AIIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

DECLASSIFIED

(CLASSIFICATION)

HANFORD TERMINAL RECORD
GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

DOCUMENT NO.

HW-77718

SERIES AND COPY NO.

DATE

May 24, 1963

☒

RESTRICTED
THIS DOCUMENT CONTAINS RESTRICTED INFORMATION
TRANSMITTED IN THE ATOMIC ENERGY ACT OF 1954.
ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED
PERSON IS PROHIBITED.

TITLE

OPERATING PHYSICS FACTORS WITH ZIRCONIUM
TUBES AT THE K REACTORS

☐

OTHER OFFICIAL CLASSIFIED INFORMATION
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 TRANS-
MISSION OR REVELATION OF WHICH IN ANY MANNER
TO AN UNAUTHORIZED PERSON IS PROHIBITED BY
LAW.

AUTHOR

R. E. Tiller
A. D. Vaughn

ISSUING FILE

THIS DOCUMENT MUST NOT BE LEFT UNATTENDED OR WHERE AN UNAUTHORIZED PERSON MAY HAVE ACCESS
TO IT. WHEN IN USE, IT MUST BE STORED IN AN APPROVED LOCKED CUPBOARD WITHIN AN APPROVED
GUARDED AREA WHILE IT IS YOUR RESPONSIBILITY AND UNTIL YOU OBTAIN A SIGNED RECEIPT FROM
CLASSIFIED FILES, IT IS YOUR RESPONSIBILITY TO KEEP IT AND ITS CONTENTS WITHIN THE LIMITS OF
THE PROJECT AND FROM AN UNAUTHORIZED PERSON. ITS TRANSMITTAL TO, AND STORAGE AT YOUR PLACE
OF RESIDENCE IS PROHIBITED. IT IS NOT TO BE REPRODUCED. IF ADDITIONAL COPIES ARE REQUIRED,
OBTAIN THEM FROM THE RELATED ISSUING FILE. PERSONS READING THIS DOCUMENT ARE REQUESTED
TO SIGN IN THE SPACE PROVIDED BELOW.

ROUTE TO:

PAYROLL NO.

LOCATION

FILES ROUTE
DATE

SIGNATURE AND DATE

MASTER

Indefinite Retention

Authority

Authority

54-3000-340

DECLASSIFIED

(CLASSIFICATION)

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DECLASSIFIED

HW-77718

[REDACTED]
This document contains Restricted Data. Disclosure of its
contents to an unauthorized person is prohibited.

This document classified

by: G. C. Fullmer

This document consists
of 12 pages. No.
of 33 copies. [REDACTED]

Distribution

1-2. AEC-RLOO Attn: AT Gifford/RL Plum	17. GC Fullmer
3. DG Albertson	18. OH Greager
4. TW Ambrose	19. AB Greninger
5. ER Astley	20. PD Gross
6. GD Baston	21. LL Grumme
7. RS Bell	22. AK Hardin
8. CE Bowers	23. CG Lewis
9. RD Carter	24. AW Medcalf
10. RA Chitwood	25. R Nilson
11. MA Clinton	26. CA Priode
12. RG Clough	27. RW Reid
13. RF Corlett	28. OC Schroeder
14. EL Conner	29. SM Skidmore
15. DW Constable	30. RE Tiller
16. JR Fredsall	31. AD Vaughn
	32. 300 File
	33. Records Center

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of DS Lewis
CG-PR-2, 3-22-94

By J. E. Savelly 3-21-94
Verified By DK Hansen, 4-4-94

May 24, 1963

OPERATING PHYSICS FACTORS WITH ZIRCONIUM TUBES
AT THE K REACTORS

[REDACTED]

DECLASSIFIED

HW-77718

Page 2

OPERATING PHYSICS FACTORS WITH ZIRCONIUM TUBES
AT THE K REACTORS

INTRODUCTION

This document lists the physics factors for the K Reactors following the transition to the KV fuel element geometry and zirconium tubes. Each new parameter with the zirconium tube lattice has been calculated relative to the factors used with aluminum tubes and the KIV fuel elements.

The purpose of this document is to provide working values for plant assistance use during the transition to the zirconium lattice. In some cases where there are large uncertainties in the absolute values, the conservative end of the range has been provided for present operational use in safety and control administration.

Refinement and publication of "best" values for the zirconium lattice based on more extensive experimental and calculational studies are included in future Reactor Physics Unit programs.

SUMMARY

There will be very little change in the sign and magnitude of the reactivity transients during operation following the replacement of the KIV fuel and aluminum tubes with KV fuel elements and zirconium tubes. However, the graphite boring necessary to straighten the fuel channels is expected to cause local changes in moderator temperatures and thus to probably require more than normal flux flattening adjustments during the early operating periods with the new fuel.

