westinghouse Analytical Service Laboratories for analysis. Eight clad hydrogen, four Mn-54, and three mass spectrometric burnup analyses were performed. Dissolution of the radial drill burnup specimens was started.

## SECTION 2

## EVALUATION OF CORE III FUEL*

(T. E. Caye, W. R. Smalley, A. C. Hott, R. C. Goodspeed, N. R. Metcalf)

### 2.1 NONDESTRUCTIVE EXAMINATIONS OF END-OF-LIFE FUEL RODS

This work was previously completed and reported.[1]

### 2.2 DESTRUCTIVE EXAMINATIONS OF END-OF-LIFE FUEL RODS

#### 2.2.1 Metallography

Metallographic examination of scoped specimens was completed with the examination of transverse sections from unfailed rods IM, PF, BE, and BK, and failed rod JX. Sections from the unfailed rods were examined for cladding corrosion behavior and hydride precipitation, clad/fuel interaction, and fuel microstructure. Sections from rod JX were examined to characterize the failures. Metallography of sections from rods LS, FI, and GM were previously reported.[1]

A. Clad Metallography

The samples from the two highest burnup rods, IM and PF, showed little or no additional increase in oxide thickness over the maximum observed in rod LZ, the lead burnup rod removed at Core III mid-life.[2] Maximum oxide film thicknesses observed on samples from rods IM and PF were 1.5 and 1.2 mils, respectively. Typical oxide thicknesses varied from 0.5 mil to 1.0 mil around the periphery of the two rods.

The two rods, BE and BK, which experienced highest power at the beginning of Core III, showed significantly different corrosion behavior in the peak power region (∿11 to 18 inches from the bottom of the rods). Rod BE had oxide thicknesses which varied from 0.7 mil to approximately 4 mils in the areas

*Hot cell operation conducted by BMI, Columbus, under contract to Westinghouse Nuclear Fuel Division.

where a white corrosion product had been observed during visual examination[1]. The abnormally thick oxide film is shown in Figure 2-1. In several areas, there was evidence that the thick oxide film had partially spalled off, resulting in the rough surface appearance previously reported[1]. On the other hand, the typical and maximum oxide thicknesses observed on the samples from rod BK were 0.8 mil and 1.0 mil, respectively.

Another feature of the external surfaces of rods BE and BK was the presence of relatively hard, adherent crud ranging in thickness from 0.2 to approximately 1.0 mil (see Figure 2-2). In addition, a soft, highly porous crud up to 3 mils thick was observed on the two samples from rod BE (Figure 2-3), where special precautions were taken to preserve the crud.

The significantly thicker oxide on rod BE and the adherent crud deposits on both rods BE and BK were in contrast to surface conditions observed on the highest power rods, BO and NI, removed at mid-life[2]. The latter rods exhibited thinner oxide films and negligible adherent crud, despite having operated for 3700 EFPH's at higher power prior to mid-life than did rods BE and BK during 2200 EFPH's after mid-life. This comparison indicates an abnormally high corrosion rate on rod BE after mid-life, the cause of which has not been determined.

Failed rod JX, which had been substituted for rod QL in the sampling plan[1], was examined at three axial locations: 13, 18, and 26.5 inches from the bottom of the rod. The first two sections were in or close to defected areas, while the third section was representative of a non-failed region of the rod. The 13 inch plane showed surface features similar to those of rod BE at the 12 inch plane, e.g. heavy oxidation of the outer clad surface, penetrating into the base metal about 8 mils (Figure 2-4). There was evidence that some of the thick oxide had spalled, which accounts for some of the surface roughness noted during visual examination and profilometry.

The 18 inch section of rod JX exhibited thick oxide on the outer surface, also, but not to the same extent as the 13 inch plane. There was some evidence of local reductions in clad wall thickness, suggesting that oxide had spalled off at this location also. The main feature of the microstructure at this location was the presence of extensive hydriding around most of the periphery,

