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STATUS REPORT: INVESTIGATION OF INNER FUEL
ELEMENT FAILURE, PROCESS TUBE No.3361,
JULY 7, 1964
(STATUS AT 5:00 p.m., July 20, 1964)

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July 17, 1964

STATUS REPORT: INVESTIGATION OF INNER FUEL ELEMENT
FAILURE, PROCESS TUBE No. 3361, JULY 7, 1964
(STATUS AT 5:00 p.m., July 20, 1964)

By

A. E. Guay
Chemistry and Metallurgy
Research and Engineering
N-Reactor Department

July 17, 1964

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July 17, 1964

M. Lewis, Manager
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N-REACTOR DEPARTMENT

STATUS REPORT: INVESTIGATION OF INNER FUEL ELEMENT
FAILURE, PROCESS TUBE No. 3361, JULY 7, 1964
(STATUS AT 5:00 p.m., July 20, 1964)

SUMMARY

The upstream end of the downstream⁽¹⁾ inner fuel element in process tube No. 3361 failed on July 7, 1964. The failure resulted in a final total loss of 312 gms of uranium core metal. The center of the volume of uranium core which was lost is situated 3/4-inch beneath the end cap; the inner cladding was collapsed to completely close the inner bore from visual sighting at this position and it was severely buckled over an additional 3/4-inch.

Radiometallurgical investigation of the failure is being conducted by Fuel Element Design, HL. Their work is currently directed at a study of the weld areas on the cap where several structural defects exist. The defects have been followed by successive light grinding, polishing, etching, and inspection to see how deeply they penetrate. One defect, which is now considered to be the most probable path of water entry was a small blow-hole on the ID weld surface; this blow hole was adjacent to a short radially-oriented flaw in the bore of the cap. The blow hole varied in cross-section from 3 to 18 mils dia. and has been observed to a depth of ~80 mils from the upper surface of the cap. The flaw in the cap, which was joined to the blow hole by a series of micro-cracks, was still present at 80 mils depth. The under-side of the cap, which has not been metallographically prepared, has a deep pit at the junction of the ID clad and braze metal and this defect is immediately beneath the hole on the side that is being examined.

The in-reactor history of this fuel element was not severe. Being at the downstream end of the top-roast tube row, the specific power of the fuel element and its thermal stresses were both low and the total exposure was low (33.5 MWD/T).

- (1) Charging records show that the ruptured inner element was in assembly No. 18. This number corresponds to the extreme upstream position. The fuel assembly was found on the bottom of the pile of fuel assemblies and it seems reasonable to assume that it must have been discharged first, i.e. was in the extreme downstream position.

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DISCUSSION

At the time the rupture was confirmed, the process tube, No. 3361, was operating at a power of 710 KW i.e. 20.3 Kw/ft average. This power level is only 18 per cent of the maximum average power under which N-fuel element assemblies have operated in the KER loops (113 Kw/ft). Exposure-wise, the reactor had reached 13,472 MWD, which leads to an average exposure of 33.5 MWD/T for the tube. Temperature-wise, the maximum uranium metal temperature within the fuel column would be 201°C and the temperature gradient within the piece would be 10°C.⁽²⁾

The above data indicate that the in-reactor history of the fuel element was not severe enough to predict a fuel element failure. The fact that a fuel element failure did occur tended to direct the analysis of the failure mechanism toward (1) damage from charging, (2) a (delayed) autoclave-type failure, (3) mistaken charging of a grossly defective piece. The work in Radiometallurgy has not disclosed charging damage to be the cause. However, the metallographic work to date indicates that a delayed autoclave-type failure has resulted from a defective end cap and inspection methods did not disclose the defect.⁽³⁾

