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SLUDGE ADHERENCE SUMMARY REPORT

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Abstract: This report summarizes the results from the first sludge adherence tests performed in the 105-K East Basin on N Reactor fuel.

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Chris Millingham
Release Approval

7-11-96
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SLUDGE ADHERENCE SUMMARY REPORT

D. W. Bergmann and W. A. Briggs

July 1996

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SLUDGE ADHERENCE SUMMARY REPORT

1.0 TEST OBJECTIVES

The objectives of the sludge adherence testing was to determine if and how easily different types of adherent sludges could be removed from fuel elements stored in the 105-K East Basin with simple mechanical methods. Several methods were developed to assess the characteristics of specific features associated with sludge removal. These methods utilized the sludge adherence test cylinder, a stainless steel brush, and the fuel handling tools.

This testing was not designed to simulate the fuel retrieval process. Rather, simple mechanical removal techniques were performed in order to provide qualitative data on specific features to aid in the design of the fuel retrieval process.

1.1 FUEL HANDLING TOOLS

Each of the fuel elements to be handled were to be moved through the water while attached to the fuel handling tools and observed for sludge removal characteristics. This type of movement was observed in an effort to determine if some of the sludges could be disturbed, or in fact removed, with slow water movement across the surface.

The use of more aggressive hydraulic methods (i.e., water jets) for determining sludge adherence was considered beyond the scope of this test. Although, it was considered in test planning, it was concluded that it would be better to concentrate on assessing the relative effectiveness of mechanical work in this test sequence. The effectiveness of hydraulic work was deliberately limited to movement of fuel through the basin water.

1.2 SLUDGE ADHERENCE TEST CYLINDER

The sludge adherence test cylinder was designed to determine the effectiveness of rotating fuel elements along two axes (end-to-end and rolling actions) to remove various types of adherent sludges.

1.3 BRUSH

A stainless steel brush was designed to scrub the outside surface of an outer element. The brush was to be utilized as a more aggressive method for sludges that were not being removed by the other methods listed above. This assessed the relative effectiveness of continuous and uniform mechanical work on sludge adherence when applied directly against the sludge and fuel surface.

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2.0 FUEL ELEMENTS

Three fuel elements were selected for testing, two inner elements, and one outer element. Element selection had to ensure that all elements could be returned to a canister from the same discharge key [Spent Nuclear Fuel (SNF) accountability requirements]. In order to ensure this, it was necessary to pull like elements from the same fuel storage canister. Each of the fuel elements selected had unique characteristics which provided data relevant to the Fuel Retrieval System (FRS) design. All of the elements selected for testing had been visually examined as part of the Phase II characterization campaign. The following describes each of the elements in detail.

Outer Element--This element was intact with no visible damage to the cladding. The lack of cladding damage was purposely chosen to allow the use of the brush on the element. Four different types of sludges/surfaces were on this element and are discussed below.

1. A dark ring was observed along the bottom of the element. This ring was rough in texture, providing the appearance that a dark sludge was adhered to the sides of the element. Additionally, the height of the ring appeared to correlate to the sludge depth in the canister.
2. Some of the spacers showed what appeared to be rust deposited on the element.
3. All of the surfaces on the element that were not emersed in the sludge in the bottom of the canister were covered with a light colored sludge. This type of sludge was present on every element that was observed during the Phase II characterization activities in the K East Basin.
4. Nodules were attached to the fuel element in the zones that were in direct contact with the fuel storage canister. It has been hypothesized that these nodules are the result of galvanic action between the cladding and the storage canisters.

Inner Element Number 1--This element had two types of sludges associated with the element. They were, the dark ring and the light colored sludge. Both of these types of sludges are described in more detail above for the outer element, see Items Number 1 and 3. This element had the unique characteristic of having a dark spot present in the upper position of the element.

Inner Element Number 2--This element had the same types of sludges as inner element Number 1. The unique characteristics of this element were that only one spacer was on the element and the dark ring along the bottom was larger.

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3.0 RESULTS

3.1 FUEL HANDLING

Movement of the fuel through the water resulted in very minor, if any, sludge removal from the fuel elements. The removal of fuel elements from the storage canister resulted in the pulling of sludges from the bottom of the canister into the water column directly surrounding the fuel element. Additionally, it was observed that extremely damaged elements, in some cases, actively drained sludges from cladding fracture sites.

