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PRODUCTION TEST IP-467-C SUPPLEMENT B
REDUCING MINIMUM DOWNTIME - K REACTORS

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PRODUCTION TEST IP-467-C SUPPLEMENT B REDUCING MINIMUM DOWNTIME - K REACTORS

OBJECTIVE

The objective of the Production Test Supplement is to evaluate at a K Reactor the operational aspects of a proposed method for reducing minimum downtime. The proposed method is to partially override the xenon transient with a block of enrichment in the central region of the reactor.

This test is nearly identical to that performed at B Reactor^{1/}; however, the differences

^{1/} HW-71809, Production Test IP-467-C, Reducing Minimum Downtime, J.F. Jaklevick
December 6, 1961

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between the two reactor types are sufficient to require a separate test at a K reactor. This test may be performed at either K reactor.

BASIS AND JUSTIFICATION

The purpose of performing this test at a K reactor in addition to the original test at one of the older reactors, is to examine the operational aspects unique to a K reactor and to evaluate the feasibility of the method for reducing minimum downtime at a reactor of that type. It is expected that differences in operating techniques will be indicated at the K plant because of its greater size, of different speed of control restrictions and of the variation in the reactivity effectiveness of enrichment, rods, and poisons. The experience at B Reactor with the use of the enriched core to reduce minimum downtime indicates the feasibility of proceeding with a similar test at one of the K reactors.

An approximation of the extent of xenon override as a function of the number of enriched columns at a K reactor is shown in Figure 1. Since the reactivity effect of an enriched column is lower at a K reactor than at an older reactor 68 enriched columns are specified as compared to 50 columns for the initial B Reactor test. The poisoning effect of a spline is slightly over two enriched columns per spline so during normal operation (operation when the enriched block is not being utilized) slightly less than 50 per cent of the block tubes will contain splines.

As at the older reactors one reduced minimum startup per metal cycle would nearly balance the cost of the loading. K plant experience indicates that an average of about two outages per metal cycle could utilize the early startup capability.

LOCATION AND SHAPE OF THE CORE

The core position was chosen to be displaced slightly to the near side of the center to increase the reactivity "worth" of the core because of the near side flux peaking during "rods out" startups and to be more readily accessible to control by the horizontal control rods. Its vertical position was designed to center on a rod bank and near the vertical center of the reactor since an even distribution of heat from top to bottom would minimize startup cycle tendencies.

It is a requirement of this test that 40 per cent half-rods used during the core utilization startup have their travel mechanically limited during this period to no deeper than 20 per cent. Due to their longer poison section the travel of the 64 per cent half-rods need not be restricted. After the compensating splines are inserted and the flux starts to expand toward the fringe this restriction may be removed.

I. Core Loading

A. Column Pattern

In the initial test loading 68 tubes will be charged with 0.95 per cent enriched fuel elements and equipped with spline caps. Recommended tube locations follow.* Deviation from this pattern is permitted as long as the density ratio of enrichment columns to natural columns in the core is at least 10:1, the near side boundary is 59 column, the shape is reasonably well rounded and it is centered on the indicated horizontal control rod bank.

*See table on page 3.

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Recommended Enriched Core Pattern

~62%	~59%		~56%		~53%		~50%		HCR Rod Position %
			3863	3864					
	3761	3762	3763	3764	3765	3766			
3660	3661	3662	3663	3664	3665	3666	3667		
3560	3561	3562	3563	3564	3565	3566	3567		
3459	3460	3461	3462	3463	3464	3465	3466	3467	3468
3359	3360	3361	3362	3363	3364	3365	3366	3367	3368
	3260	3261	3262	3263	3264	3265	3266	3267	
	3160	3161	3162	3163	3164	3165	3166	3167	
	3061	3062	3063	3064	3065	3066			
			2963	2964					

It is suggested but not a test requirement that the enriched core be charged during an unscheduled outage when the immediate startup could take advantage of the loading.

- B. The loading charge shall consist of the normal 46-piece enrichment charge with the standard downstream dummy pattern of 2 - 8" perfs, 9 - 8" tubulars, and 5 - 8" expendables. This loading will lie entirely within the vertical safety system control zone.
- C. The core loading shall proceed in the following manner:
1. All the tubes in the core scheduled to be charged during any one outage will be charged in one period of time, not interrupted by other front face work unless it is essential to do so.
 2. Normal total control requirements are to be satisfied at all times.
 3. After charging an E-column that is scheduled to have a spline inserted, insert the spline as soon as possible. The spline insertion shall not lag the number required for full compensation by more than four splines at any time. Full compensation is considered to be two splines for every four enrichment columns. It is quite likely that if the core were to be recharged with enrichment the exposure cycle would be split for charge-discharge work to simplify the splining operation. For instance: The compensating splines could be charged in tubes not scheduled for recharge during the ensuing outage; then the charge-discharge work could proceed uninterrupted by splining requirements. Such a procedure should satisfy all control safety requirements and minimize charging problems.

