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HORIZONTAL CONTROL ROD RENOVATION PROGRAM ALL PRODUCTION REACTORS

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ALL PRODUCTION REACTORS

August 23, 1965

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HORIZONTAL CONTROL ROD RENOVATION PROGRAM
ALL PRODUCTION REACTORS

I. INTRODUCTION

The purpose of this document is to outline the proposed implementation of engineering program results to remedy the major horizontal control rod (HCR) problems at Hanford production reactors.

K and C Reactors currently use a water cooled, round, aluminum control rod packed with boron carbide powder. B and D Reactors use a water cooled, flat, aluminum rod made up of sintered boron carbide-aluminum rings strung on three cooling tubes, all of which is encased in an outer aluminum shell

Since the basic problems and engineering details have been previously documented in detail (most recently in document RL-REA-580, Remedial Program, Horizontal Control Rod and Vertical Safety Rod Problems, B, C, D, and K Reactors), this will not be repeated here. Briefly, the problems are:

K Reactors -- rod binding due to distortion of the upper channels in the graphite stack and rod binding and channel blockage due to 3X System ball infiltration in the lower channels in the graphite stack.

C Reactor -- rod binding due to distortion of the upper channels in the graphite stack.

B and D Reactors -- rod binding due to overheating and distortion of the rods arising from dimensional changes in the nuclear poison material and inadequate heat transfer in the rod for current conditions.

The nature of the problems -- progressing toward a limiting condition at a predictable rate -- lends itself well to a stepwise or "as needed" approach in applying a solution. Such an approach offers the dual benefits of realizing maximum reliable usage from each piece of equipment and of distributing the renovation costs over several years time. The specific program proposed herein emphasizes the immediate application phase.

II. PROPOSED PROGRAM

A. Work

K Reactors - Each:

Replace track blocks with flat spacer plates in five upper channels

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and install uncooled, articulated rods (first choice) or flexible cooled rods (alternate) in these channels.

Note: One channel has already been modified and a flexible cooled rod installed at KW Reactor and one more set of spacer plates and a cooled flexible rod are on hand to be applied where most needed.

Continue to sleeve lower channels as they show evidence of functional problems from 3X System ball infiltration.

C Reactor:

Replace track blocks with flat spacer plates in five channels and install uncooled, articulated rods (first choice) or flexible cooled rods (alternate) in these channels.

B and D Reactors - Each:

Replace five of the existing rods with the new flat aluminum rod.

The uncooled control rod is a flat rod made up of segments about 40 inches long joined together with hinge joints. Each segment is a dysprosium oxide-nickel cermet core encased in Inconel 600. The flexible cooled rod is a flat rod made up of sintered boron carbide-aluminum or dysprosium oxide-aluminum elements strung on Inconel 600 cooling tubes and all encased in an Inconel 600 sheath. The new flat aluminum rod is a water cooled rod utilizing boron carbide powder and having optimized cooling characteristics.

B. Cost

1. Procure:

	<u>FY 1966</u>	<u>FY 1967</u>
13 uncooled or flexible cooled rods, and accessories (two assemblies are on hand)	\$ 66,000	\$156,000
13 sets of channel spacer plates (two sets are on hand)	6,500	--
Sleeve assemblies - 6 sets are on hand	--	--
One additional set of channel renovation tooling	15,000	--
10 new aluminum rods	40,000	--

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TABLE II

HCR Channel No.		Estimated Maximum Depression - Inches			HCRs By Distortion
		9-19-62	1-8-68	1-1-73	
40	KE				
	1	4.2	7.8✓	10.7	1 - 10.7
2	2	3.5	6.4✓	9.1	4 - 9.1
3	3 - 1/2	2.6	4.6	6.8	2 - 9.1
	4	3.64*	6.7	9.5	5 - 8.1
5	5	3.1	5.8	8.1	8 - 6.8
	6	1.5	2.8	3.9	3 - 6.8
	7	2.2	3.8	5.75	9 - 6.7
9	8	3.06	5.6	8.0	12 - 10.7
	9	2.56	4.5	6.7	7 - 6.7
	10 - 1/2	1.25	2.2	3.25	12 - 10.7
	11 - 1/2	1.78	3.1	4.65	15 - 12.5
12	12	2.48	4.4	6.5	16 - 12.5
	13	2.08	3.7	5.4	17 - 12.5
	14	1.02	1.8	2.7	7 - 4.4
	15	1.37	2.3	3.6	6 - 3.6
	16	1.89	3.3	4.9	15 - 12.5
	17	1.59	2.9	4.1	19 - 12.5
	18 - 1/2	.78	1.5	2.0	10 - 3.2
	19	1.31	2.3	3.4	14 - 12.5
20	20	1.09	1.9	2.58	20 - 12.5
					18 - 2.0

