1 of 1

(CLASSIFICATION)
HANFORD TECHNICAL RECORD
GENERAL ELECTRIC

~~DISTRIBUTION~~ OF THIS DOCUMENT IS UNLIMITED

DECLASSIFIED

HW-71809

DISTRIBUTION

- 1-2. AEC-HOO: Attn: AT Gifford
3. AEC-HOO: Attn: RL Plum
4. ER Astley
5. GF Bailey
6. JT Baker
7. JW Baker
8. RS Bell
9. CE Bowers
10. WA Blyckert ←
11. JH Brown
12. RJ Bursey
13. RD Carter
14. RA Chitwood
15. RG Clough
16. DW Constable
17. RE Dunn
18. JH Ferguson
19. WJ Ferguson
20. EJ Filip
21. GC Fullmer
22. SM Graves
23. OH Greager
24. CN Gross
25. LL Grumme

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of D.S. Lewis

CG-PR-2 3-3-94

By J.E. Savely 3-7-94
Verified By DK Hanson 3-21-94

26. JW Hagan
27. AK Hardin
28. RB Heiple
29. JF Jaklevick
30. AR Kosmata
31. LW Lang
32. CG Lewis
33. DG Lewis
34. AR Maguire
35. DK McDaniels
36. WS Nechodom
37. DE Newbrough
38. SL Nelson
39. R. Nilson
40. GF Owsley
41. CA Priode
42. RW Reid
43. OC Schroeder
44. HG Spencer
45. SL Stewart
46. WL Stiede
47. RE Tiller
48. AD Vaughn
49. AP Vinther
50. 300 File
51. Record Center

This document consists of
18 pages, No. 10 of
51 copies. [REDACTED]

This document classified

by: G. B. Clively

December 6, 1961

PRODUCTION TEST IP-467-C
REDUCING MINIMUM DOWNTIME

OBJECTIVE

The objective of this Production Test is to evaluate the operational aspects of a proposed method for reducing minimum downtime. The excess xenon poisoning, which occurs during the first 32-38 hours after the shutdown of a reactor from present equilibrium levels, will be partially overridden by a central enriched zone whose added reactivity contribution would be compensated during normal operation by means of poison splines. The test will be performed at B Reactor.

MASTER

DECLASSIFIED

DECLASSIFIED

HW-71809

Page 2

BASIS AND JUSTIFICATION

At the present time, when a Hanford reactor is shut down from normal operating levels, it will undergo a period, lasting from 32-38 hours, during which the poisoning effect of the Xe^{135} forces the reactor to remain subcritical. Inasmuch as many of the causes of these shutdowns are of such a nature that they can be rectified in less than this minimum downtime, a means of overriding the xenon poisoning effect and thus permitting earlier startup or even startup at any time could have very large economic incentive.

A preliminary study has been made to determine the enrichment requirements necessary to bring a reactor to critical before a minimum downtime has elapsed. The result was that the enrichment requirements and associated operating requirements would be relatively small if the enrichment were placed in a block of process tubes in the central portion of the reactor. The excess reactivity provided by the enrichment would be negated by the usage of splines in this region during normal operating conditions (see Figures 1 and 2). The poisoning effect per spline is equivalent to the reactivity contribution (related to natural uranium) of 2.4 enriched columns; each central enriched column will be supplied with a spline cap.

The bringing of a reactor to critical with such a loading, while reducing minimum downtime, would increase the nonequilibrium operating losses to some extent during the rise to equilibrium levels because of the initial central flux peak and would thus reduce in part the potential gains of the core loading. Also the actual length of time from startup to normal turnaround levels would be lengthened because of the very nature of the type of loading being attempted. However, experience with this method should permit more rapid rates of rise from turnaround to equilibrium levels because of the greater inventory of xenon present, and with the development of optimum control techniques the nonequilibrium loss increase may be relatively small. Figure 3 sketches the rate of power level increase in terms of allowable flux configurations during power level increases.

LOCATION AND SHAPE OF THE CORE CHARGE

The core ideally should be placed in the region of maximum "startup" neutron flux. This position would be in the near center portion of the reactor where for an "all-rod-out startup" the maximum flux levels would be found. The limiting factor in such a choice is the total control problem; i.e., the zone must lie within the vertical safety system. The core location is shown in Figure 4. The mixed charge length of 29 pieces of standard 0.96 enriched slugs, flanked on either end by natural slugs, as is shown in Figure 5, is specified rather than the normal 34-piece enriched charge length in current use in order to center the enriched portion of the charge within the vertical safety system's volume of control. While such a limitation on the charge length of the enrichment is not necessarily a prerequisite for the satisfaction of the total control criteria to be applied, it is felt that a completely conservative approach to the first core loading is warranted in view of the difficult geometrical problems which would be aduced when evaluating the total control criteria for a longer enriched charge length. The natural slugs are added to either end of the enriched charge so as to minimize the operational front-to-rear flux peaking caused by short charge lengths. It is anticipated that during normal operation the longitudinal flux peak in this region should not be significantly different from present conditions.