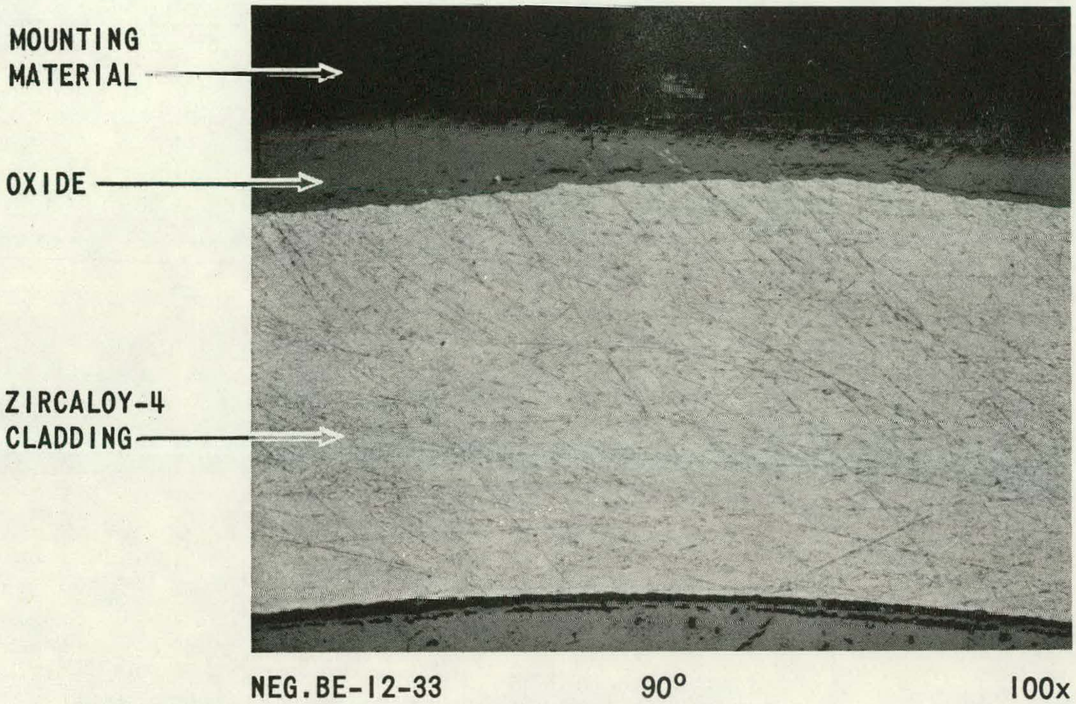
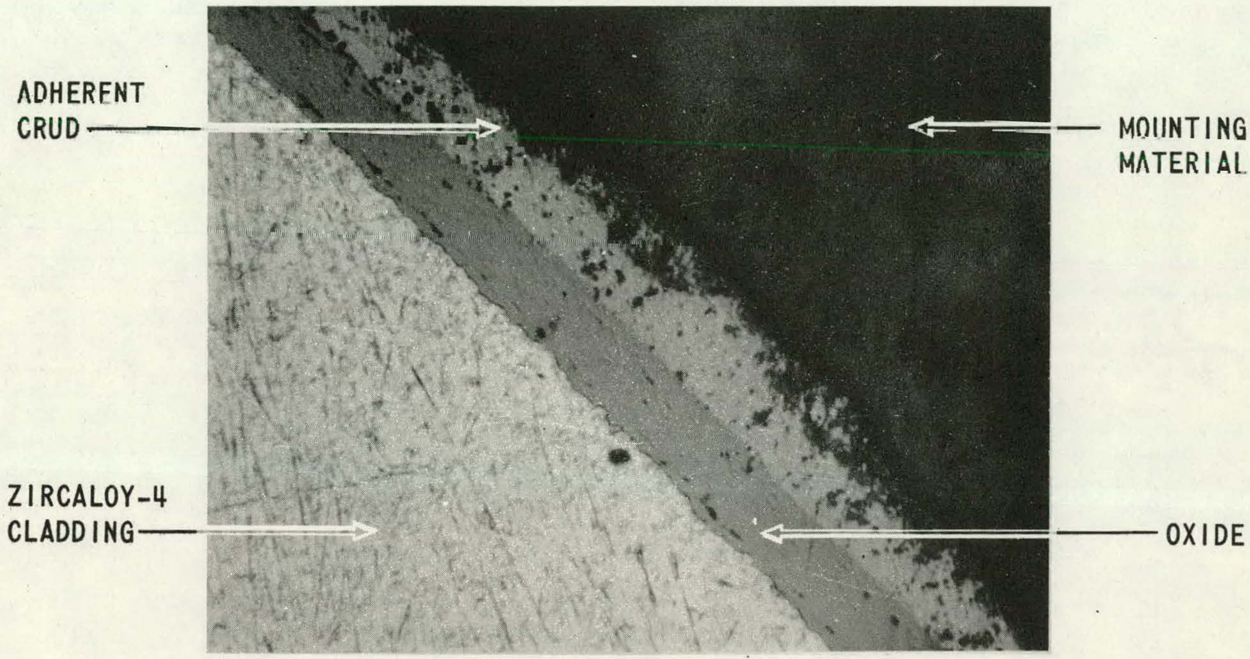



