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INSPECTION OF THE
ELK RIVER CONTROL RODS
NOVEMBER 5 THROUGH 9, 1964

Issued -
December 1964

Prepared By -

D. E. Simpson and W. G. Albert
Reactor Engineering Division
Chicago Operations Office
U. S. Atomic Energy Commission
Argonne, Illinois

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INTRODUCTION

The Elk River Reactor control rods were visually inspected in November 1964, after approximately three months of power operation of the reactor. This inspection was performed pursuant to a requirement of the Technical Specifications incorporated in the Operating Authorization, DPRA-3.

SUMMARY

The 13 control rods were examined by direct viewing under water and by close-up viewing of all surfaces through a periscope.

No cracks, damaged rivets, or other defects which would appear to affect the integrity of the rods were observed.

The boron stainless steel sections of the rods were covered with a light coating of dark oxide. Localized "worm-track" indications of corrosion were observed on some rods, probably as a result of pickling or other chemical attack prior to installation of the rods. The Zircaloy spot welds of all rods exhibited a white corrosion product, and some white corrosion product was observed at the outer edges of the cruciform in the region of the Zircaloy and boron stainless steel juncture. A wavy line indication was observed near the top of one rod (No. 11) which appeared similar to a crack; it was concluded that this indication almost certainly existed prior to completion of the rod fabrication and was probably a surface defect which occurred in manufacture of the boron stainless plate.

DISCUSSION

General

Each Elk River Reactor control rod consists of a boron stainless steel (2.2 per cent natural boron by weight) absorber section, a Zircaloy follower, and a stainless steel "bayonet" section which connects to the rod drive. The sections are joined by riveted connections. The boron stainless and Zircaloy sections are made up of 1/8-inch thick plates covered by 1/16-inch plates formed with a 90° bend,

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assembled to the cruciform shape and spot welded at regular intervals. The span of the cruciform is 14-7/8 inches.

The rod design is shown in Figure 2. Figure 1 shows the core arrangement and rod positions.

The rods are similar in design to those of EBWR. The first set of EBWR rods showed evidence of circumferential cracks about some of the spot welds in the boron stainless section, and the second set of EBWR rods suffered damage to rivets at Zircaloy to boron stainless steel connections. Based on this experience, as well as the cracking observed in the original boron stainless rods at Dresden, it was considered possible that cracks or damaged rivets might be found in the Elk River Reactor rods, although there are significant design differences which would indicate improved performance for the Elk River Reactor rods.

Inspection of the rods was performed during the period November 5 to 9, 1964. Prior to the inspection all fuel was removed from the reactor.

The operational activities associated with the inspection, including fuel and control rod handling, were planned and performed by the Rural Cooperative Power Association under the supervision of the Allis-Chalmers Manufacturing Company, the holder of the reactor provisional operating authorization. The actual visual inspection of the control rods was performed by members of the Chicago Operations Office of the AEC and consultants from Southwest Research Institute of San Antonio, Texas and Argonne National Laboratory of Argonne, Illinois.^{1/} The reports of consultants are attached as Appendices B and C.

Prior to core unloading and the start of the rod inspection, the control rod drop times were checked with the reactor cold. These were rechecked after reassembly of the rods and drives. The results of these checks and comparisons with preoperational and other tests of drop times are listed in Table I. It should be noted that operating experience, including hot and cold rod drop tests, had given no indication of damage or unsatisfactory performance of the control rods.

Close-up inspection of the control rods was performed with the periscope

^{1/} D. E. Simpson and W. G. Albert of the Chicago Operations Office, USAEC, R. D. Wylie of Southwest Research Institute, and C. H. Bean of Argonne National Laboratory.

which was set up on a bridge built across the reactor cavity. The field of view was approximately 3 inches in diameter, with some magnification of the rod surfaces. Lighting was provided by a source built into the periscope plus underwater flood lights. The periscope was positioned to inspect one quadrant of a rod (two blade surfaces) when the rod was placed in control rod position No. 12. It could be rotated to inspect through an angle of about 180° , providing complete coverage of the rod quadrant. Longitudinal movement was accomplished by raising and lowering of the control rod in the shroud guide with the 5 ton polar crane. After No. 12 rod was inspected it was set aside in the reactor cavity and the other rods were inspected by movement to the No. 12 rod position. Figures 16 and 17 illustrate the general arrangement of equipment for this inspection.

