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**Pacific Northwest Laboratory
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NONUNIFORM ALUMINUM CORROSION PROGRAM

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A. P. Larrick

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NONUNIFORM ALUMINUM CORROSION PROGRAM

By

D. O. Sheppard

A. P. Larrick

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By Authority of WA Snyder

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NONUNIFORM ALUMINUM
CORROSION PROGRAM

1. Purpose of Document

The purpose of this document is to summarize the status of the current non-uniform aluminum corrosion program. Also included are justifications for and descriptions of program activities which could continue through FY-1971. The information contained in this document was assembled prior to the recent announcement by the Atomic Energy Commission of its intentions to further reduce the number of operating single-pass reactors. Consequently, the plans and justifications outlined here must be reviewed in light of changing incentives and funding availability. As such, the following task descriptions should not be interpreted as definite commitments for technical activities, but instead they should be reviewed as a common base for discussions concerning future activities in support of this program.

2. Justification and Goals of Program

Non-uniform corrosion of the aluminum cladding has been a severe problem at Hanford; however, the problem has subsided and the impetus for improvement to standard production fuel performance has diminished. This does not mean the problem is thoroughly understood, nor can we assume it will not reappear, especially on new fuel geometries and at higher exposures.

DUN long-range goals call for the eventual overbore of the Hanford Single-Pass Reactors. The overbore fuel will produce a non-defense grade high Pu-240 product requiring over 200 percent of the normal weapons grade plutonium exposure. Aluminum is a prime candidate for cladding material and the hot-die-sizing process is the most feasible method for aluminum cladding these larger cores.

Assuming a gradual overboring of the reactors, eventual conversion of the fuel fabrication plant to the hot-die-sizing operation is foreseeable. With the versatility of hot-die-size (HDS), it seems reasonable that during the overbore project, standard production fuel could be hot-die-sized as well.

Historically, the larger-core HDS fuel has exhibited more non-uniform corrosion than AlSi canned fuel.¹ The advent of HDS fuel replacing the AlSi fuel requires a better understanding of this difference. Current test data show that HDS fuel with a larger core corroded more severely than HDS fuel with a smaller core, both having the same finished outside dimensions.^{2,3}

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Aluminum has been a very successful and inexpensive fuel element cladding for the Hanford single-pass reactors. Aluminum, however, is inherently susceptible to erosion-corrosion and with a long reactor residence time, aluminum may become unacceptable. It is for this reason alternate cladding materials are being investigated.

Sponsored work in BNW is aimed toward determining the feasibility of electroplating a 3 to 5 mil nickel plate on uranium cores to serve as the primary protective barrier. The problems of handling and charging a heavy uranium fuel element with a thin but strong protective cladding will have to be resolved. The neutron efficiency of nickel plate is equivalent to that of the existing aluminum at a plate thickness slightly less than 5 mils provided the higher cross-section of nickel is compensated by an increased thickness of uranium.

Some work has also been performed on electroplating zirconium on uranium and the feasibility of plating 5 mils was demonstrated on a laboratory scale. Problems of zirconium crystal nucleation was noted on thicker plates; however, possible solutions were never pursued. Work in this area may be continued at a later date.

The current program is directed toward understanding and reducing the nonuniform corrosion potential by: 1) investigating fundamental corrosion mechanisms, 2) investigating the differences in corrosion behavior between HDS and AlSi fuels, 3) identifying the effects of fuel fabrication processes on corrosion and 4) developing an aluminum alloy cladding or other uranium coating better able to combat erosion. A somewhat longer range goal is the development of a nickel plating technique to apply a thin plate (3 to 5 mils) on uranium. The nickel would replace the aluminum entirely and remove the high erosion potential of the aluminum cladding.

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MISSION 1:

Basic Production

FUND ALLOCATION:

R&D

FY-1969

\$20,000

(7A2B-5T50-49P.J1)

FY-1970

\$20,000

FY-1971

\$20,000

W. O.

\$ 3,500

(7A2B-5T50-422.J1)

Capital Equipment

\$ 5,000

RESPONSIBLE DUN SUBSECTION:

Reactor Materials Technology

RESPONSIBLE DUN CONTACT:

P. A. Carlson/A. P. Larrick

RESPONSIBLE BNW CONTACT:

R. L. Dillon

PROGRAM SUB-TITLE:

Corrosion Mechanisms, Laboratory Tests

FY-1969

Considerable effort has been expended to investigate the effects of water quality on aluminum-clad fuel corrosion. Much of this work has been summarized in Reference 1. It is proposed in Reference 1 that the prime mechanism for nonuniform cladding corrosion is an erosion phenomenon commonly termed erosion-corrosion. This phenomenon can be aggravated or suppressed by the altering of many variables such as coolant pH, sodium dichromate or alum concentration, turbidity level, cladding alloy composition or fuel fabrication variables.