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D. Spline Pattern

A total of 34 splines shall be charged for reactivity matching requirements. The following pattern would be appropriate for the initial core loading.

				3863				
			3762	3663	3764	3766		
		3661	3562	3564	3665	3566	3667	
	3459	3560	3461	3463	3465	3467		
		3360	3362	3364	3366	3368		
			3261	3263	3265	3267		
		3160	3162	3164	3166			
			3061	3063	3065			
				2964				

or the alternate

				3864				
			3761	3763	3765			
		3660	3662	3664	3666			
			3561	3563	3565	3567		
		3460	3462	3464	3466	3468		
	3359	3361	3363	3365	3367			
		3260	3262	3264	3266			
			3161	3163	3165	3167		
			3062	3064	3066			
				2963				

The splines used must be new splines inserted a minimum of 38 feet. In the event that a spline cannot be inserted, an adjacent unsplined core tube may be used. The final result of the splining shall be such that no more than two lattice units will separate a splined tube from its nearest neighbor, and that any square within the core which contains nine enriched tubes will contain no fewer than three standard length splines.

All splining operations are to follow the requirements of Process Standard C-120.

II. Startup Procedures for a Cold Startup

A. 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 Ball 3X system must be unbypassed.
 - b. The 49-point scanner should be operable since the system contains two tubes in the core region.
 - c. The temperature monitor must be used to continually monitor the core temperatures whenever the core is not completely compensated by splines. Monitor as outlined in Process Standard C-050.
 - d. Either both subcritical monitors or one subcritical monitor and another startup instrument sensitive to less than 500 watts, shall be in service.
 - e. Flux monitor trip settings shall be in accordance with Process Standard C-030 until the Beckman range of 3×10^{-10} is reached. At that time trips are to be set at 200 per cent or less of the indicated flux reading for at least three flux monitors.

Follow this procedure until the noticeable heating range is reached and then set the high trip to correspond to the following table.

Maximum Tube Outlet Temperature	Trip Setting % of Indication
Below 50C	200%
50-79 C	150
80-84 C	125
85-89 C	120
90-94 C	115
Above 95 C	110 max.

In addition to the usual maps required by Process Standards, when the maximum tube temperature reaches 80C the power raise is to be halted and a Flexowriter map taken.

- f. A Pile Physics representative shall be present before horizontal rod withdrawals are started, and until the core splines required for normal equilibrium operation are recharged.

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

1. Position the half rods 3, 9, 10, 11 and 18 at 20 per cent out.
2. Pull VSR's as normal for a cold startup except that only one VSR penetrating the core shall be withdrawn at a time.
3. Pull number 8 and 9 HCR's to 55 per cent out.
4. Follow the normal HCR withdrawal sequence as outlined in the "Operational Physics Factors for 105 KW²/ for all HCR's except numbers 8 and 9.

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5. Withdraw number 8 rod next at a rate no faster than 15 per cent per minute. It is to be pulled no further than 85 per cent out.
6. Number 9 rod is then to be positioned at 65 per cent out.
7. The deadman (interrupting rod activation) switch will be put into service after the rods are removed and prior to core spline pulling, and it is to remain in service until the core reactivity is fully compensated by splines.
8. Start pulling splines from the center outward at a rate not to exceed one spline every one and one-half minutes.
9. During the approach to critical a reciprocal count rate shall be maintained by the Pile Physicist present. In this manner the approach to the critical condition can be monitored.
10. If a rising period is observed, complete the spline withdrawal if one is being removed and use number 9 HCR to control the period rate.
11. If no rising period is observed after all splines are removed, pull number 9 rod from 65 per cent to 85 per cent out in steps of no greater than 5 per cent per minute.
12. After 8 and 9 rods are at 85 per cent, all other rods out, and all splines out, monitor the subcritical monitor count rate and await a minimum outage.

C. Post Criticality Procedures

1. Upon observation of a rising period, the flux level will be allowed to increase no faster than that corresponding to a 30 second period. Control of the period rate will be maintained by the use of number 9 rod, and if desired, number 8 rod also.
2. The temperature increase during the power raise shall be limited to 30 per minute for any "core" tube, and the total power increase to 100 MW per minute; adherence to both limits is to be monitored during the power rise. Compliance with the individual tube temperature rise limit may be observed by the continuous scanning of the core section with the temperature recorder.

Figure III shows the tube power limit as a function of maximum graphite temperature based upon speed of control considerations.^{/3/} There are thermocouples in the core to monitor the maximum graphite temperature.

3. If the core is being utilized, the limit to be used for initial power levels shall be a core tube power limit of 1200 KW or the power limit given in Figure III, whichever is lower. As soon 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 provided the graphite temperature requirements in Fig. III are satisfied.