The inspection procedure was as follows:

1. The control rod was raised to, or above, the surface of the water as far as radiation levels would permit (limit 500 mr/hr).
2. By use of a monocular and underwater lights the rod was surveyed for:
 - A. General areas of corrosion.
 - B. Mechanical damage.
 - C. Cracks.
 - D. Presence of rivet heads.
 - E. General straightness and warp.
3. After the general inspection, the rod was lowered into the No. 12 control rod position, where the periscope was set up. Each quadrant of the rod was surveyed by the periscope, with particular attention to:
 - A. Areas of interest as a result of the over-all inspection in (2) above.
 - B. All riveted joints.
 - C. The central web of the control rod and possible cracks in this area.

- D. The flat surfaces and spot welds in the boron stainless and Zircaloy sections; direct scrutiny of at least 20-30 per cent of all spot welds was obtained.

The condition of the control rods, as determined from this inspection, is discussed below. Specific observations concerning each control rod are described in Appendix A.

Cracks

No cracks were detected in any control rod.

The only questionable indication found was a wavy line transverse to the rod axis about 2-3 inches below the top of rod No. 11. This line was visible nearly the full width of the plate forming the surface of one quadrant of this rod, including the 90° bend area, becoming indistinct near the outer edges of the blades. No indication was visible on the exposed outer ends of the plate under direct observation; this area could not be viewed with the periscope.

Examination of this indication included periscope viewing, direct visual inspection above the water level (due to the low radiation level at the top of the rod) both before and after wiping, scraping, and emery buffing the surfaces; and subsequent periscope viewing and photographing.

An apparent waviness of the surface at this indication, together with its general appearance, indicated that it probably was a manufacturing surface defect rather than a crack. The fact that the indication extends around the 90° bend is further evidence that it is not a crack which occurred in service.

Figures 3, 4, and 5 are photographs of this indication in the flat and 90° bend areas.

Spot Welds

In the stainless steel portion of the blades, differences in the types of indentations made during manufacturing were evident from one control rod to the next. Also a few spot welds showed evidence of copper deposits about the periphery of the weld indentation. Some stainless steel spot welds showed evidence of minor corrosion about the surface adjacent to the spot weld.

The Zircaloy spot welds were sound, but exhibited a rough surface showing the effects of fusion welding of the spots. All Zircaloy spot welds had surface corrosion as noted below. Numerous double welds were observed, and in one case four welds were noted essentially superimposed.

Figures 3 through 6, 9, and 11 show spot welds in the boron stainless; Figures 13 and 14 show Zircaloy spot welds.

Corrosion

The boron stainless portion of the control rods were found to be covered with a light coating of dark oxide. One control rod, No. 6, indicated some white corrosion product at the outer edges of the cruciform where the boron stainless and Zircaloy were joined. Also, all Zircaloy spot welds had a white corrosion product on their surface.

Localized indications with the appearance of "worm tracks" were noted on some rods. Figures 9 and 10 are photographs of the most pronounced such indication, observed on rods Nos. 1 and 8; Figure 15 is a sketch showing approximately the extent of these marks on rod No. 8. The bottom of these marks was clearly visible, and appeared slightly rough and pitted. The light corrosion coating had the same color and appearance in these marks as on the cruciform rod surfaces. The depth could not be determined, but appeared small relative to the width.

These indications are thought to have been caused by collection of pickling agents or some other chemical at some time in the manufacture or storage of the rods prior to installation in the reactor.

Rivets

All rivets were observed to be intact and all rivet heads shown on drawings were inspected with the periscope. However, it was found that some additional rivets had been used during manufacture in the boron stainless blade sections of a few rods. These rivets were randomly located and one could not be certain that all such rivets were inspected by periscope. However, the general inspection near the surface of the water would have revealed any missing heads from these rivets.

Mechanical Damage

Other than normal rub marks, only rod No. 12 indicated any evidence of mechanical damage. A small area (approximately 1/4 inch wide) at the junction of the vertical and stainless steel section indicated that something had caught on the Zircaloy web which protruded slightly more than the web of the stainless steel section.

A number of scratches and scribe marks were observed on the boron stainless and Zircaloy sections. Figure 11 shows one such scribe mark on boron stainless; note that the small metal deposit raised by the scribe has not corroded away, indicating the relatively small amount of corrosion which has occurred.