Use of zirconium tubes requires a change in the application of total control criterion because of the differently defined time of irreparable damage; adequate control capacity must be maintained in the zirconium lattice until the uranium would melt whereas the present limit is aluminum melting which would take place sooner. This will necessitate earlier charging of supplementary poison; however, slightly less poison will be necessary to meet maximum supplementary control requirements.

The more reactive lattice will reduce the amount of enriched fuel necessary for operation by about a third.

DISCUSSION

In performing the calculations necessary to obtain the parameters listed and discussed in the following sections, equivalent conditions were assumed (i.e., tube power, graphite temperature, etc.) for the KV fuel element in the zirconium-tube lattice as have been experienced during operation with the KW fuel element in the aluminum-tube lattice. The new factors were obtained by calculating the relative differences between the two lattices and applying a weighted correction factor to the particular physics parameters currently in use with the KIV fuel element and aluminum tube lattice. The relative differences were calculated by the IBM 7090 computer program, "MOFDA"/1/ which uses conventional lattice physics calculational methods documented by R. E. Tiller and G. D. Joanou.^{/2/}

/1/ MOFDA "An IBM Reactor Physics Code Written by R. O. Gumprecht - Unpublished

/2/ HW-60422 Revised, "Notes on Lattice Parameter Calculations," G.D. Joanou, Revised by R.E. Tiller, October 6, 1960

DECLASSIFIED

HW-77718

Page 3

A. Operating Parameters

1. Basic Reactivity

The zirconium tubed lattice with KV fuel elements is expected to be approximately seven mk more reactive than the present lattice with KIV fuel elements in aluminum tubes. Figure 1 illustrates the potential hot and cold reactivities of the two type fuels as a function of exposure. The reactivity status for the two curves is based on a constant enriched fuel inventory (assumed in the calculations to be equivalent in the two cases) throughout the whole range of exposure variation for both lattices. The differences in enriched fuel requirements which are apparent from the curves are discussed in the following paragraph.

2. Enriched Fuel Requirements

Figure 1 illustrates that the zirconium tube lattice will not require as much enriched fuel as the aluminum tube lattice with KIV fuel elements. Figure 2 illustrates the percentage of 0.947 per cent enriched fuel columns necessary to maintain approximately 2700 c-mk of cold clean reactivity, this amount will suffice to maintain current operating efficiencies.

3. Power and Temperature Reactivity Coefficients

The reactivity transients following startup and during shutdown are expected to be approximately the same in the KIV and KV cases because the pertinent reactivity parameters such as equilibrium xenon poisoning, metal and water temperature effects, and the reactivity due to long term gains will change very little (see Table 1).

The graphite temperature is expected to be higher during operation with the zirconium tube lattice at any given power level than it was with the aluminum tube lattice at an equivalent power level. This is a result of the channel boring which has, in some regions, widened the gap between the tube and graphite moderator so that heat transfer resistance from the moderator to the coolant is increased. Experimental measurements of the moderator temperatures around a zirconium tube charged preliminary to the full reactor charging demonstrated that graphite temperatures will increase as much as 1250 at an equivalent equilibrium power level.^{/3/}

Since the graphite coefficient is assumed to be independent of the graphite temperature, the reactivity contribution due to graphite heating is expected to increase proportionally to the increase in temperature. An exact derivation of this effect is not feasible because of the nonuniformity of the moderator temperature increase throughout the pile and the difficulty in calculating neutron temperatures with a lattice physics program. However, as a first approximation it is expected that the change in the reactivity due to graphite heating will be proportional to the expected change in moderator temperature. This difference, estimated to be up to about 25 per cent, is illustrated in Table 1.

/3/ Personal communication - A. Russell - Processing and Reactor Development

DECLASSIFIED

Figure 1

Comparison of Potential Reactivity at K Reactors
With Zirconium Tube Lattice and KV Fuel Elements
and Aluminum Tube Lattice and KIV Fuel Elements

DECLASSIFIED

HW-77718

Page 5

Figure 2

Alterations In Enrichment Inventory Necessary To Maintain Adequate
Operational Reactivity During Equilibrium

(Based on 2700 c-mk cold clean reactivity at
300 MWD/T exposure with KIV fuel element)

DECLASSIFIED

HW-77718
Page 6

A new graphite power coefficient should be estimated from operating data obtained with zirconium lattice as soon as feasible.

A correction factor of 0.94 must be applied to the equilibrium concentration of iodine listed by the current xenon and iodine tables. The xenon concentration will not differ between the KIV and KV cases; however, the concentration of iodine in reactivity units of potential xenon is slightly less in the KV lattice in comparison to the KIV lattice. New tables can be provided after the parameters suggested in this document have been checked against operating data.