Figure 2-1. Abnormally Thick Oxide on Outer Surface of Rod BE, 12 Inches from the Bottom




NEG. BK-13.5-19 135° 500x

Figure 2-2. Typical Oxide Film with Adherent Crud, 13.5 Inches from the Bottom of Rod BK

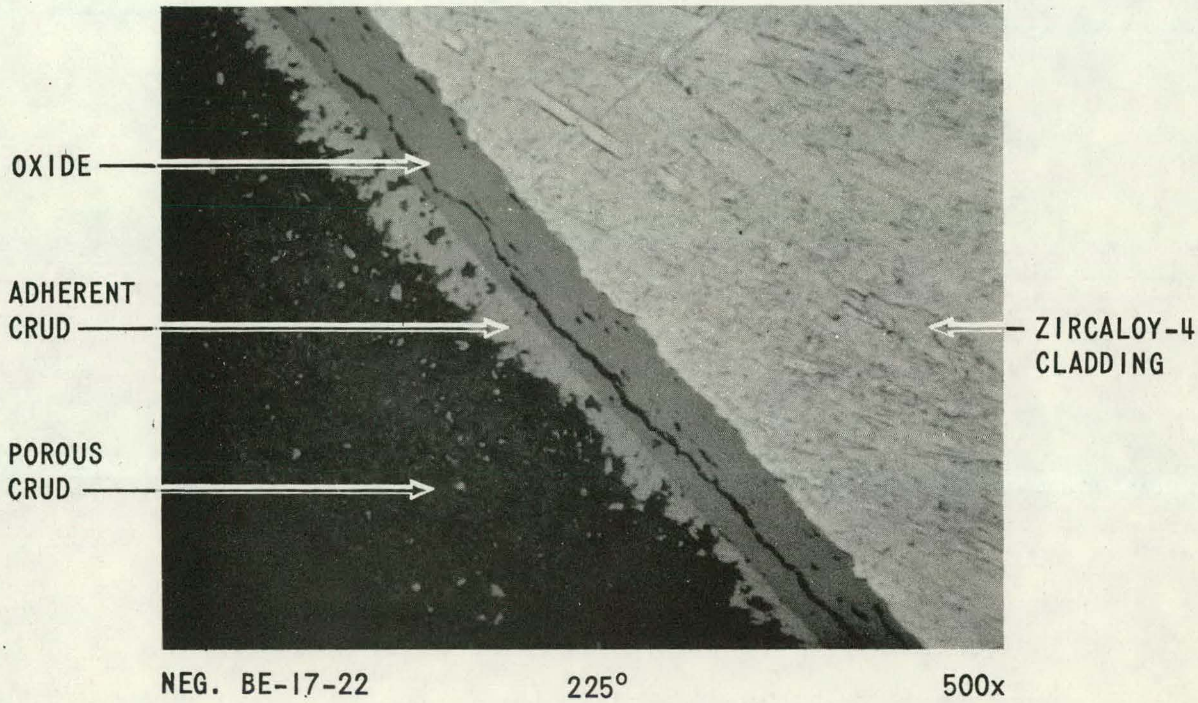



Figure 2-3. Adherent and Porous Crud and Oxide on Outer Surface of Rod BE, 17 Inches from the Bottom