Manufacturing and Workmanship

The following comments pertain to the general quality of manufacturing and workmanship as evaluated from this inspection:

1. Riveting - Quality of riveting was non-uniform as evidenced by variations in depressions in the surrounding metal. Rivets apparently were hot-headed, in air, which may contribute to corrosion of Zircaloy in the riveted region.
2. Central web of boron stainless section (90° bend area) - In one rod (No. 5), several weld deposits were observed, apparently indicating repair of cracks due to forming. There were no visible cracks in the area of these welds, nor in any other areas.
3. Surface gouges, grinding - A few areas were noted in which the boron stainless had been gouged and/or ground. Ground areas were copper colored, apparently due to corrosion of material deposited in the grinding. Figure 6 shows one area (in rod No. 1) which had been gouged and ground.
4. Forming - There was no obvious distortion of the rods or evidence of inadequate forming of the plates assembled into rods; however, there was a slight waviness at some points. This and the existence of rivets in boron stainless sections are evidence of some difficulty experienced in forming the plates to a precise fit before spot welding.

TABLE I

ERR CONTROL ROD SCRAM TIMES - SECONDS

<u>Control Rod No.</u>	<u>Preoperational Test (hot) 2/18/63</u>	<u>Hot Test 9/8/64</u>	<u>Cold Test 10/12/64</u>	<u>Cold Test 11/17/64</u>
1	1.24	1.27	1.30	1.26
2	1.22	1.24	1.35	1.26
3	1.07	1.07	1.08	1.10
4	1.15	1.10	1.10	1.09
5	1.28	1.27	1.27	1.24
6	1.18	1.23	1.32	1.24
7	1.22	1.24	1.26	1.22
8	0.99	1.09	1.09	1.04
9	0.99	1.10	1.11	1.08
10	1.07	1.07	1.09	1.08
11	0.98	1.01	1.05	1.03
12	1.08	1.06	1.09	1.05
R	1.03	1.06	1.09	1.04

fuel element
storage well

dummy element

spiked element

regular element

*

indicates center pin removed and
control rod material inserted

ERR CORE LAYOUT

Note: Control rod designations "R" and "6" above
are interchanged from designations in
current use.

FIG. 1

FIG. 2

Figure No. 3 - Shows mark across top of rod No. 11.
A typical spot weld is also shown in
this photograph.

Figure No. 4 - Showing mark on rod No. 11 after
buffing. (Approximately 3X.)

Figure No. 5 - Photograph shows mark at top of rod No. 11 as it appears in the bend section at the base of the cruciform. Note light corrosion about spot weld.

Figure No. 6 - View of top edge of poison section of rod No. 1. Lightly damaged area in picture was gouged and ground.

Figure No. 7 - Illustrates quality of some rivets
in regulating rod.

Figure No. 8 - Another view of rivet heads in
regulating rod.

Figure No. 9 - Worm track type of corrosion on
rod No. 1

Figure No. 10 - Worm track type of corrosion on
rod No. 8. See Figure 15 for general
location of this area.

Figure No. 11 - Scribe mark on rod No. 2. Note small pimple of metal from scribe tool.

Figure No. 12 - Surface of boron stainless steel on regulating rod. A spot weld with a very shallow indentation may be seen to the left in the photograph.

Figure No. 13 - Photograph of the lower riveted junction between Zircaloy follower and bayonet section. This photograph from regulating rod is typical of all control rods. Typical Zircaloy spot welds are shown in the top of the photograph and rivets are shown at the bottom.

Figure No. 14 - Typical Zircaloy follower to boron stainless junction. Photograph (from regulating rod) shows two rivets and a spot weld.

Figure 15 - Showing extent of "worm track" corrosion on one blade of Control Rod No. 8. Another blade of this control rod also showed similar corrosion tracks.

Figure No. 16 - General view of reactor cavity showing a control rod and periscope at the right. Tool at the top of the photograph is a guide for inserting control rods in the shrouds.

Figure No. 17 - View of area above reactor cavity. Fuel handling bridge is to the left. Temporary bridge for periscope viewing of the control rods is on the right.

APPENDIX A

ERR CONTROL ROD OBSERVATIONS

SUMMARY DATA SHEET

No. 1 Control Rod

Rivets

All riveted heads were intact at both riveted junctions. Workmanship was generally poor.

Stainless Steel Spot Welds

No cracks were observed. Spot weld impressions were shallow.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

Thin film of dark oxide over entire surface. Some evidence of light worm track corrosion.

