DECLASSIFIED

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

HW-60244

COPY 1 OF 1, SERIES MA

4

MAY 1 1959

THIS DOCUMENT CONTAINS RESTRICTED DATA AS
DEFINED IN THE ATOMIC ENERGY ACT OF 1954
ITS TRANSMISSION OR DISCLOSURE OF ITS
CONTENTS IS PROHIBITED TO ANY NAUTICAL
PERSON IS PROHIBITED

SUPPLEMENT B - PRODUCTION TEST IP-190-a

IRRADIATION OF ALUMINUM CLAD DOE ELEMENT
IN THE KER TEST FACILITY

N. R. Miller

W. K. Kratzer

THIS MATERIAL CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECS. 793 AND 794, THE TRANSMISSION OR REVELATION OF WHICH IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

RECEIVED FOOD AREA

MAY 22 1959

RETURN TO

TECHNICAL INFORMATION FILES

[illegible][illegible]

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

54-3000-340 (3-57) AEC-GE RICHLAND, WASH

MASTER

DECLASSIFIED

04/20/1994

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DECLASSIFIED

HW-60244
Page 1

DISTRIBUTION

1-2. AEC-HOO, Att: AT Gifford
3. FW Albaugh
4. WK Alexander
5. JA Ayres
6. RS Bell
7. JL Benson
8. WA Blanton
9. AG Blasewitz
10. RW Bown
11. JJ Cadwell
12. AC Callen
13. TL Deobald
14. RL Dickeman
15. DR Dickinson
16. RV Dulin
17. JM Fouts
18. FC Franklin
19. GC Fullmer
20. SM Gill
21. SM Graves
22. RE Hall
23. TM Hall
24. Wm Harty
25. ME Jackson
26. PC Jerman
27. CE Jones
28. WK Kratzer
29. RJ Lobsinger

30. JP McBride
31. LH McEwen
32. NR Miller
33. JF Music
34. JG Myers
35. WI Neef
36. SL Nelson
37. R Nilson
38. GF Owsley
39. HM Parker
40. CA Priode/WG Albert
41. T Prudich/RE McGrath
42. RW Reid
43. RJ Shields
44. HG Spencer
45. JT Stringer
46. WL Swanson
47. JW Talbott
48. P Thompson
49. LD Turner
50. RE Trumble
51. FW Van Wormer
52. EC Wood
53. FW Woodfield
54. HF Zuhr
55. 300 Files
56. Record Center

Classification Canceled and Changed To

DECLASSIFIED

By Authority of SE Engdalen

RLO-CG-4, 2-3-94

By DK Hanson, 4-21-94

Verified By J E Savely 4-21-94

COPY 1 OF 1, SERIES A

RESTRICTED DATA

This document contains restricted data as defined in the Atomic Energy Act of 1954. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.

This document consists of 10 pages, No. 4 of 56 copies,

This document classified by

R L Dukeman

May 1, 1959

SUPPLEMENT B

PRODUCTION TEST IP-190-A

IRRADIATION OF ALUMINUM CLAD DOE ELEMENTS IN THE KER TEST FACILITY

OBJECTIVE

The objective of this supplement is to authorize exposure of aluminum clad elements at higher temperatures than authorized by the original test.

DECLASSIFIED

04/20/1994

SUMMARY

This supplement authorizes testing of aluminum jacketed Doe alloy elements at surface temperatures up to 315°C. A thermocouple fuel element will be included to yield data on jacket temperatures. The test may require five hours of reactor outage time but will not cause any loss of reactor reactivity.

BASIS AND JUSTIFICATION

Production Test IP-190-A⁽¹⁾ authorized exposure of aluminum jacketed Doe alloy fuel elements at surface temperatures up to 277°C. This surface temperature was the maximum allowable from burnout considerations. However, new, better quality zircaloy process tubes are to be installed in KER Loops 2 and 3 during the extended outage starting 4-15-59. These improved tubes can be safely operated at higher pressures than the old tubes, thus raising the burnout limit.

A long term test at the higher permissible surface temperatures should give valuable data on the behavior of aluminum clad elements in high temperature water which in turn should better define the maximum service conditions of aluminum cladding.

