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PRODUCTION TEST AUTHORIZATION - 065
UNAUTOCLAVED FUEL CORROSION TEST -
D REACTOR

D. W. Peacock

Research and Engineering Section

March 16, 1967

DOUGLAS UNITED NUCLEAR, INC.
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PRODUCTION TEST AUTHORIZATION - 065
UNAUTOCLAVED FUEL CORROSION TEST
D REACTOR

OBJECTIVE

The objectives of this test are to determine if autoclave film has an important role in the groove and ledge corrosion mechanism, to evaluate the performance of unautoclaved fuel in corrosion environments of different severities, and to verify the importance of process water pH in regulating the frequency and severity of groove and ledge corrosion.

JUSTIFICATION

At the present time localized corrosion, in particular groove and ledge corrosion, is a poorly understood phenomenon. Past and possible future operational difficulties have prompted considerable attention to this problem. In-reactor testing in support of these investigations is expected to increase in the immediate future. The purpose of this test is to evaluate the corrosion aspects of autoclave film and process water pH.

Autoclaving of fuel elements has been practiced for many years as a means of corrosion control and to detect weld defects. The autoclave treatment is thought to be somewhat beneficial in reducing corrosion during the early part of the metal cycle. It has been suggested that autoclave film defects may be a parameter in the groove and ledge corrosion mechanism. Recent laboratory experiments¹ have shown that the location of localized groove attack is correlated with positions on the fuel element surface where damage to the autoclave film is likely to occur. The time required to replace this preformed oxide film with in situ film has not been established. However, no autoclave film could be detected² on fuel elements recently discharged after only seven days of reactor operation. If the in-reactor life of autoclave film is less than seven days, it seems unlikely that it could significantly affect uniform corrosion. However, autoclave film defects may initiate localized corrosion sites that continue to preferentially corrode during the remainder of the irradiation cycle.

A comprehensive development program is planned to evaluate the corrosion aspects of fuel element surface characteristics. These studies include such items as autoclave cycle procedures, dichromate films, film thickness, film fracture patterns, and others. Before considerable development effort is expended in these studies, an in-reactor test is needed to confirm the postulated film effects. This test will serve this function by comparing the irradiation behavior of standard autoclaved and unautoclaved fuel. This design should detect any gross differences in the corrosion performance of these two fuels. If the results of this test indicate that autoclaving improves the corrosion resistance of fuel surfaces, greater emphasis on programs to study the film characteristics would be indicated. If no differences were detected, or if the unautoclaved fuel exhibits improved corrosion performance, the incentives and economics of autoclaving would require review. In either event, valuable basic corrosion data would be obtained.

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It is proposed to vary corrosion severity in this test by altering reactor process parameters. The effects of process water variables on the incidence and severity of groove and ledge corrosion is not well defined. It is thought that localized attack increases with increasing pH. This seems intuitively correct as higher pH water is known to increase uniform corrosion rates, and localized corrosion would be expected to follow uniform corrosion trends. In a forthcoming summary of localized corrosion data³, the reduction of pH from 7.0 to 6.6 will be cited as the most important process change which was responsible for eliminating the high incidence of groove and ledge corrosion ruptures which occurred during the period from 1962 to 1964. This finding contradicts results⁴ from a production test⁵ which investigated the corrosion aspects of pH 7.0 and pH 6.6 water. Fuel elements exposed to pH 6.6 coolant exhibited only a minor or no significant reduction in both the incidence and severity of groove and ledge corrosion when compared to fuel cooled with pH 7.0 water. Thus, in addition to varying the corrosion severity of the unautoclaved fuel portion of this test, the effect of changing process water pH will also be investigated.

The need to identify and define all reactor process variables which affect groove and ledge corrosion is justifiable on two counts. First, the quantitative identification of these parameters would provide a technical basis for recommendations to control severe groove and ledge corrosion should future process changes produce another outbreak of fuel failures. Second, this knowledge may permit fuel test designs in which reactor variables could be altered to provide environments with known potentials for localized attack. The probability of detecting significant differences in any test of fixed size is strongly dependent on the frequency of occurrence of the test statistics. The variability of groove and ledge corrosion may have compromised previous tests, and may compromise future testing. In this test, only the effect of process water pH will be investigated to verify its effects on localized attack.

This test is essentially two separate tests. It is designed to detect differences in the corrosion aspects of autoclave and unautoclaved fuels, and to verify that process water pH is one of the important reactor process variables which affects localized corrosion. Either function can be justified separately. Combined in a single test, they complement one another and offer a rare opportunity to gain valuable corrosion information with a minimum impact on production.

TEST DETAILS

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A. Reactor

This test will be conducted at D Reactor during the last operating period prior to shutdown for deactivation.

B. Process Water

After initiation of this test, the pH, sodium dichromate feed rate, and alum feed rate of the 100-D Area process water will be maintained as shown in Table I.