Zircaloy Blade Condition

Normal.

No. 2 Control Rod

Rivets

All rivet heads were intact at both riveted junctions. Workmanship on rivets was not the best.

Stainless Steel Spot Welds

All spot welds were normal; no cracks were observed.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

Dark oxide over entire surface. Scribe marks were evident.

Zircaloy Blade Condition

Scribe marks were evident on three blades. One area was noted which required four spot welds. On the outside edge of two blades (opposite) there were heavy rub marks.

No. 3 Control Rod

Rivets

All rivet heads were intact at both riveted junctions. Three additional rivets were noted approximately half way up the SS blade.

Stainless Steel Spot Welds

No cracks were observed. Spot weld impressions were deep with some copper deposits on periphery of a few welds. Some spot welds showed evidence of slight pitting corrosion in the metal adjacent to the spot weld.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

Thin film of dark oxide over the entire surface. One blade showed an area which had been ground during manufacturing.

Zircaloy Blade Condition

One inside corner had a very heavy rub mark.

No. 4 Control Rod

Rivets

All rivet heads were intact at both riveted junctions.

Stainless Steel Spot Welds

No cracks were observed. Spot weld impressions were shallow.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

Thin film of dark oxide was over entire surface. The general condition of the surface was good.

Zircaloy Blade Condition

Normal.

No. 5 Control Rod

Rivets

All rivet heads were intact at both riveted junctions. Slight evidence of corrosion was noted around some rivets at the junction of the Zircaloy and the boron stainless steel.

Stainless Steel Spot Welds

No cracks were observed. Spot weld impressions were very indistinct.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

The corner of one quadrant indicated weld repairs had been made during manufacture. Some minor worm track corrosion on one blade was found.

Zircaloy Blade Condition

Normal.

No. 6 Control Rod

Rivets

All rivet heads were intact at both riveted junctions. Two extra rivets in the stainless steel blade were noted.

Stainless Steel Spot Welds

No cracks were observed.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

Thin film of dark oxide was over entire surface. The general condition of the surface was good.

Zircaloy Blade Condition

In the inside corner of one quadrant was a heavy scratch. Scribe marks were noted on one blade.

No. 7 Control Rod

Rivets

All rivet heads were intact at both riveted junctions. Workmanship at the junction between the Zircaloy and the boron stainless was poor as was evidenced by rivet heading tool damage.

Stainless Steel Spot Welds

Spot welds left rather deep impressions. No cracks were observed.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

Thin film of dark oxide was over entire surface. The general condition of the surface was good.

Zircaloy Blade Condition

Normal.

No. 8 Control Rod

Rivets

All rivet heads were intact at both riveted junctions. However, the workmanship on the rivets did not appear as good as some of the other rods.

Stainless Steel Spot Welds

Welds were rather indistinct; no cracks were observed.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

The stainless steel surface of three blades showed evidence of light corrosion which produced a series of worm tracks. Photographs of this condition were made. The stainless steel blades had the characteristic film of dark oxide and their general condition was good.

Zircaloy Blade Condition

Normal.

No. 9 Control Rod

Rivets

All rivet heads were intact at both riveted junctions.

Stainless Steel Spot Welds

No cracks were observed. A few spot welds showed some evidence of copper deposits at the edge of the weld.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

A thin film of dark oxide was over the entire surface of the rod. The rod was pulled partially out of the water and the depth of this oxide film was checked by rubbing with a rag. The general condition of the surface was good.

Zircaloy Blade Condition

Other than scribe marks from manufacturing, nothing unusual was noted.

No. 10 Control Rod

Rivets

All rivet heads were intact at both riveted junctions.

Stainless Steel Spot Welds

Very weak surface indentations made welds difficult to observe. No cracks were noted.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

Thin film of dark oxide was over entire surface. The general condition of the surface was good.

Zircaloy Blade Condition

Normal.

No. 11 Control Rod

Rivets

All rivet heads were intact at both riveted junctions.

Stainless Steel Spot Welds

No cracks were observed.

Zircaloy Spot Welds

Light oxide on surface of all welds. Many double spot welds observed near junction of Zircaloy and boron stainless.

Stainless Steel Blade Condition

Thin film of dark oxide over entire surface. Heavy rub marks at edges of blades which had a brown color. A scratch near the top of one quadrant was closely inspected. It was buffed and again inspected closely out of water. The conclusion was

that no crack existed since sections of the mark could be buffed out. Also mark followed across blade and through the curved section at the base of the cruciform indicating it was a manufacturing scratch. Photographs of the mark were made.