Also, the inclusion of a "thermocouple element", an element fitted with thermocouples embedded in the can wall, will provide valuable information on temperature gradients across the corrosion product layer at these more severe conditions. These thermometry data, plus data obtained at less severe conditions, will give a basis for evolving a more basic understanding of the mechanism of corrosion of aluminum fuel jackets.

The irradiation conditions specified for the test are considerably more severe than have been previously authorized. Therefore, no guarantee can be made that a fuel element failure will not occur or even that the probability of a failure is remote. However, the use of relatively inert Doe alloy fuel cores does prevent a fuel failure from being a reactor safety hazard and the cost of a failure should be limited to a minimum outage.

In view of the interest in aluminum cladding at HAP0 and at other sites, and the definitive nature of the test, it is concluded that the possibility of incurring a minimum outage is justified by the value of the test.

TEST DETAILS

1. Fuel Elements

The fuel elements will be 1.440 inch diameter aluminum clad, Doe alloy elements as described in the original test. The cladding used will be X-8001 alloy and alloy C-810. Alloy C-810 is essentially X-8001 to which is added 0.1% Ti.

-
- (1) HW-56855, "Production Test IP-190-A, Irradiation of Aluminum Clad Doe Elements in the KER Recirculation Test Facility", N. R. Miller and W. K. Kratzer, July 24, 1958.

DECLASSIFIED

2. Loading

The basic tube loading is shown in Table 1 below. Modification of the loading is authorized provided revised limits are established for the changed loading.

TABLE 1

Position From Rear	Element
1	Thermocouple Train (1)
2	Doe
3	Doe
4	Spacer (2)
5	Doe
6	Doe
7	Spacer
8	Doe
9	Doe
10	Spacer
11	Doe
12	Doe
13	Spacer
14	Doe
15	Doe
16	Spacer
17	Doe
18	Doe
19	Spacer
20	Doe
21	Doe
22	Spacer
23	Doe
24	Doe
25	Spacer
26	Doe
27	Doe
28	Spacer
29	Doe
30	Doe

(1) Thermocouple slug and train extend 244 inches from the rear of the exit nozzle. In the first loading, the thermocouple train will be omitted and replaced with spacers.

(2) The spacers will be eight inches long. Some of the spacers may be replaced with coupon holders the design of which is shown in SK-1-22425.

DECLASSIFIED

04/20/1994

3. Irradiation Facility

The fuel elements may be irradiated in KER Loop No. 2 or No. 3. Present plans are to utilize Loop 3.

4. Operating Condition

The coolant will be demineralized water with the pH (as measured at room temperature) adjusted to 4.3 to 4.7 by phosphoric acid addition. Except for flows, other operating conditions are dependent on the allowable tube exit pressure. The tube exit pressure will be limited to 1650 psig or the outlet pressure at the rear pigtails will be limited to 1600 psig, whichever is the more restrictive, provided Loop No. 3 conforms to the requirements given for Loop No. 2(2). At a flow of 60 gal/min, the tube exit pressure exceeds the pigtail exit pressure by about 24 psi and hence the second criterion is more limiting. Other operating limits and conditions correspond to these relations. Other conditions are:

a. Flow as indicated by flow meters:

- (1) Desired, 60 gal/min
- (2) High Flow Trip, 68 gal/min
- (3) Low Flow Trip, 48 gal/min

b. Exit Pressure:

- (1) Low Pressure Trip, 1500 psi

c. Tube Exit Temperature:

The desired exit temperature and the high exit temperature trip as a function of tube power are shown in Figure 1.

d. Boiling Point Suppression Trip:

The boiling point suppression trip as a function of tube power is shown in Figure 1.

5. Power and Temperature Relationships

a. Tube Exit Temperature Limits

At observed tube t 's up to 24°C , the tube exit temperature trip limit is 300°C based on the minimum allowable tube pressure. At higher tube powers (higher tube t 's) tube exit temperatures are limited by burnout considerations.