Leiby and Allred⁽⁴⁾ have calculated that 0.648 gm of uranium were released from the rupture as a function of (1) the concentration of uranium in the coolant-based on the ratio of gross gamma signal to background (10^{-8} gmU/ml of coolant), (2) a release rate of 216 mg/hr at 96.6 gpm flow rate, and (3) an exposed uranium surface area of 0.6 cm² with an assumed corrosion rate of 360 mg/hr cm² at 200°C. This small uranium loss was compatible with the gamma energy spectrum and gross gamma energy surveys performed prior to reactor shutdown.⁽⁵⁾⁽⁶⁾ When the rupture was viewed in the basin at 11:00 am on July 10, the uranium loss was estimated at 40 gms ($2 + \text{cm}^3$). Visual examination of the rupture in A cell, Radiometallurgy, on July 11, showed a circumferential crack in the outer cladding at the base of the cap; the crack extended over 300° of the circumference. At one end, this crack changed direction and ran longitudinally down the outer cladding for 1/2-inch and then changed direction and ran circumferentially for 30°. This crack formation left the cap in contact with the outer clad along two 1/2-inch lengths - one circumferential and one longitudinal. Examination of the bore of the inner tube showed it full of Zircaloy cladding debris and direct sight through the bore was blocked. After the cap was detached by wiggling and sawing of the sound clad, the bore was found to be blocked over a longer length. Approximately 5-inches of the fuel section was sawed off and weighed; J.W. Goffard calculated a loss of 272 gm of U from the weight of the measured length. Subsequent nitric acid

- (2) Verbal communication. R. J. Shields, July 9, 1964.
- (3) Process Control (D. W. Darsow) to Files, July 10, 1964.
- (4) D. W. Leiby and D. O. Allred, "Preliminary Interpretation of Suspect Fuel Element Indication in Process Tube 3361 on July 7, 1964", EM-CISA-64-14, July 8, 1964, (Confidential)
- (5) G. L. Erickson and G. R. Klingler, "Data for Suspect Fuel Element Rupture, 100-N Area, July 7, 1964", HW-83195, July 8, 1964.
- (6) HW-81395, Sup. 1, July 8, 1964.

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pickling removed another 42 gms of core metal equivalent in the form of uranium oxides and showed inner clad collapse and contact over a 3/4-inch length and another 3/4-inch of buckling.

All the time the rupture was viewed in the north transfer pit, the end of the fuel element appeared to be "smoking" i.e. a fine particulate solid, which was thought to be colloidal uranium oxide, was seen to float upward in the convection current created by the assembly being propped up at 30° from horizontal (i.e. chimney effect). Because the corrosion reaction continued after reactor shutdown and in the basin, the extent of uranium core loss is very much greater than that estimated by Leiby and Allred.

Examination of the cross-section at the bottom of the damaged area shows nothing unusual in the cladding, the core, and the uranium to clad bond. Some light pitting of the inner clad exists (1/2 mil deep pits) but the relation of this corrosion to the failure has not yet been assessed.

Attempts made to leak test the cap to determine if the damage on the welds extends through the braze layer were unsuccessful. To determine if the flaws on the outer surface of the end cap and welds could be the path of water entry, the cap has been progressively ground, polished, etched and examined by standard metallographic techniques. What appeared to be a tiny blow-hole on the inner weld adjacent to a stained area on the cap surface was seen to be a gross gas void in the braze area and the void is connected to a flaw in the cap by a series of microcracks. The gas blow hole terminated at ~80 mils beneath the top of the cap but the flaw in the cap continues to the present depth of examination at ~90 mils.

Two small spots of uranium metal were found adhering to the bottom side of the cap and they were opposite each other. These pieces discount the mechanism that the failure was caused by cap to core shear.

CONCLUSIONS

The cause of the rupture has not yet been conclusively shown. At the present time, a blow hole, a defect in the bore of the cap, and a series of microcracks show a path for water entry through 90 mils of the cap thickness. If this series of damage continues, the failure can be classified as "caused by a pin hole through the weld and braze and propagation along a flaw on the inner surface of the cap." Accordingly, the failure is attributed to a flaw in a material, the cap.

Radiometallurgical work should be concluded by July 24.

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