Zircaloy Blade Condition

Normal.

No. 12 Control Rod

Rivets

All rivet heads were intact at both riveted junctions.

Stainless Steel Spot Welds

No cracks were observed. Spot weld impressions were deep with some copper deposits on periphery of a few welds.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

Thin film of dark oxide was over entire surface. The general condition of the surface was good.

Zircaloy Blade Condition

One inside corner at top of Zircaloy sheet showed evidence of mechanical damage over an area approximately 1/4 inch long.

Regulating Rod

This rod was formerly designated as No. 6 rod and is shown in Figure 1 as No. 6 rod. However, after the regulating circuit was adapted to this rod, the designations "R" and "6" were interchanged.

Rivets

All riveted heads were intact at both riveted junctions. The rivet heads seemed more prominent and the workmanship below average.

Stainless Steel Spot Welds

Spot welds were very difficult to observe because of very shallow impressions.

Zircaloy Spot Welds

Light oxide on surface of all welds.

Stainless Steel Blade Condition

The oxide film which was characteristic of all rods, seemed to be heavier on this rod. However, this could not be verified by wiping the surface because of the higher radiation level characteristic of this particular control rod. Also, all four outside edges of the control rod showed a white corrosion product over approximately 1/2 inch of length at the junction of the stainless steel and Zircaloy sections.

Zircaloy Blade Condition

Approximately 2/3 of the way up on the Zircaloy a distinct change in color was evident.

Spare Control Rod

The spare rod in the Rural Cooperative Power Association warehouse was inspected to determine a frame of reference for the underwater inspection of the irradiated rods and to obtain the opinion of consultants on the suitability of this rod as a replacement, since it had been used for drop tests (2000 cycles). The spare rod was in good condition and satisfactory for service.

APPENDIX B

COPY OF CONSULTANTS REPORT - R. D. WYLIE

SwRI 1228-47 - November 23, 1964

At the request of the Chicago Operations Office of the Atomic Energy Commission, the writer visited the Elk River Power Station of the Rural Cooperative Power Association in Elk River, Minnesota for the purpose of inspecting the reactor control rods. The inspection was performed from November 4-9. Present at the inspection were Mr. W. Albert, AEC-COO, Mr. D. Simpson, AEC-COO, Mr. C. Bean, Argonne National Laboratory and the writer, Mr. R. D. Wylie, Southwest Research Institute.

Subparagraph 20 of Section 14.3 of the Technical Specifications for the operation of the Elk River Reactor required the inspection of all control rods after three months of full power operation for cracks. The specification further required that the blades be used only if the examination showed no observable cracks.

In compliance therefore with the specification each control rod was removed and inspected over substantially its full surface from the riveted joint between the Zircaloy and stainless steel in the follower section to the top of the boron stainless steel poison section.

Each rod was brought near the surface for a visual examination to check for distortion, separation of the layers, unusual surface conditions, etc. This examination was aided by a telescopic sight glass. As the rods came near the surface, radiation monitors checked for excessive radiation. Except for the center rod, the rods could be lifted until the top of the boron stainless steel section was out of water approximately 18". This permitted removal of surface films and a close visual examination of the top of the element in air.

At the completion of the examination each rod was inserted in the shroud which originally housed the #12 control rod. A borescope had been positioned so that the surface of an entire quadrant could be examined in a single traverse. The borescope was equipped with a camera attachment which permitted photographing of unusual or typical conditions. The rod was raised or lowered past the borescope lens which could be rotated about 180°. There was a rod marker which identified the quadrant being examined. Detailed records were kept of unusual conditions observed. Special attention was given to the condition of the two riveted sections and to the spot welds in the Zircaloy and boron stainless steel.