* Value from traverse data (5)

Accurate calculation of the limiting channel deflection for use of the existing HCR assembly presents a rather formidable challenge when the number of variables and the very limited data on complete channel profile are considered. No significant effort has been devoted to this aspect simply because a more reliable measure already exists, i.e., significant problems of rod binding are now being experienced with the upper rods at both reactors with 3.5" to 4" maximum channel distortion.(9) In view of this, it is quite reasonable to assume that with a maximum channel distortion of 5.5" to 6", the existing HCR assembly will be essentially inoperable. Looking at Table II with this in mind, it can be conservatively predicted that rods 1, 2, 4, 5 and 8 will be virtually inoperable within five years and that rods 3, 7, 9 and 12 in addition will become inoperable within ten years due to graphite distortion in the vertical plane. Furthermore, the ten year operational integrity of rods 6, 11, 13, 16 and 17 would appear questionable.

Distortion in the horizontal plane does not appear to constitute a major problem in the HCR channels. Very limited data (10) presently available on this aspect indicates that a maximum horizontal distortion of about one-half to three fourths of an inch exists in the HCR channels. Also, distortion in this plane can be overcome to a degree by removal of graphite from the filler blocks forming the sides of the HCR channels.

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2. Install:

	<u>FY 1966</u>	<u>FY 1967</u>
Channel spacer plates	\$ 16,000	\$ 7,000
Flexible rods	--	26,000
Channel sleeves - 6 channels	5,500	5,500
New aluminum rods	--	<u>6,500</u>
TOTAL	\$149,000	\$201,000

C. Schedule

The estimated performance schedule is shown on the following page.

III. DISCUSSION AND JUSTIFICATION

The basic approach of attacking the problem on an "as needed" basis rather than one large repair effort is considered sound. In all cases, the problems affect the rods to varying degrees depending upon the location and operational use of the rod. The proposed program provides for remedial work at those rod locations which are in need of early attention. A similar scope of work will almost certainly be required in five or six years to correct similar problems as they develop at other rod locations; however, in the meantime, the remaining useful life of these rods should be utilized.

More specifically, considering the proposed work by reactor:

A. K Reactors

The number of replacement rods and attendant channel modifications proposed is sufficient to take care of those rod locations needing early attention. If the uncooled rod still looks as promising at the end of the development program as it does now, the replacement rods should be of the uncooled type. This will accomplish two things. It will alleviate the current functional problems arising from channel distortion and it will provide a period of operational experience with the new HCR concept. If for some unforeseen reason, the uncooled rod does not prove out in the final developmental testing, the replacement rods would be of the flexible cooled type now being tested in No. 2 rod location at KW Reactor. An aluminum rod is not considered adequate from a materials standpoint as a long term replacement rod in those locations at the K Reactors where it would be exposed to the combined environment of high temperature and extensive channel distortion.

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HCR SYSTEM RENOVATION SCHEDULE - ALL REACTORS

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	FY-66												FY-67											
	1965						1966						1967											
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
<u>A REACTORS - EACH</u>																								
INSTALL FIVE FLEXIBLE HCR'S																								
CHANNEL SPACER PLATES:																								
PROCUREMENT																								
INSTALLATION																								
RODS AND ACCESSORIES:																								
PROCUREMENT																								
INSTALLATION																								
<u>SLEEVE SIX HCR CHANNELS</u>																								
PROCUREMENT																								
INSTALLATION																								
<u>C REACTOR</u>																								
INSTALL FIVE FLEXIBLE HCR'S																								
CHANNEL SPACER PLATES:																								
PROCUREMENT																								
INSTALLATION																								
RODS AND ACCESSORIES:																								
PROCUREMENT																								
INSTALLATION																								
<u>D REACTORS - EACH</u>																								
INSTALL FIVE NEW ALUMINUM HCR'S																								
PROCUREMENT																								
INSTALLATION																								

COMPLETED

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Sleeving is a relatively inexpensive (about \$2500 per channel) means of combatting 3X System ball infiltration into the lower HCR channels. It should be applied only where the need is indicated. Design Change 702, which authorizes this work on a maintenance basis, authorizes sleeving all of the HCR channels in the lower half of the pattern at both K Reactors, but this should not be an objective in itself. Two channels have been sleeved at KE Reactor and three at KW Reactor. There are six additional sets of sleeve assemblies on hand.