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TABLE I

Process Water Conditions

<u>Water Variable</u>	<u>Control Side</u>	<u>Test Side</u>
pH	6.6 $\pm$ 0.05	7.0 $\pm$ 0.05
Dichromate Feed (ppm)	1.0 $\pm$ 0.1	1.0 $\pm$ 0.1
Alum Feed (ppm)	18.0 $\pm$ 1.0	18.0 $\pm$ 1.0

C. Process Tubes

All fuel elements in this test shall be irradiated in existing central zone process tubes. These tubes will be selected by the test author and a representative of the Process Engineering Unit, with concurrence of the Manager, D Processing, and the Manager, Production Subsection.

D. Fuel Charge

1. Model

O3NB fuel elements will be used in this test.

2. Fabrication

All fuel elements used in this test will be manufactured by the AlSi "F" process using 8001-F aluminum cladding and natural uranium cores. The unautoclaved fuel will, of course, be exempted from the autoclave specification.

3. Fuel Quantity and Column Makeup

These fuel columns are essentially normal production charges. Charges without mixers shall contain 32 O3NB fuel elements. Charges with mixers shall contain 31 O3NB fuel elements and a mixer element in position 7. Forty-two of the columns will be prepared with alternate autoclaved and unautoclaved fuel to remove the between-tube irradiation variations. Four columns of unautoclaved fuel are included to verify that no within-tube interactions occur between the autoclaved and unautoclaved fuel. The charge pattern for these columns is shown in Table II.

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TABLE II

CHARGE PATTERN - PTA - 065

<u>Charge Makeup</u>	<u>Number of Columns</u>	
	<u>Control Side</u>	<u>Test Side</u>
Alternate autoclaved and unautoclaved fuel without mixers	11	11
Alternate autoclaved and unautoclaved fuel with mixer in position 7	10	10
Unautoclaved fuel without mixers	2	2

Each of these fuel charge categories will be divided between relatively new and medium age tubes. This will give various levels of corrosion severity. Other variables being equal, new tubes should produce a greater potential for fuel corrosion than medium age tubes; charges without mixers should incur more corrosion than charges with mixers; the test (high pH) side charges should exhibit greater uniform and localized corrosion than the control (low pH) side fuel.

E. Irradiation

1. Charging

All fuel columns of the test will be machine charged in numerical order with piece number 1 downstream. A representative of Research and Engineering will monitor the charging and record the fuel series number corresponding to each process tube.

2. Exposure

These test columns will operate for approximately 58 days prior to the final shutdown of D Reactor.

3. Discharge

The test columns will require special pickup after discharge. No more than seven columns of test fuel shall be placed in a single bucket.

F. Fuel Element Measurements

1. Pre-Irradiation Measurements and Testing

All fuel elements used in this test will receive and conform to all standard pre-irradiation tests, except that the unautoclaved fuel will not be subjected to the autoclave weld integrity test. The fuel will be

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identified by position number within the column (piece number 1 is downstream), and a series number will identify each column. The sixteen downstream elements (excluding mixer elements) shall be weighed in 32 of the alternate autoclaved - unautoclaved columns. All elements of the remaining ten alternate autoclaved - unautoclaved columns and the four unautoclaved columns shall be weighed.

2. Post-Irradiation Measurements

All fuel elements in the test columns shall receive the normal post-irradiation visual examination. Fuel elements with known pre-irradiation weights shall be weighed.

G. Operating Data

1. Daily Data

The following data are to be recorded daily:

- a. average outlet coolant temperature of each of the 46 test columns.
- b. average pH and dichromate feed to both sides of the reactor.
- c. the period and extent of deviations from the specified test conditions.

2. Weekly Data

Panellit and front crossheader pressures will be recorded weekly for each of the 46 test columns.

H. Start and Duration of Test

It is planned to start this test during the scheduled D-Reactor outage in April. This will provide approximately a sixty-day test period prior to shutdown for deactivation.

I. Discharge of Sub-Goal Exposure Fuel Columns

In order to accommodate this test, the early discharge of up to 46 normal production columns is authorized. In addition, the early discharge of up to 30 columns of PTA-019⁶ fuel is authorized.

J. Tube Probologging

In order to follow the terminal corrosion aspects of process tubes, the PTA-019 columns on the test (high pH) side of the reactor will be discharged and probologged prior to the start of this test. In the event unscheduled outages occur during the test, additional discharge and probologging of these tubes is authorized.

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K. Early Termination of Test

This test may be terminated by the mutual consent of the Manager, Reactor Engineering, and the Manager, D Processing Unit. In the event the test must be terminated, all test columns must be discharged prior to changing water variables.

L. Costs

All outage time and expenditures will be charged to cost code XXXX-5R41-XXX.80. Outage time associated with this test is estimated to be 15 hours for the charge-discharge and special pickup of 46 charges.

M. Process Standards

This Production Test authorizes the following specific deviations from Process Standards. All other aspects of these Process Standards will apply.

1. Process Standard - Water Plant - 183-A-020, Section 20.01 -- pH Control

The deviation from this Process Standard is to allow half reactor operation with pH 7.0 coolant. The intent of this production test is to investigate the corrosion aspects of increased coolant pH.