The results of this examination indicated that there were no observable cracks or even indications which appeared to be crack like on 12 of the 13 control rods (I personally witnessed 8 of the 13 rods). On

control rod #11 there was a visual line in one quadrant which was clearly visible in the borescope. This line occurred within two inches of the top of the blade in the boron stainless steel. Fortunately, this location was such that it could be examined out of water after scraping the surface. The line extended from near the edge of the blade to the center of the blade and around the 90° flanged corner. The line did not intersect any of the spot welds. It was at least 1/2" away from any weld. It did appear to distort slightly away from the welds it passed. A considerable amount of visual examination could not in my opinion conclusively demonstrate that the indication was not a crack. The probability of it being a crack, however, is very low for the following reasons:

1. The location of the indication was a very unlikely spot for a crack to occur. There was no stress concentration or other defects which could initiate a crack.
2. The indication went around the flanged corner without deviation which seems unlikely for a crack.
3. The indication was not associated with welds which in previous experience with the EBWR rods was the most likely spot for cracks to occur.
4. The statistics do not favor having a single crack of the size of this indication in as many square feet of surface as exists on the control rod blades.
5. The stresses at this location are not particularly high.
6. The radiation exposure at this area is extremely low.

While it would have been preferable to confirm this by dye penetrant examination, it is probable that the observed indication was a manufacturing defect such as a roll mark or press mark rather than a crack.

There were several other observations which might be made on the control rod blades. These may be summarized as follows:

1. There was evidence of corrosion of the boron stainless steel around the spot welds particularly where high heat or high pressure was obviously employed. There was a considerable variation in the spot weld characteristics. In isolated locations there was evidence of copper or a mixture of copper and molten stainless steel around the welds. In most cases the welds had been ground to remove the flash. It is probable that the corrosion was associated with this condition.

2. Investigation of the riveted areas indicated that all rivet heads were intact. Except for manufacturing variations such as the damage caused by the heading tool, etc., the only observed condition which appeared to be service connected was at the riveted section between the Zircaloy and boron stainless steel on the center rod where the rivets had extended and loosened slightly. Even at this location the heads were intact.
3. At very isolated areas extra rivets were observed which were apparently used away from the designated rivet area to assist in assembly. Such a condition was confirmed on the spare control rod in storage. None of the extra rivets observed showed distress.
4. There were a number of isolated corrosion pitted areas on the boron stainless steel. Some of these were in line pits but large majority were very small and randomly oriented. They could have been present on the rods in the as fabricated condition.
5. There were many abrasion marks and scratches from rubbing contact with the shroud. Some of these had a reddish brown color indicative of slight rusting.
6. The fusion spot welds on the Zircaloy section exhibited a corrosion pattern in rings around the weld. In some cases, the corrosion product appeared rather heavy.
7. There was isolated localized corrosion of the Zircaloy at the junction between it and the boron stainless steel where irregular double spot welds were made or where arc strikes melted off the edge.
8. There was a slight deposit on the surface of the blades which did not interfere with the inspection. The center blade had the heaviest deposit.

In addition to the blades in the vessel, an examination was made of the spare control rod which is in storage at RCPA. This rod appeared to be in satisfactory condition for service should it be required.

In conclusion, the inspection of the control rods showed no cracking of the type observed in the EBWR rods. The other conditions noted above are not considered to affect the structural adequacy of the blades.

APPENDIX C

COPY OF CONSULTANTS REPORT - ARGONNE NATIONAL LABORATORY

January 7, 1965

Mr. K. A. Dunbar, Manager
Chicago Operations Office
U. S. Atomic Energy Commission
Argonne, Illinois

Dear Mr. Dunbar:

As a result of your request of October 23, 1964, Mr. Charles Bean participated in an examination and evaluation of the Elk River Reactor control rods, and the following report has been prepared:

A scheduled inspection of the Elk River Reactor control rods was performed on November 6, 7, and 8, 1964. This inspection was made by the following:

W. G. Albert, RE	CH-AEC
D. E. Simpson, RE	CH-AEC
R. D. Wylie, Consultant	Southwest Research Institute
C. H. Bean, MET	ANL

As a result of this inspection, it was concluded that all control rods were in satisfactory condition for continued use in the reactor.

There are a total of 13 control rods in the Elk River Reactor core. These control rods consist of 2 w/o natural boron-stainless steel absorber sections with Zircaloy-2 followers and are of a cruciform design patterned after similar rods used for the 100 MW run in EBWR. The rods have 17-4 PH steel rack and pinion bottom drives with Type 304 stainless steel bayonet extensions leading up to the Zircaloy-2 follower sections. The stainless steel bayonet and the Zircaloy-2 follower sections are joined with Inconel rivets, as are the Zircaloy-2 follower and boron-stainless absorber sections.