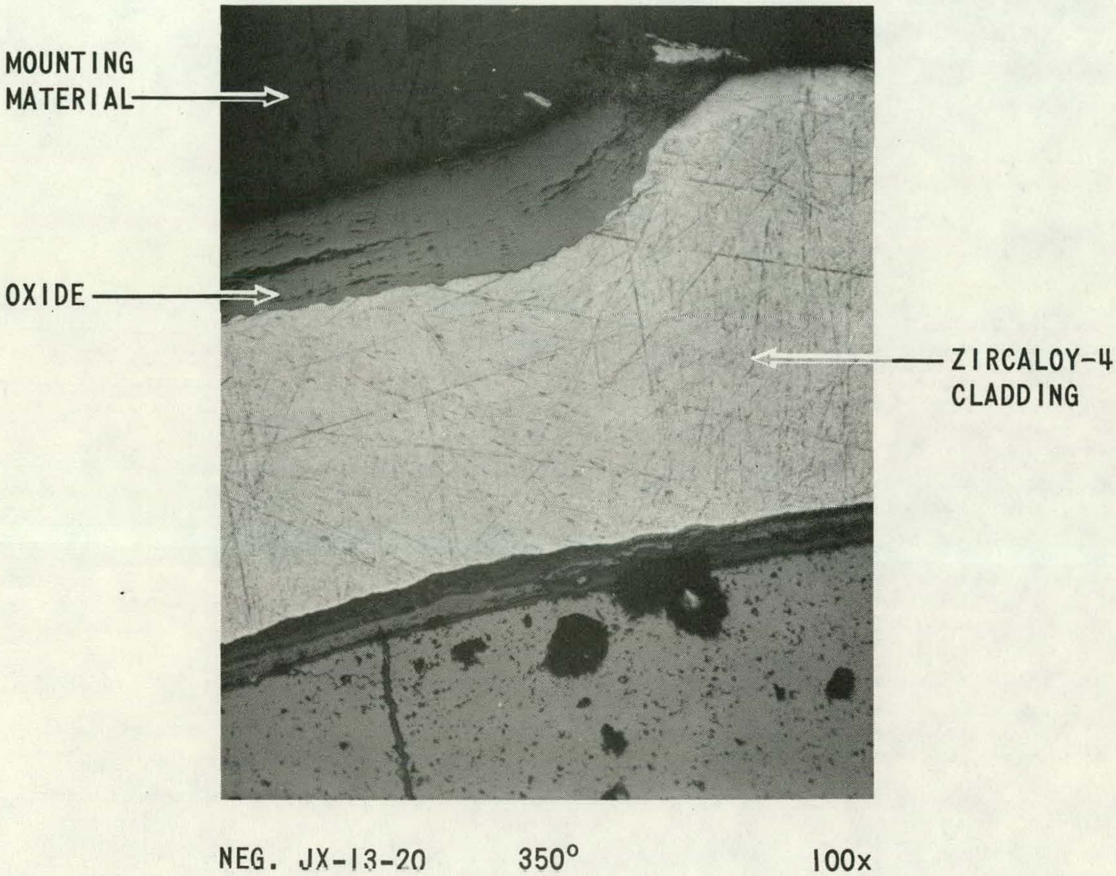



Figure 2-4. Thick Oxide on Outer Surface of Rod JX, 13 Inches from the Bottom

as indicated by numerous hydride precipitates and several areas of solid zirconium hydride, one of which contained two small cracks originating at the external surface. There was also considerable oxidation (several mils) of the inner surface of the cladding, which is characteristic of a failed rod which has operated for an extended period following failure. Examples of these latter conditions are shown in Figures 2-5, 2-6, and 2-7.

Although defected rod symptoms are clearly evident, neither the 13 inch nor 18 inch sections showed complete penetration of the cladding. Therefore, an additional section has been identified for detailed characterization of the principal defected area just above the 13 inch plane during the next quarter.

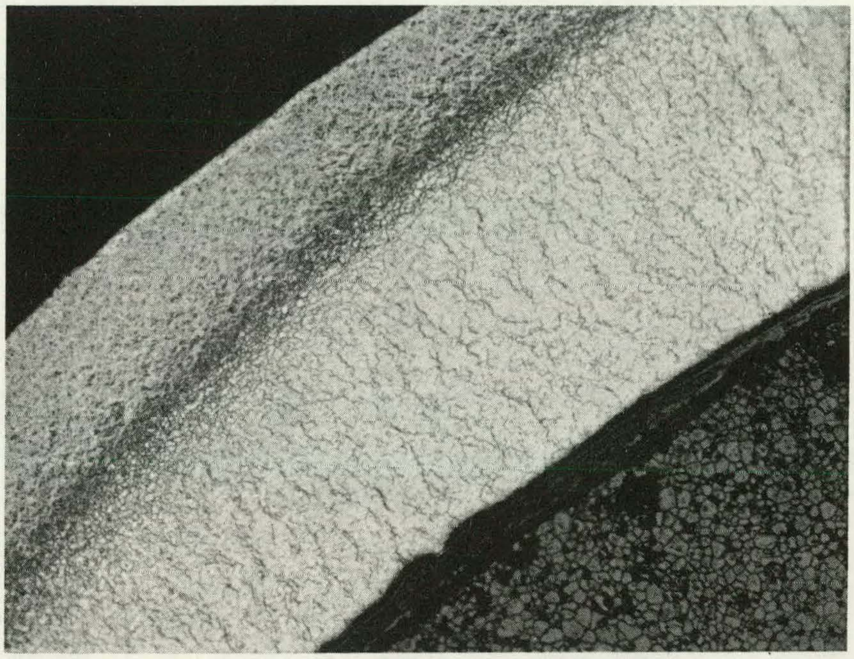
The 26.5 inch plane of rod JX also showed extensive hydride precipitation and a thick oxide layer on the internal clad surface. It also exhibited outer oxide films of about 0.5 mil and intermittent adherent crud.