4. Compensation for reactivity gains shall be made by splines inserted into the core and HCR's 8 and 9. Spline insertion should be made at a rate that will maintain HCR's 8 and 9 at an effective control position in the core, or no deeper than about 50 per cent.
5. Normal spline insertion rates should easily compensate for the reactivity gain in the core after startup. However in the unlikely event that the HCR tips extend beyond the core while it is being utilized, the reactor shall be scrammed by the number 1 safety circuit and total control poison charged as recommended by the pile physicist.

III. Startup Procedures for a Secondary Cold Startup

If the reactor shuts down while the enriched core is being used, and if the normal requirements for a secondary cold startup are met, these additional procedures shall be observed.

- A. If the enriched core is not needed for the startup, all of the normal compensating splines are to be inserted and shall not be removed for 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 are to be observed.
 1. Sufficient core splines plus three shall be inserted to ensure that the reactor will be subcritical with VSR's out and all HCR's out except 8 and 9, both of which shall be positioned at 65 per cent.
 2. The above condition being met, the procedures set forth under "Startup Procedures for a Cold Startup" shall be followed.
 3. In determining the reactivity worth of HCR's when the core is not fully compensated assume the following values for the rods that are inside the core. (Within the region from 45 to 65 per cent.)

HCR 7 and 10	15 c-mk/%
HCR 8 and 9	20 c-mk/%

During a startup utilizing the enriched core a rod calibration test will be performed to substantiate these estimates. For those HCR's that lie outside the core, the normal evaluation given in "Operational Physics Factors for KW"² will be used.

IV. Miscellaneous Operating Criteria

- A. Only new full-length black splines that have been approved for total control usage may be charged into the core. For this purpose a spline may be considered as new if during its time in the reactor, the reactor did not operate at appreciable power levels.
- B. During operation the number of splines in the core will be adjusted so that a favorable heat distribution exists. It is considered that if sufficient splines

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were in the core prior to shutdown to effectively cancel out the additional reactivity effect of the core as determined by a flat flux distribution, so long as no splines are withdrawn during an outage the core can be assumed to be cancelled out for Total Control purposes without additional splines. These splines may be replaced during the outage, and the number inserted may lag the number required for compensation by a maximum of four.

- C. Splines may be inserted into the core at any time but after critical (10, pg 6), may not be withdrawn from the core until the reactor has operated at 50 per cent of equilibrium level for at least one hour following a normal cold or secondary cold startup. Following a hot startup, splines may be withdrawn as needed to maintain efficient control after the reactor reaches 50 per cent of its pre-shutdown power level.
- D. Splines are not to be counted for total control if they have been in the reactor core more than 30 operating days. Any spline with more than 30 days of exposure must be replaced within eight hours following a reactor shutdown. Outages of less than eight hours duration are excluded.

TERMINATION

The test will be terminated with the discharge of the second enriched core, or earlier by mutual agreement of the Pile Physics Operation and the appropriate K Processing Operation.

COSTS

The cost for the 60-tube block will be about \$50,000 for one metal cycle. A minimum spline cost will be \$450 (assuming \$15 per spline). Additional splines will be used depending upon the utilization of the block.

The increased costs for charge-discharge work have been estimated at 50 per cent over the normal time to charge 60 enriched tubes. Spline inserting and pulling requirements are responsible for this increase.

The reduction of one minimum outage by complete utilization of the core will nearly pay the core costs.

HAZARDS

As demonstrated in the Nuclear Safety Analysis of a core loading,^{/3,4/} there is no significant difference between the nuclear safety hazard associated with operation of the partially enriched core as specified in this production test and the hazards associated with the operation of the normally loaded reactor. As discussed in reference 3 and shown in Figure III, the maximum core tube power is limited initially to 1000 KW and can be gradually increased as graphite temperatures rise.

^{/3/} Letter to G.F. Owsley - "Speed of Control Limits for K Reactors with Xenon Override Production Test," R.E. Tiller, April, 1962
^{/4/} HW-71957, "Reducing Minimum Downtime - A Nuclear Safety Analysis," J.F. Jaklevick, G.F. Owsley, 5-9-62

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RESPONSIBILITY

K Processing Operation - Responsible for operating continuity, safety and for charging and discharging the enriched core and splines in accordance with the 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 the results, developing and securing approval for modified techniques as indicated by the initial experience and issuing a final report with appropriate recommendations.

Ronald Chitwood

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

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Figure 1

Shutdown Xenon Transient as a Function
of Time for Two Power Levels

Levels I = 4000 MW

II = 4400 MW

and:

Core Sizes for Xenon Override at Various
Shutdown Times

Figure 2

Position of Enriched Core
in K Reactor

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Figure 3

Tube Power vs. Maximum Graphite Temperature

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APPROVALS

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