The round sleeves currently being installed in the lower channels are limited to use with a round rod; they are not compatible with the flat rod designs. The latter would require a rectangular sleeve. At the time the present sleeve assembly design was conceived and tested, there was no intention of departing from the existing round rods in the lower channels. Estimated long term (10 year) distortion in these channels does not appear to require substituting a flat rod for that reason. Hence, a round sleeve being easier to fabricate and install was a logical choice for use with a round rod.

Even with the now recognized potential of installing flat uncooled rods in all channels to eliminate the rod cooling water system and its attendant maintenance and operational problems, departure to a rectangular HCR channel sleeve at this time is not considered justified. It is presently contemplated that it would be about five years before flat uncooled rods would be installed in these lower channels. Recognizing that ball infiltration into the HCR channels is only a secondary problem due to 3X System balls escaping from the VSR channels, a major effort is in progress to correct the source of the trouble by renovation of the VSR channels. If this effort is successful by the time flat HCR's are installed in the lower channels, very likely no sleeves at all would be needed. If it is necessary to replace existing round sleeves with rectangular sleeves, the portion of the initial effort which would be sacrificed would be minor -- \$300 in sleeves, \$400 for a compression assembly and about \$400 in labor per channel. Since six sets of material are already on hand, the above material costs can not be counted until the number of additional channels sleeved exceeds six. Finally, converting to rectangular sleeves will require a significant design effort which can be utilized to better advantage at this time to complete development of the new HCR concepts.

B. C Reactor

Comments relative to the K Reactors apply also to C Reactor. Channel sleeving, however, has not yet become a point of concern at C Reactor because opening of voids in the graphite stack has not been nearly as extensive as at the K Reactors.

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C. B and D Reactors

The five replacement rods proposed for each reactor is a sufficient number to replace the equilibrium control rods. These are the rods which reside in the reactor during operation and hence experience the most severe service. There are approximately 18 spare HCR's of the existing B-D Reactor design. Unless the deterioration rate for this type of rod is greatly accelerated by a change in mode of reactor operation, these spares should serve satisfactorily as replacements for the non-equilibrium rods until they are used up. At that point, any further replacements would be with the new type aluminum rod.

With relatively insignificant channel distortion and somewhat lower graphite temperatures, ^{and, therefore, less channel distortion} compared to K and C Reactors, aluminum remains attractive as a rod structural material at B and D Reactors. This in turn opens the opportunity to obtain a rather low cost rod (approximately \$4000 each). Although from a mechanical standpoint, either the flexible cooled rod or the uncooled rod can readily be applied at B and D Reactors, justification for so doing appears doubtful at this time.

D. Application of the Uncooled HCR

At the outset of the HCR engineering program, feasibility of an uncooled HCR for the Hanford production reactors appeared questionable even though its advantages were obvious. With the need for an improved rod replacement to be available in a limited period of time for use at K and C Reactors, effort was concentrated on refinement of the cooled concept. Work on an uncooled rod, continued on a secondary basis, has since shown that an uncooled rod is almost certainly feasible and practical. Being an articulated rod, the uncooled rod provides greater assurance of HCR system functional integrity for an indefinite period than even the flexible cooled rod can provide.

The ultimate objective now is to replace all cooled rods at K and C Reactors with uncooled articulated rods. By the proposed program, this would be accomplished by first installing five at each of the three reactors to satisfy current replacement needs and to provide a rather large scale prototype experience. In roughly five years, about five more rods at each reactor will need replacement because of continued increase in channel distortion. Assuming satisfactory experience with the first batch of uncooled rods, it is proposed that at this time the rod systems be converted to all uncooled rods.

About half of the rods at each of the K and C Reactors will require

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replacement with a more sophisticated rod over the next five to ten years to overcome the problem of increasing channel distortion. Since the cost of the flexible cooled rod and the uncooled rod is similar (approximately \$12,000 each) and both will meet the service requirements, it is irrelevant economically which is used. This leaves conversion of the other half of the rod complement to uncooled rods which must be justified purely on the unique merits of the uncooled rod.