This production test authorizes an initial test loading of 50 standard 0.96 per cent enriched columns centered within B Reactor. Each enriched column is to be supplied with

Page 3

The speed of control limitations shall be prescribed in terms of tube power limits versus graphite temperatures in a separate document to be issued by Process and Reactor Development. The tube power limits in that report should not limit the power level significantly; however, the specified speed of control limits will override those limits stated here.

In the charging of the enrichment core for this test, 50 tubes will be charged with 0.96 per cent enriched fuel elements and equipped with spline caps. The density of the special enriched columns shall be no less than 80 per cent of the total tubes in the zone. The zone shall be centrally located in the top to bottom direction, slightly near side of center, but completely within the full vertical safety system coverage zone. Within these limitations a location mutually agreeable to Processing and Pile Physics will be chosen. A typical solid pattern would be as follows (also see Figure 4).

Although not necessary for successful execution of the test it is suggested that the core be charged during an outage for which the reactor will be prepared to start up within 20-22 hours after shutdown including the time to charge the core. The purpose of this suggestion is to make use of the enriched loading as soon as it is charged. The actual charge date, subsequent to approval of this test, will be at the discretion of B Processing.

The loading charge shall be as follows: 16-8" + 2-5" dummies + 5 regular I&E slugs + 4 0.96 per cent enriched slugs + 1 mixer slug + 24 0.96 per cent enriched slugs + 5 regular I&E slugs + 14 dummies for the spline cap seating charge. The mixer may be replaced with an enriched slug if desired. In either event the proper spring loading of the spline cap is to be confirmed and appropriate changes made in the upstream dummy pattern if the check indicates such action is necessary.

C. Initial core loading of the charges shall proceed in the following manner:

1. All the tubes in the core to be charged during one outage will be charged during one period of time, not interrupted by other front face work unless it becomes essential to do so.
2. Normal total control requirements are to be satisfied at all times.
3. After each E-column has been charged, any spline prescribed for that column shall be inserted before charging is started on the next tube.

D. Spline Pattern

A total of 22 splines shall be charged for local reactivity matching requirements. The following pattern would be appropriate for the suggested core loading.

2669	2770	2671	2772	2673	2774	2675
	2570				2574	
2469		2471	2472	2473		2475
	2370				2374	
2269		2271		2273		2275
	2170		2272		2274	

The splines which are to be used in the above tubes for normal control purposes must be inserted a minimum depth of 28 feet from the front cap; which distance corresponds to the downstream end of the enriched charge.

In the event that a spline cannot be inserted in an indicated tube, any adjacent unsplined core tube may be used; however, the final result of the splining shall be such that except during the special startups permitted by this production test, no more than two lattice units shall separate a splined tube from its nearest neighbor and that no square which contains nine enriched tubes within the enriched area shall contain fewer than three standard length splines. In all cases the actual splining operation shall be governed by Process Standard C-120.

II. Startup Procedures for a Cold StartupA. Pre-startup Control Requirements

1. If the expected outage time will exceed the normal "minimum downtime," all of the prescribed "total control" splines shall be left in the core and shall not be removed for startup reactivity purposes. These conditions being met, normal pre-startup and startup requirements and procedures shall be followed.
2. If an attempt will be made to reduce minimum downtime by the method permitted in this production test:
 - a. The 3X system shall be unbypassed.

- b. At least four of the "core" ZTM points must be operable.
- c. At least ten of the "core" enriched tube thermocouples shall be monitored on the "cornpopper," the monitored tube thermocouples being symmetrically representative of the core.
- d. Either both subcritical monitors or one subcritical monitor and a PC of demonstrated sensitivity of 100 watts or less, shall be in service. Rod withdrawal rates shall depend on whether or not both subcritical monitors are in service in accordance with the Process Standards.
- e. Flux monitor high trip settings shall be in accordance with Process Standard C-030.02 until a power level corresponding to a tube temperature rise of 10C is reached. When a 10C rise is reached, stop the power raise, take a Flexowriter temperature map and set the flux monitors to trip at no more than 150 per cent of the reading. So long as any tube temperature exceeds a rise of 10C but an outlet temperature less than 80C the flux monitor trip shall be no more than 150 per cent of the indicated reading for at least three flux monitors. When the maximum tube temperature reaches 80C the power raise is to be stopped to take a Flexowriter map. Above an 80C maximum tube outlet temperature the high trip setting on at least three flux monitors shall correspond to the following table.