3.2 SLUDGE ADHERENCE TEST CYLINDER

The type and amount of sludge removed was not easily observed during the actual end-to-end and rolling operations of the test cylinder. This was due to the limited ability to see movement within the test cylinder. Most of the observations made for these operations were the result of careful examination of the fuel surfaces before and after each operation.

3.2.1 End-to-End Action

The end-to-end action changed three of the sludge types which were adhering to the outer surfaces of the fuel elements placed into the cylinder. This action also caused one of the spacers on inner element Number 2 to fall off. The sludges that were affected are described below.

1. The outer surfaces of the fuel elements were covered with sludge in locations that were not emersed in the sludges located in the bottom of the storage canister. This fine, adherent sludge was removed at the impact zones (the ends). Some of this sludge was removed from the sides of the elements in locations that scraped against another surface (i.e., the sides of the cylinder and other fuel elements).
2. All of the fuel elements placed into the test cylinder had dark rings along the bottom of the fuel elements. These rings appeared to be the result of being emersed in sludge that collected in the bottom of the storage canister. The relative heights of the rings appeared to correlate to canister sludge depth (no direct measurements of the ring heights were made). These rings were rough in texture and appeared to contain adherent sludge. The end-to-end action of the fuel elements caused the dark rings to appear more like a smooth metallic surface. The result of the end-to-end rotation appears to have removed some dark sludge that was adhering to the side of the elements in the vicinity of the dark rings. Later operations (brushing) determined that the dark rings were most likely clean zirconium cladding.

3. The outer surface of the element which was in direct contact with the storage canister had, nodule type of sludge deposits on its side. There is some speculation that this material is the result of galvanic action between the storage canister and the fuel elements cladding. The amount of this type of sludge was reduced during the end-to-end action.

The end-to-end action in the test cylinder was similar to but not identical to the end-to-end action in the design of the current FRS. The vertical drop of the fuel tested was approximately 2.9 in. The fuel retrieval designs vertical drop ranges between 4 and 6 in. The somewhat smaller drop in the test cylinder was considered sufficient to characterize the general effect of a sudden deceleration upon sludge adherence.

3.2.2 Rolling Action

The rolling action of the fuel within the cylinder showed that when the fuel elements rolled and scraped against another surface, the fine, light colored sludge (which was on most of the fuel surfaces) could be removed. The areas of the fuel elements that did not roll and scrape against any other surfaces did not remove this fine sludge. The amount of sludge removed during this operation was relatively minor due to the limited number of contact surfaces.

This action also caused a reduction in the amount of the nodule type corrosion located on outer elements. Since the outer element did not roll, it is believed that the sliding action against the test cylinder of the element caused the sludge reduction.

The fuel elements that contained clips did not roll. The one element with no clips rotated/rolled.

The rolling action of the test cylinder was similar to the current fuel retrieval design, however, it did not simulate this process. The diameter ratio of the fuel elements to test cylinder and the fuel retrieval washing machine are not identical. The intent was to assess the relative effectiveness of the rolling feature in the absence of water circulation. Additionally, the fuel retrieval washing machine has a water circulation system that will aid in sludge removal.

3.3 BRUSH

The brushing action was performed on the outer fuel element. This element had four different types of sludges attached to it. When the fuel element was placed into the brush nearly all of the remaining visible adherent sludges (note: the dark sludge associated with the bottom ring of the element had been removed in the test cylinder) were removed from the element. After the fuel element was brushed the outer surface of the element appeared smooth and dark, very similar to, if not the same as, a freshly autoclaved fuel element.

The brushing operation also showed that the sludges adhering to the fuel element were relatively light, settled slowly, and were not tightly adhered to the fuel surfaces.

Brushes are not part of the fuel retrieval design. The purpose of the brush was to provide a more aggressive technique of sludge removal to determine if all of the visible adherent sludges could be easily removed from the elements.

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A P P E N D I X A

SUPPORTING FIGURES

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Inner Element #1
Initial Loading into Test Cylinder

Inner Element #2
Initial Loading into Test Cylinder

Outer Element
Initial Loading into Test Cylinder

Test Cylinder in Basin
for End-to-End Action

Inner Element #1
After End-to-End Action

Inner Element #2
After End-to-End Action

Outer Element
After End-to-End Action

Test Cylinder on Canister Cubicle
Rack for Rolling Action

Inner Element #1
After Rolling Action

Inner Element #2
After Rolling Action

Outer Element
After Rolling Action

Outer Element
Going into Brush

Sludge Plume when Outer Element
Extracted from the Brush

5-31-96 2H
10:43:00

Outer Element
After Brushing

5-31-96 2H
10:43:18

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