Previous experience at ANL revealed some Inconel rivets in transition sections of the EBWR rods had failed. The cause of failure was attributed to shear stresses resulting from the differential expansion of Zircaloy-2 and boron-stainless steel, or mechanical damage to the rivet shank during cold heading operations, or a combination of both. The possibility of radiation damage resulting in a decrease in ductility of rivets seemed unlikely but could not be ruled out as a contributing

factor in their failure. Some cracks had also developed in the heat affected zone of boron-stainless steel resistance spot welds on the EBWR rods.

Individual Elk River control rods were removed from their respective locations in the core for inspection. Inspections were performed with the control rod completely submerged in water. Detailed examinations were made of all surfaces by traversing the rod vertically and viewing the surface through a borescope. The area which could be viewed effectively at any one time consisted of a 2" to 3" dia. circle. Each rod was rotated into 4 different positions to permit complete scanning of each quadrant of the cruciform. Photographs were taken of typical surface defects using a camera attachment on the borescope. A general view of each rod was also obtained with the rod fully withdrawn, scanning the surfaces with an underwater light. In several instances, particularly rod Nos. 4, 9, and 11, the top portion of the absorber section for a distance of 6" to 10" was pulled up out of the water, surface oxide film wiped off, and the boron-stainless steel surface was examined for possible defects which might have been concealed by the oxide film.

For all 13 rods inspected in the Elk River Reactor there was no evidence of any missing or damaged rivets at any of the transition sections nor any evidence of crack type defects in any of the materials examined. A light black corrosion film was noted on the boron-stainless steel absorber surfaces. This film was heaviest on those rods which were near the center of the core making it more difficult to observe weld surfaces. However, in no case could this film be considered excessive or harmful and did not begin to resemble the heavy ferric oxide coating observed on EBWR control rods. On the top surfaces of rods where the film was removed, no defects were noted and the surfaces were smooth and free from pitting. Some minor selective corrosion resembling etch bands was noted on the surface of rod No. 8. This may have been the result of cleaning or acid pickling operations during fabrication and should not be considered detrimental.

Although the Elk River control rods were patterned after the EBWR rods, several changes were made in their fabrication. The principle change was in the use of a fusion spot weld for the Zircaloy-2 follower sections of the Elk River rods instead of the resistance spot welds used in EBWR rods. These fusion spot welds were made on corrosion tested sheet material and were not corrosion tested after welding. No attempt was made to condition the welds to remove contaminated metal from the surface. In many instances, particularly at the plate edges, a second fusion weld has been superimposed on or overlaps an existing fusion weld. In nearly all cases the white oxide corrosion

film which is forming on the surface of the Zircaloy-2 fusion welds and in the heat affected zone adjacent to these welds is excessive. There is decided evidence of breakaway corrosion forming on some welds on rod No. R. The presence of oxide contamination on welds is not sufficiently severe at this time to constitute a hazard to the integrity of the control rods.

Another departure in fabrication of the Elk River rods was hot heading of the Inconel rivets in the transition sections. This should produce a desirable structure in the rivet shank but in many cases the riveting operation left severe depressions in the surface of the boron-stainless steel. In some instances the outline of the head of the riveting fixture could be seen on the plate surface. This was not detrimental to the boron-stainless steel but might have damaged the Zircaloy-2 which is sandwiched between B-SS plates at the transition sections and can not be completely examined. It is possible that the Zircaloy-2 could also have been overheated and contaminated by the hot heading operation. The Zircaloy-2 exposed at the edges of the transition section showed white breakaway corrosion product on some control rod blades. This was particularly noticeable on control rod Nos. 3 and R.

There were indications that the fabricator had difficulty forming the B-SS and holding the tolerances required for assembly of the control rods. The B-SS surfaces were generally wavy as a result of the steel being forced into alignment for spot welding. On two blades, Nos. 3 and 6, rivets were observed in the absorber section which were probably used to hold the surfaces of backed-up angles into close contact for spot welding. The irregular use of rivets in the absorber section was confirmed by examination of the spare control rod which was in storage. Rivets were used in both the absorber and follower sections of this spare rod in addition to the spot welds. Examination of this rod also confirmed the fact that the follower section had not been corrosion tested after fusion spot welding.

The presence of weld deposited metal in the fillet of some angle sections of B-SS in rod No. 5 was possibly intended to repair a crack in the steel which occurred during forming operations. There was no evidence of selective corrosion or any other detrimental effects from this repair.

Sincerely,

A. V. Crewe
Director /s/

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