Table 1

Expected Operating and Shutdown Reactivity Parameters at K Piles

<u>Parameter</u>		<u>Zirconium Tube Lattice</u>	<u>Aluminum Tube Lattice</u>
1.	Metal Coefficient	-0.15 c-mk/MW	-0.15 c-mk/MW
2.	Graphite Coefficient $\bar{E}$ (MWD/T) (at 100% Helium)	c-mk/MW	c-mk/MW
	0	+0.250	+0.200
	200	+0.409	+0.327
	400	+0.516	+0.413
	600	+0.574	+0.459
	800	+0.580	+0.464
	1000	+0.538	+0.430
3.	Horizontal Control Rod Strength	1825 c-mk	1825 c-mk
4.	Equilibrium Xenon $\bar{E}$ (MWD/T)	c-mk	c-mk
	0	-2880	-2900
	100	-2840	-2830
	200	-2770	-2780
	300	-2700	-2720
	400	-2630	-2660
	500	-2580	-2600
5.	Equilibrium Iodine in Reactivity Units of Potential Xenon $\bar{E}$ (MWD/T)	c-mk	c-mk
	0	-14830	-15650
	100	-14330	-15140
	200	-13900	-14770
	300	-13420	-14390
	400	-12520	-14030
	500	-11950	-13700

4. Effect of Changes in Operating Reactivity Parameters on Reactor Efficiency

Large changes in reactor operating efficiency due to changes in reactivity transients are not expected after the transition to zirconium tubes and KV fuel elements. However, the uncertainty of graphite temperature effects may require an alteration in control procedures, especially because the boring necessary to straighten the fuel channels will not be uniform in the channel itself nor between adjacent channels. Distribution control and flattening adjustments for graphite temperature limitations will almost certainly be required during the earlier operating periods; however, sufficient reactivity should be available to poison troublesome areas. Such eccentricities in pile temperature may reduce the number of effective central tubes by as much as five to ten per cent during initial operation following a major tube installation outage, but should be resolved shortly thereafter by available flattening and enrichment techniques.

B. Nuclear Safety Parameters

1. Material Bucklings and Local Control Strengths

The calculated material bucklings of the green K pile lattice with KV fuel elements are listed in Table 2. These fuel parameters were derived by applying incremental correction factors to the buckling values of solid fuels measured during the K Reactor startup tests. The correction factors for the respective fuel types were derived from differences in the k infinity values calculated by the lattice physics program MOFDA.

Although the material bucklings are higher in the dry lattice with KV fuel elements, the effective buckling of the whole dry pile is expected to decrease because of a smaller reactivity gain with water loss.

Supplementary control requirements necessary to satisfy total control will probably decrease by at least ten splines per outage. However it should be pointed out that the supplementary poison requirements necessary to compensate the operating reactivity transient following startup usually exceed the total control requirements; thus over-all poison usage will probably remain approximately the same.

The various local control strengths were estimated by applying correction factors derived from Wheeler's method^{74/} to conservative results from actual measurements during the K pile startup tests.

^{74/} M-2292 "Principles of Nuclear Power," Chapter 22; Control P77, JA Wheeler

Table 2

Physics Factors to be Used for the
K Reactors in Nuclear Safety Calculations

<u>Parameter</u>	<u>Aluminum Tube Lattice With K1V Fuel Element</u>	<u>Zirconium Tube Lattice With KV Fuel Element</u>
Dry Green Material Bucklings		
I&E Natural	78 μ b	84 μ b
I&E Enriched	320 μ b	328 μ b
Wet Green Material Bucklings		
I&E Natural	42 μ b	60 μ b
I&E Enriched	259 μ b	282 μ b
Local Control Strengths		
Ball 3X	-131 μ b	-131 μ b
VSR's	- 95 μ b	- 95 μ b
Compensating Poison Effect	2.0 Splines/0.947% Enriched Fuel Column	1.95 Splines/0.947% Enriched Fuel Column

2. Revised Practices - Total Control Administration

The total control criterion, in general, requires that a delayed neutron critical state should not be permitted until a significant number of process channels would have already been rendered useless. With aluminum tubing the channels would be useless when the aluminum melted (660C) since coolant could not be restored to those channels and uranium melting would eventually take place.

When zirconium tubes are used the melting temperature of zirconium (1400C) exceeds the melting temperature of uranium (1133C). Therefore with zirconium tubes the requirement for fulfilling total control criterion is as follows: a delayed neutron critical state should not be permitted until a significant number of process tubes would have been rendered useless as coolant channels by the melting of uranium.