Such a replacement is justified on the following bases:

1. Improved reactor safety. It has already been demonstrated that a temperature in excess of 1600° C is required before the poison material slumps and loses its shape in the assembly presently contemplated. This provides a significant degree of backup for the primary safety systems in considerations of ultimate reactor safety.
2. Loss of cooling water to the HCR's would be eliminated as a threat to reactor operating continuity. Records¹ show that over the 3-1/2 years preceding July, 1965, twelve outages were caused by some type of HCR cooling water system malfunction. About 100 outage hours were charged to the cause.
3. Elimination of the cooling water would simplify the HCR system and eliminate radiation zone maintenance work on hoses, hose reels and piping.
4. A small amount of process water (~0.2% of the total reactor flow) would be freed for more lucrative use.

One qualification to applying the uncooled rod at C Reactor even on a limited basis should be noted. Use of this rod at C is contingent upon successful redesign of the reactor atmosphere gas seal around the rods to accommodate the higher temperature rod. At the K Reactors, this seal is located on a separate seal section in the HCR assembly and is thus unaffected by use of the higher temperature, uncooled control rod. At C Reactor, the gas seal is penetrated by the control rod itself and must, therefore, be capable of withstanding the higher rod surface temperature. Modification of the C Reactor HCR assembly to provide a separate seal section would be an extensive undertaking and impractical from an economic standpoint. Redesign of the C Reactor gas seal is part of the remaining engineering work.

¹ Reactor Outage Time Ledgers, 1962, 1963, 1964, 1965, D. L. DeNeal.

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IV. ALTERNATE CONSIDERED

An alternate to the proposed program would be to conduct an in-reactor prototype test of the uncooled HCR and make initial replacements at K and C Reactors with the flexible cooled HCR. This approach is not proposed because it is not considered necessary to test a single prototype of the uncooled rod in-reactor.

Extensive (10,000 hour) environmental testing of materials under conditions significantly more severe than those presently existing in the reactors will have been completed as part of the uncooled rod development program. Mechanical action of the rod, drive forces and stress levels have been investigated in a grossly distorted channel mockup using a full size simulated rod assembly. Data on induced radioactivity derived from in-reactor testing the flexible cooled rod will be directly applicable to the uncooled rod since the structural materials are the same -- Inconel 600. The uncooled rod uses dysprosium oxide as a nuclear poison instead of the boron carbide used in the flexible cooled rod. The nuclear characteristics of dysprosium oxide can be predicted with reasonable accuracy from theory and experimental work. Effective control strength of the uncooled rod can be determined accurately by comparing samples of the uncooled rod and the flexible cooled rod in the 305 Test Reactor.

This alternate approach thus appears to be a needless detour in reaching the objective of converting to uncooled HCR's at K and C Reactors.

V. ENGINEERING WORK REMAINING

The major segments of engineering work requiring completion before the proposed application program can be initiated are listed below with the estimated completion date.

1. Complete the uncooled HCR development program. The end point of this program calls for preparation of design drawings, material and fabrication specifications and documentation of developmental test results. 11/1/65
2. Receive aluminum rod prototypes. 9/1/65
3. Test aluminum rod in the laboratory. 9/1/ to 10/1/65
4. Test aluminum rod in-reactor. 10/1 to 12/1/65

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5. Complete in-reactor test of the flexible cooled HCR. 12/1/65
The test rod was installed in KW Reactor the first week of June, 1965. A minimum of six months service is considered necessary to constitute a significant demonstration of this rod.
6. Finalize design on replacement rods and channel renovation tooling. 12/1/65
7. Design a new gas seal, step plug and channel spacer plate necessary to utilize a flat rod (cooled or uncooled) at C Reactor. 1/1/66
8. Finalize design of a K Reactor step plug for use with the uncooled HCR. 1/1/66
9. Issue summary report of test experience on all of the replacement rod designs. 2/1/66

The completion schedule on engineering work is directed toward being prepared to initiate procurement of replacement rods by early 1966. Procurement time for the rods is estimated to be nine to twelve months while that for the other equipment (step plugs, spacer plates, gas seals, etc.) should not exceed six months. It is thus apparent that rod procurement must receive primary emphasis.

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