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**SPECIAL PEREVIEW
FINAL
DETERMINATION**
Class. 1
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Date 5-4-82

EXTERNAL CORROSION OF SINGLE ELEMENTS
(Title Unclassified)

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Classification cancelled (or changed) to
by authority of H.F.C. TIC, date SEP 11 1973

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INTRODUCTION

During the regular evaluation of fuel elements, hydrogen was inadvertently introduced in the normally inert helium atmosphere that surrounds the fuel element. Several interesting aspects of the behavior of the element surface were observed. Some behavior patterns showed a similarity to the KIWI-B-4E elements. This leads to the following discussion and points out the need for experimental work to further verify the external element corrosion behavior.

DISCUSSION

With the introduction of hydrogen to the normally inert atmosphere surrounding the fuel element, hydrogen corrosion started at a distance of 29 inches from the cold end and continued up to 37 inches at which point it virtually ceased and reappeared at the extremely hot end. During any test, the inlet hydrogen pressure matches the pressure on the outside of the fuel element. Hence the pressure on the outside of the element starts at virtually no pressure difference between the outside of the element and the flow channel and then progressively increases up to approximately 78 pounds per square inch pressure difference in the hot end. Hence, if there is no communication between the atmosphere and the flow channels the pressure difference would vary from practically zero at the cold end to 78 psid at the hot end. The typical pressure and temperature distribution are shown in Figure 1. The temperature distribution is the surface temperature measured experimentally by an optical pyrometer. The experimentally measured points are indicated.

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Corrosion started at a point 29 inches from the cold end which corresponds to an element surface temperature of 3280°R and continued to 37 inches which corresponds to an element surface temperature of 3750°R. In the range from 38 inches to 47 inches there was very little corrosion, but severe corrosion again occurred in the region at the hot end from 47 to 50 inches. It should be noted that the temperature at which the "low temperature corrosion" stops corresponds approximately to the temperature at which the elements are coated ($T=1900^{\circ}\text{C} = 3900^{\circ}\text{R}$). This would imply that the corrosion occurs between the corrosion temperature threshold (3200 R) and continues to the liner coating temperature (3900°R). In this temperature region the cracks in the niobium carbide liner are open. Above 3900°R the liner cracks are closed and corrosion is reduced until the extremely high end temperatures are encountered. Furthermore, by careful examination, it can be seen that at the start of the corrosion band, each of the small craters of corrosion have as their center a crack in the fuel element coating. These are shown in Figure 2. The entire test evidence of the two particular tests, where appreciable hydrogen concentrations existed in the helium atmosphere, tend to collaborate the theory that hydrogen gas diffused from the exterior surface of the wall into the flow channel only in that part of the element between the threshold of corrosion and the point at which the niobium carbide cracks are closed due to thermal expansion. Furthermore, the initiation of corrosion which can definitely be seen around each crack in the tube substantiates this supposition. The experimental evidence of these tests shows a behavior similar to that seen in the corrosion behavior of the KIWI-B-4E elements, and support the theory that

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radial inflow by diffusion is responsible for the "corrosion band". Large corrosion pockets in the corrosion band would lead to the corrosion progressing at an ever increasing rate once the initial passage through the graphite into the channel has been established. A 9-foot composite photograph for the special purpose of showing the discussed phenomena was prepared from enlarged photographs of the element and is shown in Figure 2.

CONCLUSIONS

The above discussion is the present understanding of the external corrosion phenomena in fuel elements. The similarity between the external element corrosion seen at the corrosion facility and that observed in past hot reactor tests indicate that considerable knowledge can be obtained by testing elements in atmospheres of controlled composition. Once the present knowledge has been expanded, and an understanding of the external behavior of fuel elements at the corrosion facility has been attained, this information can then be applied to hot reactor tests.

The appearance of this corrosion phenomena in a particular pattern and at a particular portion of the element leads to the feasibility of reproducible tests. Once enough of the recommended tests are completed, ways to prevent or slow down this external corrosion can be developed.

RECOMMENDATIONS

1. Initiate a series of tests to determine the effect of corrosion on external surface of fuel elements. To run this series of tests, the existing corrosion facility, with minor modifications, can be used.

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These tests would include:

- a) Introduce a mixture of hydrogen and helium to the atmosphere surrounding the outside of the element. During this series it would be possible to determine what percentage (if any) of hydrogen could be allowed to diffuse into the element without inducing excessive corrosion.
- b) Introduce other controlled corrosion suppressant gases into the controlled external atmosphere.
- c) Make controlled suppressant gas additions directly to the coolant passages of the element.
- d) Combine the controlled suppressant gases both in the external atmosphere and through the coolant passages.
- e) Completely enclose an individual element in a casset which provides prototype interstitial gaps.

DATA TO BE OBTAINED

- 1. The effect of hydrogen on the external surface of fuel elements.
- 2. The effect of corrosion on the external surface of fuel elements by additives to the external atmosphere.
- 3. The effect of external corrosion as determined by internal additives
- 4. The effect of external corrosion as produced or inhibited by additives externally and through the coolant passages simultaneously.
- 5. External corrosion (if any exists) as determined by running an element in a casset.

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TEST NUMBER 832

Figure 1 - Element Length (inches)

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COLD END

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December 9, 1964

LEGEND

RUN #832

ELEMENT #AC-99-15950

HOT END

FIGURE 2