In calculating the burnout limit, it was conservatively assumed that three conditions might occur simultaneously: 1) The tube flow could drop to a value just above the low flow trip, 2) The tube exit pressure could drop to a value just above the low pressure trip, and 3) The tube exit temperature could increase to a value just below the high temperature trip. At these conditions, the heat flux generated

(2) Letter, R. E. Trumble to J. F. Music, "Limits for KER Loop No. 2," May 5, 1959.

DECLASSIFIED

04/20/1994

by the highest powered element will be only two-thirds of the calculated burnout flux.

5. Desired Exit Temperatures

At tube Δt 's up to 19°C , the desired exit temperature was arbitrarily set 15°C below the maximum outlet temperature limit for operational convenience. At tube Δt 's between 19°C and 26°C , the desired exit temperatures are the maximum obtainable without incurring nucleate boiling on the highest powered fuel element during normal operation. Nucleate boiling may occur at trip conditions. At tube Δt 's above 26°C , the desired temperatures conform with the maximum desired severity of operating conditions.

6. Boiling Point Suppression Limit

At tube Δt 's up to 26°C , the boiling point suppression limit is set at 25°C , the minimum allowed by Process Standards. At higher tube Δt 's, more conservative boiling point suppression limits are specified to insure a reactor scram if the high exit temperature is exceeded. (Both a boiling suppression trip and a high temperature pressure trip are required to produce a reactor scram.)

6. Graphite Temperature

The graphite temperature within $1\frac{1}{2}$ lattice units of the tube in which this production test is charged will not be used to determine reactor power or helium concentrations. The maximum graphite temperature expected in the region is about 650°C . This temperature exceeds the limit specified by Standard C-040 but will cause no appreciable reactor damage for the time this production test is charged.

7. Exposures

Allowable exposures for the test are limited to four months at designated operating conditions. These limits are designed to limit the probability of a fuel element failure due to uniform corrosion. A more complete discussion of the basis for the limit is included in the appendix.

8. Delayed Neutron Monitor

Process Standards require that a high trip from the delayed neutron monitor automatically scram the reactor, depressurize the system and route flow through the emergency storage tanks. The most important basis for this standard is that a failure of a uranium fuel could cause tube failure if the uranium-water reaction is allowed to proceed for a significant period.

DECLASSIFIED

The mechanism postulated for damage to the tube is the swelling of the fuel against the tube resulting in severe hydrogen embrittlement of the tube.

With Doe alloy elements, the nominal minimum annulus will be about 280 mils which would require significant swelling before contact could reasonably be expected to occur. Also, the Doe alloy-water reaction rate is orders of magnitude slower than a uranium-water reaction. Therefore, removal of the delayed neutron monitor from the No. 1 Safety Circuit does not violate the spirit of the standard and has sound engineering justification. Therefore, in order to avoid unnecessary reactor outages because of spurious scrams and a potential premature termination of the test, removal of the high trip limit from the safety circuit is authorized.

This relaxation is not to be construed as authorization for continued operation with a ruptured element in the charge. The delayed neutron monitor trips shall be set according to provisions of the Process Standards. A high trip shall result in an annunciator alarm. In such an event, immediate action will be taken to determine whether the trip occurred from some cause unrelated to a failure, such as instrument malfunctioning. If no non-failure mechanism can be found to account for the trip, and secondary indications of a failure are present, such as sympathetic indications on adjacent monitors and abnormally high loop activities, the reactor will be scrammed and the test discharged. If, after 15 minutes, a reasonable doubt exists as to the cause of the trip, loop temperatures will be reduced to the minimum obtainable until decision based on all available evidence can be made.

9. Special Procedures

Charging and discharging the thermocouple train, and storage and handling of the Doe alloy elements are covered in the original test.

10. Number of Charges

The number of charges tested under the terms of this authorization is not limited. However, current plans call for the irradiation of two charges.

11. Priority

Additional downtime is authorized if charging or discharging cannot be accomplished during a normal outage.