<u>Maximum Tube Outlet Temperature</u>	<u>Trip Setting % of Indication</u>
80-85C	125
85-90C	120
90-95C	115
above 95C	110

- f. A Pile Physics representative shall be present before horizontal rod pulls are initiated and during operation at least until those splines required for "normal control" of the enriched zone have been re-charged.

B. The Approach to Criticality; Startup Rod and Spline Withdrawal Sequence

- 1. Pull the VSR's as prescribed in Process Standards for cold startup.
- 2. Position No. 2 and No. 8 HCR's to 135 inches, all others being full in.
- 3. Pull No. 5 HCR to near side boundary of the enriched core.
- 4. Follow the normal HCR withdrawal sequence as specified in the 105 B Process Physics Data Manual for all HCR's except No. 5 HCR.
- 5. After all rods except No. 5 HCR have been removed, pull the first spline, using the spline coiler system, from the center of the core.
 - a. All spline removals shall be performed by means of the controls in the control room.

6. Wait at least three minutes, then repeat step 5, for another spline, removing the splines radially outward from the center of the enriched core.
7. During the approach to critical, a reciprocal count rate measurement shall be maintained by the Pile Physicist present after each spline pull so that the approach to critical can be monitored.
8. If a rising period is observed before the completion of a spline withdrawal, the removal of that spline shall be completed, further control being accomplished with No. 5 rod. If no rising period is observed after completion of all spline withdrawals No. 5 HCR shall be pulled to 250 inches, in steps of ten inches per minute, whereupon a minimum outage shall be awaited.
9. For each cold startup the physicist will supply a curve valid until the reactor is started up which will limit the number of splines which can be out of the reactor as a function of time. This curve will be necessary to assure that total control requirements are maintained during spline withdrawal to critical. Actually, unless an error were made in the reactivity calculations the reactor will become critical during the spline pulls before this total control limit on the number of splines is reached. In the unlikely event the reactor were not critical when this limit was reached it will be necessary to insert splines as required by the curve thus preventing startup. Once the tube temperature rise in the central core has exceeded five degrees the limits presented by this curve would not be applicable. After this time it is sufficient to assume that during operation the total control restrictions would be satisfied by inserting and removing poison to achieve or maintain a balanced flux distribution; however, spline insertion must proceed at a rate to satisfy part C4 below.

C. Post-Criticality Procedures

1. Upon observing a first indication, a rising period no shorter than 30 seconds shall be maintained. The initial control of the rising period shall be maintained by the insertion of No. 5 HCR, supplemented by No's. 4 and 6 HCR's as necessary.
2. The temperature rate-of-rise for any "core" tube shall not exceed 3 C/min and the total power rate-of-rise shall not exceed 50 MW min; adherence to both limits is to be monitored during the power rise. Compliance with the individual tube temperature rise limit may be observed continuously from monitoring the "corn-popper" and the ZTM, operation of which have been specified elsewhere in the production test.
3. If the enriched core is being utilized, the limit to be used with regards to initial power levels shall be a core tube limit of 1000 KW or the limit as designated by speed of control limitations^{/2/} whichever is lower. It shall be the responsibility of the Pile Physics representative to interpret and apply these limitations. As soon after startup as the pile is under stable control as determined by Processing supervision and the Pile Physicist, normal tube power limits and temperatures as defined in the Process Standards may be observed in this region.
4. Upon reaching the core tube power limit, compensation for reactivity gains shall be accomplished by the insertion of new splines into the central

DECLASSIFIED

HW-71809
Page 7

core and the usage of No's. 4, 5 and 6 HCR's for fine core control during the splining operation. The spline insertion rate shall be such that no more than one of the HCR's (4, 5 and 6) shall be allowed to penetrate the reactor more deeply than 100 inches. In the unlikely event that such control of the HCR's cannot be maintained while the reactor core is in use, the reactor shall be scrammed by the No. 1 safety circuit and total control poison requirements as determined by the physicist shall be inserted. Failure to insert enough splines could require a partial core discharge as determined from total control requirements. Normal spline insertion rates should very adequately compensate the reactivity gain rate in the central core after startup.

III. Startup Procedures for a Secondary Cold Startup

If a reactor shutdown occurs during that phase of the startup in which the enriched core is being used, and providing that the normal conditions for a secondary cold startup are met, the following procedures shall be observed.