A laboratory technique to investigate the effects of these variables on localized (nonuniform) aluminum corrosion will be developed. The technique should have sufficient fidelity with reactor conditions to permit investigation of process water, reactor and fuel parameters as they relate to frequency and severity of attack. The technique envisioned involves the use of an impingement apparatus in which the important parameters can be varied. Corrosion will be measured by linear polarization, visual examination, and weight loss.

Initial tests will be directed toward obtaining conditions which will reproducibly result in nonuniform corrosion on 8001 aluminum alloy. The effects of pH, water temperature and velocity on corrosion will then be investigated.

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FY-1970

The laboratory nonuniform corrosion studies will be expanded to include the parameters of turbidity, dichromate concentration, pressure, and channel dimensions. The temperature parameter will be further investigated by varying both the sample surface temperature and the bulk water temperature. The controlling parameters determined in the laboratory tests will be investigated in the TF-18 pilot plant loop to verify their importance under prototypical reactor conditions.

FY-1971

The laboratory tests and confirming pilot plant tests will be completed. Significant results will be applied to an in-reactor, half-plant test as a final proof test.

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MISSION 1: Basic Production

RESPONSIBLE DUN SUBSECTION: Reactor Materials Technology

RESPONSIBLE DUN CONTACT: P. A. Carlson/A. P. Larrick

PROGRAM SUB-TITLE: Corrosion Mechanisms, Reactor Tests

FY-1969

- 1) In-reactor tests with the goals of reducing operating costs and providing more efficient operation will continue. Initial data from a half-plant test conducted at B Reactor under PTA-057 indicates that a reduction of dichromate concentration to one-half ppm does not increase water corrosivity at pH 6.6. Analyses of the data will be completed and published in FY-1969. A similar in-reactor test with reduced dichromate concentration is being conducted in KE Reactor. Sufficient data should be available from fuel columns under PTA-011 by January, 1969 to determine if one-half ppm dichromate operation can be extended to KW Reactor.
- 2) Fuels irradiated during an in-reactor test being conducted under PTA-142⁴ to determine the effect of reactor effluent turbidities up to 0.3 JTU (normally 0.03-0.08) on effluent activity will be closely monitored to increase the understanding of the effects of the high turbidity on nonuniform corrosion.
- 3) Predictions of aluminum-clad fuel element corrosion rates are calculated from an equation developed several years ago. With the advent of numerous water chemistry changes in recent years, the accuracy of the predicted results is unknown. Proposed changes in fuel power and increased exposures also make it necessary to determine the applicability of the equation under more severe conditions.⁵ PTA-138 authorizes charging of aluminum-clad Oralloy fuels operating with high heat fluxes and thermocouples embedded in the cladding to obtain corrosion data and surface temperature data. This test will be used to determine the current validity of the corrosion equation. Charging is anticipated in January, 1969.

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MISSION 1: Basic Production

FUND ALLOCATION: FY-1969

\$25,000 (7A27-5T40-49P.DO)
\$12,000 (7A27-5T40-49P.NO)

WORK ORDER ESTIMATE: \$30,000 (7A27-5T40-422.DO)
\$20,000 (7A27-5T40-422.OO)

RESPONSIBLE DUN SUBSECTION: Fuel and Target Technology

RESPONSIBLE DUN CONTACT: D. O. Sheppard

RESPONSIBLE BNW CONTACT: R. L. Dillon

PROGRAM SUB-TITLE: Cladding Development

FY-1969

- 1) The goal of this work will be to suppress or eliminate those cladding performance phenomena, such as ledge and groove corrosion, that prevent single-pass reactor fuel elements from attaining very high exposures. Emphasis will be on those processes which significantly improve fuel cycle costs, not only by increasing exposure capability, but also by decreasing total fuel fabrication costs or by increasing the amount of uranium in the reactors.