All metallographic sections from the non-failed rods, including rods LS, FI and GM, showed oxide films on the inner surface of the cladding which were similar in extent to those seen on essentially all of the end-of-Core II rods examined.[3] However, the end-of-Core III rods consistently exhibited greater chemical fuel/clad interactions than did either end-of-Core II or Core III mid-life rods. In no case, was there any evidence of cracks, gross hydriding, or other defects originating at the internal clad surfaces.

B. Fuel Metallography

Macroscopic examination of all sections indicated that the gap between clad and fuel was either non-existent or very small. A characteristic pattern of radial and circumferential cracks was present in all cases. A typical macrograph of a transverse cross section is shown in Figure 2-8.

The pattern of grain growth in the non-failed, high power rods BE and BK was consistent with the power, and the microstructures were similar to those observed and previously reported[2] for mid-life, high power rods BO, NI, and RD. Columnar grain growth was observed in rod IM as well as in rods BE and BK. Central voids were not observed in any section of any rod. The grain growth pattern in the failed rod JX was different in that the grain size at



NEG. JX-18-62 45° 100x

Figure 2-5. Extensive Hydriding, 18 Inches from the Bottom of Rod JX

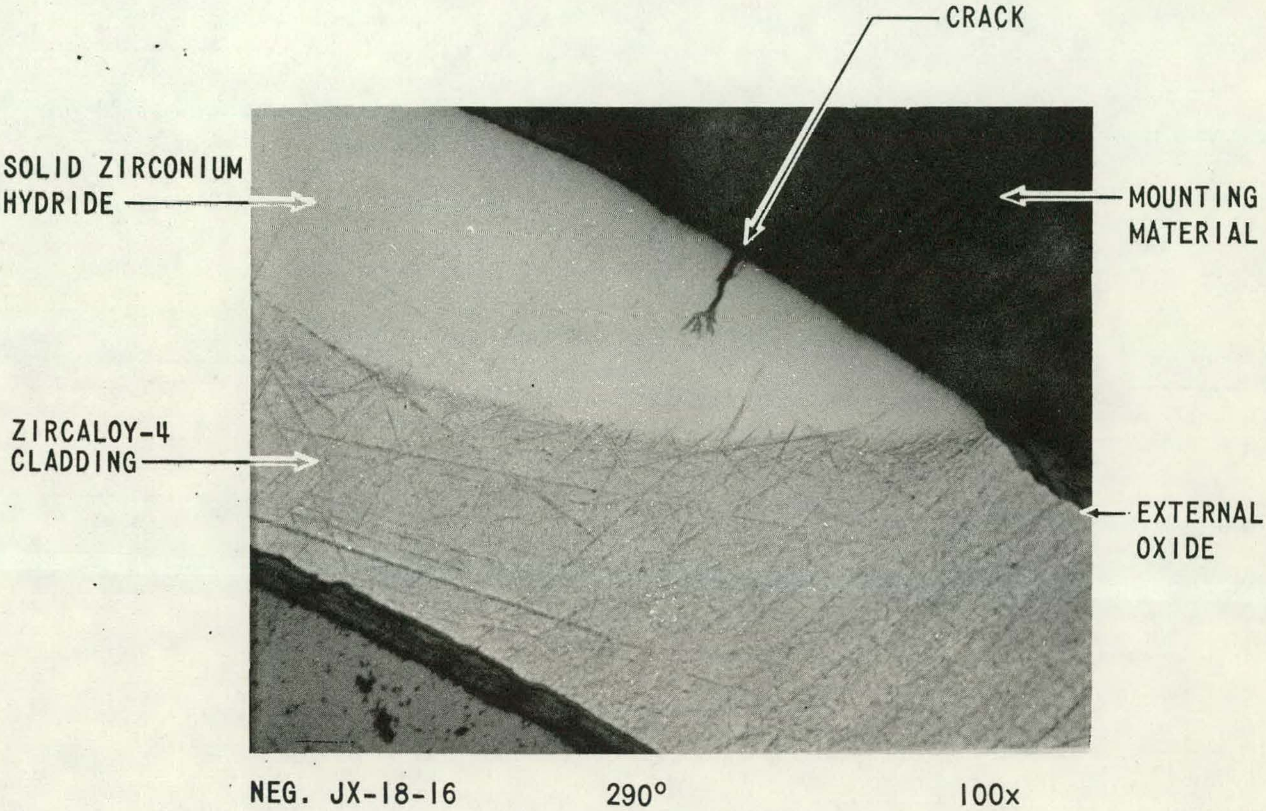



Figure 2-6. Part of Solid Hydride Area Containing External Crack, 18 Inches from the Bottom of Rod JX

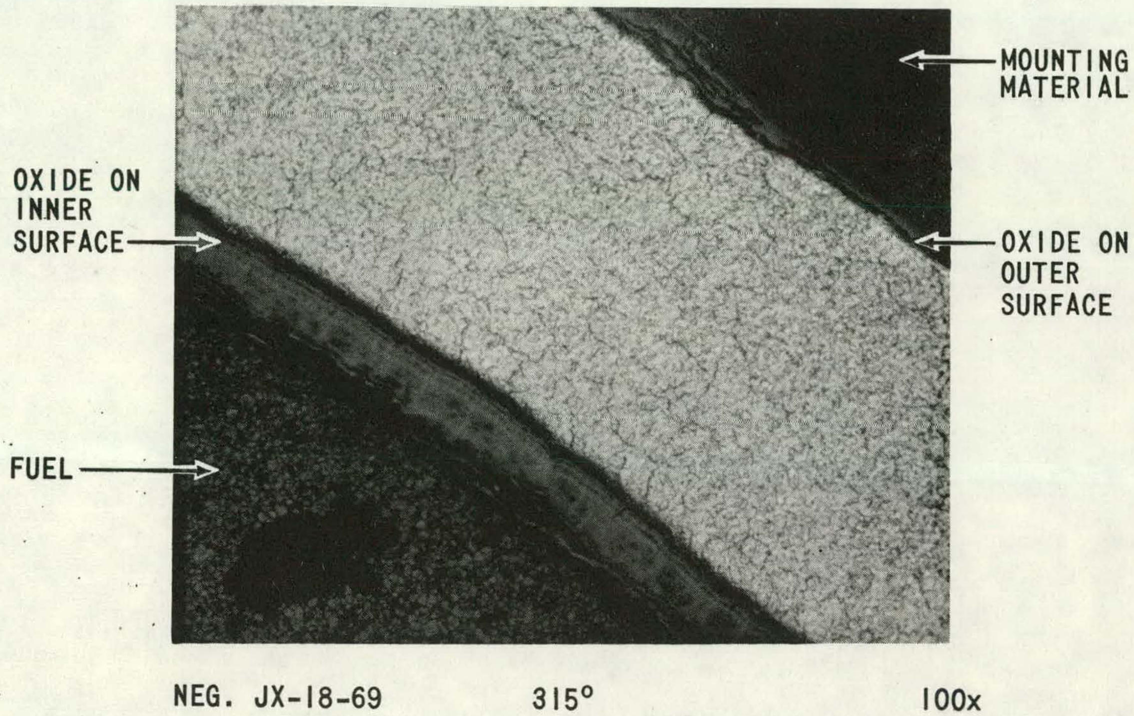
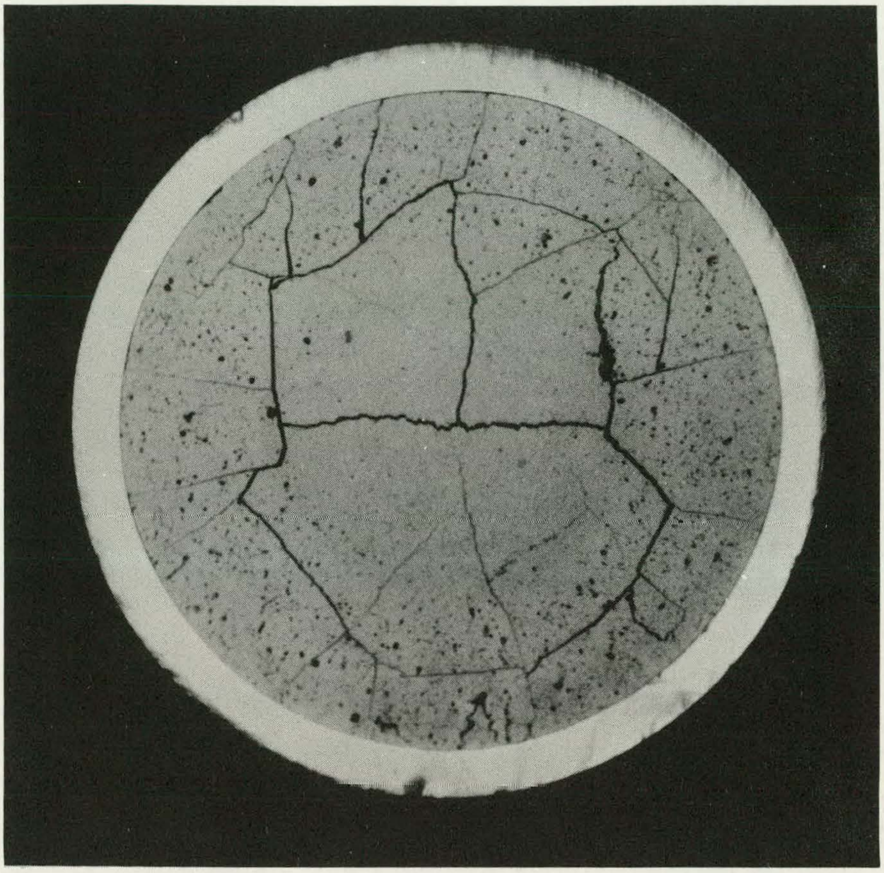