- A. If the enriched core is not to be used for the secondary cold startup, all of the prescribed "normal control" splines shall be inserted into the core and shall not be removed for startup reactivity purposes. This condition being met, normal secondary cold pre-startup and startup requirements and procedures shall be followed.
- B. If the enriched core is to be used the following procedures shall be observed:
 1. Sufficient core splines plus three shall be inserted to ensure that the reactor will be subcritical with the VSR's out and all HCR's out with the exception of No. 5 HCR which will be positioned at 180 inches.
 2. The above condition being met, the procedures set forth in this document under the heading "Startup Procedures for a Cold Startup" shall be followed.
 3. In determining the reactivity worth of HCR's, No's. 4, 5 and 6 for removing rod during a secondary cold startup when the core is utilized, the following values are to be used for that part of the HCR system which lies in the core (i.e., within the region from 180 inches to 110 inches).

HCR No. 4: 3.0 c-mk/inch
HCR No. 5: 3.6 c-mk/inch
HCR No. 6: 2.7 c-mk/inch

For those HCR's which lie outside the core, the normal evaluation as set forth in the B Process Physics Manual will be used.

The purpose of this secondary cold startup procedure is to permit leaving a portion of the full complement of normal total control splines out when a lesser number very definitely satisfies safety requirements and sufficient scram recovery time is available to make a well controlled deliberate startup.

IV. Miscellaneous Operating Restrictions

- A. Only new splines which have been approved for total control usage may be charged into the core. A spline may be considered as new if it was in the reactor but withdrawn before any operation occurred.
- B. During operation at equilibrium conditions less than the number of splines specified to meet initial total control requirements may be in the reactor. So long as no splines are withdrawn from the core area following a period of operation during which the additional reactivity of the core is cancelled out with splines, it may be considered that the splines in the core prior to a shutdown effectively cancel out the additional reactivity effect of the enriched core during the outage.

Splines may be replaced in the core during an outage one at a time; i.e., if a spline has been withdrawn it must be replaced before withdrawing a second spline.
- C. Following a scram from equilibrium or near equilibrium conditions a hot startup may be attempted so long as no splines in the enriched core are removed after the shutdown is initiated.
- D. It is permissible to insert splines into the core at any time; however, splines are not to be withdrawn from the core until the reactor has operated at 50 per cent or more of equilibrium level for a minimum of one hour following a normal cold or secondary cold startup. Following a hot startup splines may be withdrawn as necessary to maintain efficient control, or even to continue operating, after the reactor reaches 50 per cent or more of its pre-shutdown level.
- E. Splines are not to be counted for total control purposes if they have been in the reactor more than 50 operating days. Any spline with more than 50 operating days' exposure must be replaced within eight hours following a reactor shutdown. This excludes outages of less than eight-hour duration.

TERMINATION

This test will be terminated with the discharge of the first enriched core load as specified herein. The material shall be discharged during one outage at normal exposure for enriched material. When discharged, total control splines will be removed from the row to be discharged, subsequently that row shall be discharged before splines may be withdrawn from the next row.

COSTS

The approximate incremental cost of using the 50 tubes of enrichment for one metal cycle will be \$26,500.

A minimum spline cost will be about \$330 (at \$15 per spline). Additional spline costs will result from utilizing the block to achieve an earlier startup. Although there is no detailed schedule assuring that this enriched core will be utilized for achieving earlier startups, it is estimated, based on past operating experience, that about four startups will be shortened in this manner during the two-three months that the core is in the reactor. It is estimated that the gain from one outage shortened by the full

DECLASSIFIED

HW-71809

Page 9

amount possible will nearly pay for one cycle of the core. Any additional outage time saved would be pure profit except for the relatively small cost of additional splines.

HAZARDS

As demonstrated in the referenced nuclear safety analysis of this enriched core loading^{1,2/} there is no significant difference between the nuclear safety hazard associated with operation with or without the central core loading. As discussed in reference ^{2/} the maximum tube power in the enriched core shall not exceed 480 KW until the graphite temperature starts to increase; as soon as the weighted temperature reaches 160 C a tube power limit of 1000 KW may be observed. Once the calculated ECT reaches 1000 tubes the normal standard limit will apply.

RESPONSIBILITY

B Processing Operation - Responsible for operating continuity, safety, and for charging and discharging the enriched core and splines in accordance with safety restrictions specified in this report.

Pile Physics Unit - Responsible for providing complete instructions for satisfying nuclear safety requirements and for monitoring compliance with these requirements, for providing detailed operating technique recommendations designed to maximize operating efficiency, and for analyzing the results, developing and securing approval for modified techniques as indicated from initial experience, and issuing a final report with appropriate recommendations.