For the Hanford Reactors the most reactive state, following a water loss incident, would occur at either the time of water loss or at the time of melt-down. Therefore the reactivity transient must be known until uranium melting would occur in the zirconium tube lattice and until aluminum melting would occur in the aluminum tube lattice.

3. Differences in Temperature Effects and Melting Times

Figure 3 illustrates the time interval between the water loss and uranium melting in the zirconium tube lattice. These times are approximately twice as long as the intervals between water loss and aluminum melting and were derived using the data for uranium melting times in the aluminum-tube lattice.^{/5/} Because of poorer heat transfer across the gas gap to the moderator in the zirconium-tubed reactor, uranium melting time would be shorter than the melting times in the aluminum case from which the calculations have been assumed.^{/6/} For purposes of total control administration, the use of the longer aluminum-lattice melting times would be conservative; transient calculations would include less xenon at time of melting and thus indicate larger supplementary control requirements.

Figure 4 illustrates the net reactivity contribution, in microbucks, of the combined temperature coefficients at a pile temperature of 1133C and as a function of fuel exposure (MWD/T). To derive the curves the assumption was made that the graphite and uranium were both at 1133C and that the aluminum had already melted. The uranium must certainly be at this temperature or higher, but the graphite may be cooler. If this is the case the net temperature reactivity effect at high exposures would be less positive than assumed and the results would be conservative. At low exposures, the over-all coefficient in the dry lattice is negative and the maximum reactivity conditions would occur in the cold reactor.

Figure 4 contains three curves depicting the temperature effects of three different fuel elements. The graph for the KIIN fuel element lattice was calculated by D. E. Simpson^{/7/} and is based on graphite temperature effects calculated by W. E. Niemuth.^{/8/} The other two graphs are results of calculations performed by the computer program MOFDA for the KIV and KV lattice respectively.

4. Effects of Total Control Parameter Changes on Operating Efficiency

If water loss occurs near the time of a minimum outage the KV lattice will be more reactive at time of meltdown than at the time of water loss once the average fuel exposure exceeds 50 MWD/T whereas this effect does not occur in the KIV lattice until a fuel exposure around 250 MWD/T. If water loss occurs after an infinite outage (with no xenon present) the most reactive state occurs at meltdown rather than at water loss, when the KV fuel attains an exposure of 250 MWD/T and after the KIV fuel attains an exposure 600 MWD/T. This change would not be limiting under present operating conditions of loading and exposure; however, it will require earlier charging of supplementary control or earlier removal of the lockbars from ball 3X channels during outages. These requirements will thus affect outage timing rather than operating efficiency; poison requirements will never exceed the amounts required for efficiency during startup transients.

/5/ Unpublished work of W. F. Ekern

/6/ Personal Communication, FR Zaloudek

/7/ HW-56655, Pt. 1, Rev. "Calculation of Supplementary Disaster Control Requirements - Hanford Piles Part I - Basis and Procedures," DE Simpson, June 15, 1955

/8/ HWN-1864 Personal Notes - CL Miller, February 6, 1957, P. 67, Curves by WE Niemuth, April 16, 1957

DECLASSIFIED

Figure 3

HW-77718

Page 10

Time Between Water Loss and Tube Melting - Hours

DECLASSIFIED

HW-77718
Page 11

Figure 4

Net Temperature Coefficient Reactivity Contribution
at 660C for KIV and KII
at 1133C for KV

DECLASSIFIED

5. When to Convert to KV Nuclear Safety Parameters

The charging of the KV fuel and use of zirconium tubes will take place throughout several operating periods. The nuclear safety parameters (i.e. temperature effects and melting times) of the KIV fuel geometry and aluminum tubes may justifiably be used until 30 per cent of the pile has been converted. Irreparable damage can be prevented if sufficient coolant can be provided to keep the uranium from melting and the minimum number of cooling channels necessary to prevent uranium melting during shutdown is estimated to be approximately 30 per cent.

C. Changes In Conversion Ratio

The conversion ratio changes are favorable with the KV fuel element in the zirconium tube. The over-all conversion ratio will increase by approximately 2.0 per cent over the conversion ratio for KIV fuel elements in aluminum tubes. Conversion ratios for these fuels are listed in HW-50300-B, Revised.^{79/}

R. E. Tiller

Reactor Physics
Process & Reactor Development Operation
Research and Engineering Section

Archie D. Vaughn

Process Physics Studies
Operational Physics Sub-Section
Research and Engineering Section

RE Tiller:AD Vaughn:gs

Information provided by this document recommended for operational use during the transition to the zirconium lattice:

HC Fullmer

Manager, Operational Physics
Research and Engineering Section

[Signature]

Supervisor, Reactor Physics
Process and Reactor Development
Research and Engineering Section

DATE

FILMED

8/4/94

END