Figure 2-7. Oxide on Both Outer and Inner Surfaces of Rod JX,
18 Inches from the Bottom



NEG. HC 30906 ~10X

Figure 2-8. Macrograph of Transverse Section of Rod IM, 12.25 Inches from the Bottom the pellet surface was unusually large compared to that observed in the non-failed rods of similar power history.

Microstructures of the end-of-life sections, like their mid-life counterparts[2], showed homogenization of $PuO_2$ and $UO_2$ in the central region of the fuel. Also, metallic precipitates were present in all sections which operated at high temperature.

### 2.2.2 Clad Hydrogen Analyses

Duplicate samples from a 1/4 inch section of cladding from each of the eight end-of-life fuel rods were analyzed for hydrogen by the hot vacuum extraction method. The results are summarized in Table 2-1 and are generally consistent with the hydride precipitate levels observed in adjacent metallographic sections. With two exceptions, the data reflect a favorably low hydrogen uptake during irradiation in Cores II and III. The exceptions are the samples from rod BE, where locally heavy corrosion of the outer surface had occurred, and failed rod JX, in which severe hydriding was observed.

TABLE 2-1

SAXTON END-OF-LIFE CLAD HYDROGEN ANALYSES

| Rod Number | Sample Location (Inches from Bottom) | Average $H_2$ Concentration (ppm) (1) | Range of $H_2$ Concentration (ppm) |
|---|---|---|---|
| FI | 12.1 | 60 | 57-62 |
| LS | 12.1 | 64 | 59-68 |
| GM | 12.1 | 38 | 32-43 |
| BE | 12.1 | 361 (2) | 140-910 |
| BK | 13.4 | 100 | 62-138 |
| JX (Failed) | 26.6 | 653 | 627-678 |
| IM | 19.1 | 116 | 92-139 |
| PF | 18.1 | 95 | 94-95 |

(1) Average of two determinations

(2) Average of four determinations

SECTION 3

REFERENCES


1. R. C. Goodspeed, "Saxton Plutonium Project Quarterly Progress Report for the Period Ending December 31, 1972," WCAP-3385-34, March 1973.

2. T. E. Caye, "Saxton Plutonium Project Quarterly Progress Report for the Period Ending March 31, 1972," WCAP-3385-31, November 1972.

3. W. R. Smalley, "Saxton Core II Fuel Performance Evaluation, Part I: Materials," WCAP-3385-56, Part I, September 1971.