The major funding will be concerned with determining the feasibility of electroplating nickel directly on uranium for the primary corrosion barrier. Pre-plating treatments of the uranium to roughen the surface and permit a strong mechanical bond will be developed. Nickel thicknesses in the 3 to 5 mil range will be attempted.

Nickel plating of the aluminum for erosion resistance is also under consideration and shows promise. A baked anodized surface treatment under investigation may demonstrate improvement. These areas are not being actively pursued due primarily to other priorities; however, work will continue when time and money become available. The erosion facility developed for the mechanism studies will be used to examine all candidate coatings and claddings with respect to their relative erosion resistance.

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- 2) A continuing effort to develop an erosion resistant cladding alloy has been underway for some time. The HDA, high silicon alloys, were an attempt in this direction.^{6,7} Presently, 18 various aluminum alloy cladding candidates are under investigation. These alloys include three basic types: Ni-Fe alloys; Si-Mg alloys; and a Fe-Ni powder metallurgy alloy. Casting and fabrication of these alloys have been successfully demonstrated. Uniform corrosion tests in a high temperature autoclave and at low velocity in the TF-18 flow loop showed no significant difference among the alloys.⁹ The alloys will be evaluated near the end of FY-1969 for erosion-corrosion resistance in the erosion facility after the mechanism studies determine which parameters must be controlled to obtain erosion-corrosion.

FY-1970

The program will continue to develop and test new coatings and alloys for increased erosion resistance. Efforts will be applied to the development of claddings to withstand the increased exposures required for non-defense plutonium production. Evaluations will be completed in the 1706 KE Corrosion Facility before proceeding to in-reactor testing. Upgrading of the TF-18 flow loop will be completed to better provide a simulated environment for evaluation of the most promising claddings.

FY-1971

Fuels clad with the more promising alloys or coatings will be evaluated in-reactor.

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MISSION 1: Basic Production

RESPONSIBLE DUN SUBSECTION: Fuel and Target Technology

RESPONSIBLE DUN CONTACT: D. O. Sheppard

PROGRAM SUB-TITLE: Fuel Fabrication Variables

FY-1969

The incentives for hot-die-sized fuel have been shadowed by the greater nonuniform corrosion frequency of the hot-die-size fuel as compared to the AlSi fuel. It is not completely understood whether this is due to fuel fabrication variables or results from the increased surface temperature of the larger core HDS fuels. A test conducted with larger core HDS fuels and AlSi core size (universal core) HDS fuels yielded three times as many hot spots and almost three times as much primary groove corrosion on the large-core fuels. The average of the highest surface temperatures was 122.3 C for the large core and 117.8 C for the small cores.

A production test has been prepared which will compare the the corrosion behavior of universal core fuel with universal core AlSi (same core size). Both will have the same heat generation rate and by alternating HDS and AlSi fuels in the charge, reactor environmental effects will be consistent. If the pieces corrode similarly, then it can be concluded that temperature was the dominant effect causing the larger core HDS fuel to corrode more readily. However, if the HDS fuel show poorer corrosion resistance than the AlSi fuel, some fuel fabrication variable or a combination of temperature and fuel fabrication is causing the difference.

Also to be included in the test are control tubes containing alternate large and universal core fuels clad by the HDS process to see if the temperature effect still exists.

FY-1970

Evaluation of the above in-reactor test will be completed.

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1. DUN-2213, "Non-Uniform Corrosion of Reactor Fuel Elements - Summary, " D. W. Peacock.
2. DUN-2904, "PTA-060 - Hot-Die-Size Process Variables Test," J. P. Schmidt.
3. DUN-4639, "FEDC Report - September, 1968," H. F. Tew.
4. DUN-4313, "PTA-143 - Half Plant Test of Process Water Turbidity, 183 KE, August 14, 1968," R. G. Geier and G. W. Wells. (Unclassified)
5. DUN-4300, "PTA-138 - Corrosion Testing of Highly Enriched Fuel in C Reactor," W. K. Kratzer and B. A. Ryan, July 7, 1968. (Secret)
6. "Basis and Justification - High Silicon Aluminum Alloy," January 3, 1966.
7. Letter, R. D. Williams to H. F. Tew, "High Silicon-Aluminum Alloy Program," January 10, 1967.
8. BNWL-CC-1705, "Aluminum Alloys for Ledge and Groove Corrosion Resistance," J. C. Tverberg, et al, June 25, 1968. (Confidential)
9. Reference for clad alloy corrosion results.

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