ATTACHMENT 1

ANO-2 CYCLE 2 REFUELING OUTAGE

FUEL EXAMINATION RESULTS

MARCH 17, 1983

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1.0 INTRODUCTION

Arkansas Nuclear One - Unit 2 completed cycle 2 and shutdown for refueling on August 20, 1982. All 177 fuel assemblies in the core were off-loaded to the spent fuel pool by September 11, and fuel examinations were then initiated. The examinations conducted may be divided into three types: (1) leak tests, (2) shoulder gap measurements, and (3) visual inspections. The results of each type will be discussed in the following sections of this report. Then an effort will be made to correlate the fuel examination results with those obtained during the cycle 1 outage.

2.0 LEAK TESTS

The presence of a few leaking fuel rods in the core was indicated early in cycle 2 by the iodine activity levels in the primary coolant. This was reported to the Commission in reference 1. Near the end of cycle 2, AP&L estimates for the number of perforated rods ranged from 4 (based on I-131) to 14 (based on I-133). Two testing campaigns to detect the leaking assemblies by the wet sipping method were conducted. The first took place September 11-16, and concentrated on assemblies to be used in the cycle 3 core. One hundred and twenty (120) assemblies were sipped including sixty (60) Batch "D" assemblies, fifty-six (56)

Batch "C" assemblies, three (3) Batch "B" assemblies, and one (1) Batch "A" assembly. Based on the activity levels of I-131, Cs-134, and Cs-137 measured in the sipping tests, three leaking assemblies were identified. These assemblies were reconstituted and one leaking fuel rod was found in each assembly.

The second sipping campaign was conducted November 3-7, and focused on the remaining fifty-seven (57) discharged Batch "B" assemblies. Since the I-131 level had diminished due to decay, only Cs-134 and Cs-137 activities were used for leak detection. Two assemblies were identified as probably containing perforated rods. A visual examination of one of these assemblies revealed a failed peripheral rod. Based on the activity levels, an estimate was made that each bundle contained one or two leaking fuel rods.

Table I lists all of the leaking assemblies detected and gives further details of the reconstitution effort. Figures 1a and 1b present the locations of the leaking rods, and the other rods that were replaced. Also shown are the locations of two inadvertant rod interchanges that occurred during fuel assembly reconstitution.

3.0 SHOULDER GAP MEASUREMENTS

Shoulder gap is the clearance between the top of a specified fuel rod and the bottom of the upper end fitting flow plate. Measurements of this gap were made on six assemblies selected for characterization after fabrication, but before cycle 1 exposure. Remeasurement of the

gap following cycle 1 indicated that the closure rate was somewhat higher than expected, and that continued observation was in order. Accordingly, five assemblies were scheduled for gap measurements after cycle 2. Included in these five were one Batch "B" and two "C" assemblies that were in the original group of six characterized assemblies.

The measurements were made on the outside rod rows of an assembly with calibrated optical equipment mounted in the spent fuel pool. Due to fuel handling limitations, the gaps were usually measured only on two opposing faces of an assembly. The corner pins, usually poison rods, were also excluded from measurement. If a small gap size made a fuel rod visible which was in the first four rows, however, its gap could also be measured. Since the measured gaps did not agree favorably with predictions, the measurement program was expanded to include all 56 Batch "C" assemblies. Through special handling techniques, all four faces on the two characterized Batch "C" bundles were measured.

A conservative application of the available gap closure rate data to the gaps measured on some of the Batch "C" assemblies indicated that the possibility of fuel pin-to-flow plate contact existed before the end of cycle 3. A fuel assembly modification was devised and discussed with the NRC at a meeting on October 6, 1982. The material presented at that meeting was documented in our December 10, 1982, communication to the NRC (reference 2). Essentially, the modification increased the available shoulder gap by one-half (½) inch through the use of spacer shims on the corner guide tubes under the upper end fitting. Stainless

steel sleeves have been used in the upper part of the guide tubes to reduce guide tube wear. Under the initial modification procedure, these sleeves were to be pulled and new sleeves reinstalled. Difficulties in pulling the sleeves were encountered in the first few assemblies modified, so the procedure was changed to cut the flared sleeve tops off. This permitted removal of the upper end fitting and shim insertion without having to de-sleeve the assembly. Modified upper end fitting posts were then used which allowed for expansion of the upper ends of the cut sleeves.