2. Process Standard - Water Plant - 183-A-020, Section 20.01 -- pH Adjustment

The deviation from this Process Standard is to disallow changes in pH during reactor shutdown. Since in-reactor films may be highly sensitive to short exposures to nonequilibrium chemical compositions, the water parameters specified in this test will be maintained during operating and shutdown conditions.

3. Process Standard - Reactor-F-010, Section 10.02 Process Material

The deviation from this Process Standard is to permit irradiation of unautoclaved fuel elements. The unautoclaved fuel will deviate from Process Specification - Fuel and Target Manufacturing Process, Section F-405.4.- Finished Fuel Specifications, only in that the autoclave requirement will be eliminated. The intent of this production test is to investigate the corrosion aspects of unautoclaved fuel.

4. Process Standards - Reactor-E-010, Section 10.01 Film Removal by Purge

The deviation from this Process Standard is to disallow reactor purging during this test. Experiments have indicated that suspended solids can promote localized attack, and the effects of this parameter should not be combined with other test parameters.

N. Hazards

Potential hazards to operating continuity associated with this test are as follows:

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1. Fuel Failures in Test Side Columns

The increased corrosion that is associated with pH 7.0 coolant may lead to fuel element failures. The majority of the charges on the test (high pH) side of the reactor will have accumulated approximately thirty days' exposure at the start of this test. An additional sixty days of operation would accumulate during the test period. These high exposure increased corrosion conditions increase the potential for fuel failures. In the event that fuel failures cause early termination of this test, a pH reduction to 6.6 or lower should prove beneficial to the test side fuel. However, it must be realized that latent fuel failures may continue to occur after the pH reduction.

2. Increased Tube Corrosion on Test Side Tubes

The increased uniform corrosion that is associated with pH 7.0 coolant will cause increased tube corrosion and perhaps tube leaks. The incremental tube corrosion resulting from pH 7.0 as compared to pH 6.6 coolant for the sixty-day test period is as follows: the majority of the process tubes are expected to corrode 4 mils, a small fraction of the tubes may corrode up to a maximum of 8 mils, but in no case should any tube corrode to less than 32 mils remaining wall thickness. These corrosion estimates are based on uniform corrosion rates. The effect of increased pH on Van Stone pitting is not known. Localized attack can occur in addition to uniform corrosion and may cause tube leaks. This has a bearing on final reactor shutdown if the pile environment must be free of excess water before deactivation.

3. Unautoclaved Fuel Failures

Fuel jacket welding technology and quality control has improved such that weld defects occur with very low frequency (approximately six/year). The unautoclaved fuel will receive an additional visual inspection of weld areas, however weld defect failures are still possible. No particular hazard is associated with uniform corrosion of the unautoclaved fuel.

DW Peacock

D. W. Peacock, Senior Engineer
Reactor Process Development Unit
Research and Engineering Section

DWP:mm

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1. Schaffer, J. S., "Interim Report - Groove Corrosion Simulation Through Autoclave Film Testing," DUN-1925, February 17, 1967. (Confidential)
2. Personal Communication with J. P. Schmidt.
3. Peacock, D. W., "Summary of Nonuniform Corrosion Data," DUN-2213, to be issued.
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5. Geier, R. G., "Interim Report I, Production Test IP-442-A," HW-78986, September 20, 1963. (Secret)
6. Ufkes, L. B., "Production Test Authorization - 019, Investigation of Terminal Corrosion Rates in Aluminum Process Tubes," DUN-905, March 30, 1966. (Confidential)

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RESPONSIBILITIES

Production Fuels Section shall be responsible for the canning, finishing, pre-irradiation testing, quality control, pre-irradiation measurements, and marking of fuel elements used in this test.

W. M. Mathis, Manager
Production Fuel Section

Research and Engineering Section

Reactor Engineering Subsection shall be responsible for providing assistance to D Processing Unit on preshutdown scheduling, for providing assistance in the selection of test channels, to monitor charging of the test columns, for providing data forms to record test data, for data analysis, and for issuance of the final report.

R. W. Reid, Manager
Reactor Engineering Subsection

Testing and Irradiation Services Subsection shall be responsible for post-irradiation fuel examination and measurements, and probologging of process tubes.

L. V. Barker, Acting Manager
Testing and Irradiation Services
Subsection

Fuels Engineering Subsection shall be responsible for machine processing of reactor and fuel examination data, and assistance in data analysis.

J. T. Stringer, Manager
Fuels Engineering Subsection

Manufacturing Section

D Processing Unit shall be responsible for operational safety and production continuity of the reactor, for charging and special pickup of test material, and for supplying operating data on the test columns as requested.

J. T. Baker, Jr., Manager
D Processing Unit

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D Power Unit shall be responsible for supplying process water as specified in this test and for providing operating data as requested.

G. D. Geise, Manager
D Power Unit

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APPROVALS

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Research and Engineering Section

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