Pile Physics Unit
Operational Physics Sub-Section
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

JF Jaklevick:gs

^{1/}HW-71957, "Reducing Minimum Downtime - A Nuclear Safety Analysis," J.F. Jaklevick, 12-6-61

^{2/}HW-7207, "Speed of Control Limits for Xenon Override Production Test," R.E. Tiller, December, 1961

Figure 1

Hours from Normal Minimum Time

HW-71809
Page 10

DECLASSIFIED

R = MK
20.00

-40.00

The shutdown xenon reactivity transient vs. time with
"core" enrichment strengths necessary for various re-
duced minimum times.

Normal minimum
time

27 E-Col.

42 E-Col.

52 E-Col.

70 E-Col.

88 E-Col.

105 E-Col.

118 E-Col.

Xenon override power level
at shutdown winter levels

Core charge: 28 I&E²
(See Fig. 5)

Reference: Pgs. 7, 18, 19, HWN 2885
Personal Notes, J.F. Jaklevick, Jr.

Figure 1

DECLASSIFIED

HW-71809

Page 11

Figure 3

A sketch of the rate of rise to equilibrium in terms of approximate flux shapes when utilizing an enriched core

Reference, Pg. 23, HWN 2885
Personal Notes, J.F. Jaklevick, Jr.

Figure 4

Suggested location of initial "xenon-override" test loading. Spline caps would be inserted on each of the indicated tubes.

Figure 5

DECLASSIFIED

Charges and Relative Displacement

Standard Loading I&E Slugs (31 + 1 Mixer)

16-8" + 2-5" Dummies	9 - I&E	M	22 I&E	Upstream Seating Charge
138 inches	79.8 inches	8.9 inches	195 inches	113 inches

Core Loading, I&E + I&E² Slugs

16-8" + 2-5" Dummies	5 I&E	4 I&E ²	M	24 I&E ²	5 I&E	Upstream Seating Charge
138 inches	44.3 inches	26.6 inches	8.9 inches	159.4 inches	44.3 inches	113.6 inches

Average maximum spline penetration

I&E = 8.865 inch (ave) natural uranium slug

I&E² = 6.64 inch (ave) 0.96% enriched slug

M = 8.865 inch (ave) water mixer slug

Dummy = 8 inch filler slug

Figure 6

Total number of splines needed to compensate for a given number of 0.96% enriched columns to satisfy total control requirements during an outage. The number of splines needed during reactor operation at equilibrium levels can be found by multiplying the indicated number by the factor 0.88

DECLASSIFIED

Reference: Pg. 18, HWN 2885
Personal Notes, J.F. Jaklevick, Jr.

Figure 7

HW-71809
Page 16

Figure 8

HW-71809
Page 17

$\frac{\Delta R}{\text{Sec}}$ = rate of reactivity gain per sec. in c-mk

DECLASSIFIED

Rate of gain in reactivity per second as a spline is removed from a 9-rod reactor versus seconds from start of spline pull.

This curve is calculated for the maximum loading which would be used at a 9-rod reactor.

Integrated area under curve = 1.62 MK

References: Pg. 13, HWN 2885
Pg. 62, HWN 2633
Personal Notes: J.F. Jaklevick, Jr.

APPROVALS

H.C. Fullmer
Manager, Operational Physics
Research and Engineering Operation
IRRADIATION PROCESSING DEPARTMENT

R. Nelson
Manager, Process & Reactor Development
Research and Engineering Operation
IRRADIATION PROCESSING DEPARTMENT

R. W. Reed
Manager, Process Technology
Research and Engineering Operation
IRRADIATION PROCESSING DEPARTMENT

O. H. Snager
Manager, Research and Engineering
IRRADIATION PROCESSING DEPARTMENT

X. W. Baker
Manager, B Processing Operation
B-C Reactor Operation
IRRADIATION PROCESSING DEPARTMENT

M. J. Ferguson
Manager, B-C Reactor Operation
IRRADIATION PROCESSING DEPARTMENT

L. P. Nichols
Manager, Production
Manufacturing Operation
IRRADIATION PROCESSING DEPARTMENT

E. L. Ostley
Manager, Applied Reactor Engineering
Manufacturing Operation
IRRADIATION PROCESSING DEPARTMENT

O. L. Schneider
Manager, Manufacturing Operation
IRRADIATION PROCESSING DEPARTMENT

DECLASSIFIED

**DATE
FILMED**

12/16/94

END