12. Costs

Cost Code: XXX-5320-XXX.09

Time per charge of element:

DECLASSIFIED

	<u>Elevator Time</u>		<u>Manhours</u>
	<u>Front</u>	<u>Rear</u>	
Charge	1	3	10
Discharge	1	2	2
	<u>2</u>	<u>5</u>	<u>12</u>

Reactivity Loss, None

Data Desired

Same as outlined in original test.

HAZARDS

Due to the severe operating conditions and relatively long exposures, the probability of a fuel element failure is not insignificant. However, with the Doe alloy core, a fuel failure will not result in damage to the process tube nor a severe contamination of the loop.

RESPONSIBILITIES

The Coolant Testing Operation, Research and Engineering Operation shall be responsible for determining whether a fuel element failure has occurred in the charge after a delayed neutron high trip has occurred.

Also, the Coolant Testing Operation is responsible for reactor safety and production continuity as they are affected by loop operation.

Other responsibilities are the same as outlined in the original test.

NR Miller
Reactor Engineering Unit
Process & Reactor Development Operation
IRRADIATION PROCESSING DEPARTMENT

W. J. Kratzer
Reactor Fuels Unit
Process & Reactor Development Operation
IRRADIATION PROCESSING DEPARTMENT

NR Miller:WK Kratzer:nmd

DECLASSIFIED

Figure 1

Operating Limits, and Desired Tube
Outlet Temperature

APPENDIX

BASIS FOR DETERMINING EXPOSURES

Maximum exposures are limited by the need to minimize the probability of a fuel failure induced by failure of the cladding. The most likely causes of cladding failure are foreseen to be poor quality components, canning defects, or uniform corrosion. The first two items are not predictable. The components and the fabricated fuel elements have passed all inspections, and insofar as can be determined, the fabricated fuel elements are of good quality. However, the absence of undetected defects cannot be guaranteed and the probability of failure due to an undetected defect will increase with exposure in some undefined manner. While the probability of such failure is finite, it cannot be determined and is not considered in exposure determinations.

Uniform corrosion is the third factor which could reasonably be expected to cause failure. There rates cannot be predicted accurately. (If the reverse were true, there would be no particular incentive in conducting the test.) Two estimations of uniform corrosion rates have been made. These estimates are based on extrapolations of data obtained under less severe conditions. The first estimate was derived on the assumption that corrosion rates are controlled by the rate of dissolution of aluminum oxide corrosion products from the surface of the element.⁽²⁾ At the desired test conditions this estimate predicts a corrosion rate of about 2.0 mils/month. If this estimate is correct, exposures of about a year could be justified from the standpoint of uniform attack.

The second estimate was made assuming that the rate limiting step is the diffusion of an oxidizing specie across the corrosion product layer. The estimate made on this basis predicts a corrosion rate of about 9 mils/month. If this estimate is correct, the maximum exposure should be no higher than about three months. Use of this more conservative estimate for determining exposures has the disadvantage of limiting the test's worth if it is in error. Thus the reactor outage time required for the test and the worth of the irradiation time in the KER Loop would be to some extent wasted. Further, future KER testing will be nearly limited to irradiation of zircaloy clad material in support of the NPR. Therefore, if this present test is unduly limited, a true evaluation of aluminum cladding may well be delayed for a prolonged period of time.

Because of the incentives for appreciable exposures and the real possibility that the conservative estimate is inaccurate, it is reasonable to extend exposures somewhat beyond three months at the most probable set of conditions. Therefore, a four operating month exposure is authorized.

(2) HW-60207, "Corrosion Rate of Aluminum Clad Elements In KER-3",
D. R. Dickinson, 4-29-59.

DECLASSIFIED

APPROVALS:

R L Dickman

Manager
Process & Reactor Development Operation
IRRADIATION PROCESSING DEPARTMENT

J. F. Music

Manager
Process Technology Operation
IRRADIATION PROCESSING DEPARTMENT

M Jackson

Supervisor
Coolant Testing Operation
IRRADIATION PROCESSING DEPARTMENT

J. F. Music for

Manager
Research & Engineering Operation
IRRADIATION PROCESSING DEPARTMENT

Quinn

Manager
KE-KW Reactor Operation
IRRADIATION PROCESSING DEPARTMENT

DECLASSIFIED