A statistical methodology was developed to determine which Batch "C" assemblies should be modified. The acceptance criterion applied was:

> "At a 95% probability, the worst rod in the assembly will not have a gap closure at the end of cycle 3."

Thirty of the fifty-six Batch "C" assemblies were modified during the cycle 2 outage. In the final statistical analysis, six of the thirty assemblies would have been acceptable without modification. Table II lists the assemblies that were modified. Following the modification, before cycle 3 exposure, all of the modified assemblies have shoulder gaps greater than 0.9 inches.

4.0 VISUAL INSPECTION

All sixty Batch "B" fuel assemblies and a combination of twenty-five Batch "C" and "D" assemblies were visually examined in the September

through November, 1982, period. The fuel examinations were performed to evaluate fuel assembly appearance and overall structural integrity, fuel and poison rod condition, spacer grid wear condition, handling damage, upper end fitting spring and post wear, and crud deposition. Table III lists the assemblies that were examined.

On October 13, prior to sealing the reactor vessel, the results of twenty-one visuals were verbally communicated to the NRC. These examinations included the three leaking assemblies which were reconstituted, assemblies selected because of fuel handling difficulties encountered, and assemblies located adjacent to those on which damage had been noted at EOC1. No serious damage was found on the non-leaking assemblies.

The final results of all 85 examinations indicated that 75 of the assemblies were in good condition and contained no anomalous conditions on either the fuel rods, poison rods, or remaining structural components. Observations on the other ten assemblies included: perforated fuel rods, one perforated poison rod, torn grids, non-uniform shoulder gap spacing, and debris lodged within an assembly. The ten assemblies and the anomalies noted are presented in Table IV. Of these ten assemblies, six are Batch "B" assemblies which are not included in the cycle 3 core. One, AKC-401, was reconstituted and two, AKD-039 and AKD-040, had shoulder gap disparities which do not pose a cycle 3 problem. The remaining assembly, AKC-303, had only minor damage, a missing tab, on the south face of grid 2. (The third from the bottom).

5.0 COMPARISON OF CYCLES 1 AND 2 FUEL EXAMINATION RESULTS

During the cycle 1 outage, in April 1981, all 177 fuel assemblies were wet sipped and seven (7) leakers identified. A total of fifteen (15) perforated rods were found in the five (5) assemblies that were reconstituted; and three (3) more were believed present in the remaining two assemblies. In the case of two of the assemblies, AKC-203 and AKB-045, it was concluded that the perforations were due to fretting induced by foreign material trapped within the bottom Inconel grid. The cause of the remaining failures could not be established. These results were reported in reference 3.

As previously discussed in section 2.0 of this report, five (5) leaking assemblies were identified when all of the cycle 2 core was wet sipped. Table I presented the assemblies in which three (3) leaking rods were found and those in which one or two were suspected, for a total of five (5) to seven (7) perforated fuel rods. It should be noted from Table I that the seven (7) rods replaced in assembly AKC-401 showed debris related wear within the bottom of the Inconel grid; and that the perforated rod observed in assembly AKB-032 could be associated with the perimeter grid strip damage found on that assembly. A perforated poison rod was found by visual examination of assembly AKB-013.

The core loadings for cycle 1 and cycle 2 are shown in Figures 2 and 3, respectively. The assemblies which were found to be leaking at the end of each cycle are identified by heavy outlines. In the case of cycle 1, two of the assemblies, AKC-308 and AKC-203, were located on the

periphery against the core shroud. However, the reason for failure of AKC-203, fretting from material trapped by the bottom grid, has already been noted. In addition, the failed rods in assembly AKC-308 were distributed throughout the assembly and could not be associated with shroud wear with the possible exception of a corner poison rod which had a perforation at grid 8. Furthermore, none of the leaking assemblies in cycle 2 were located on the core periphery. Therefore, although some grid to shroud wear has been observed, it has not been a significant cause of perforated rods. Although there were three out of seven leakers in cycle 1 in adjoining locations, none of the cycle 2 leakers shared a common face or even a corner. In the first two cycles, then, assembly location has not been a major factor in causing fuel rod perforations.

The total of leaking assemblies by fuel batch for each cycle are:

Cycle 1: 2 Batch "A", 3 Batch "B", 2 Batch "C"

Cycle 2: 2 Batch "C", 2 Batch "B", 1 Batch "D"

It appears that the fuel batch has not been a factor, so far, in determining which rods will develop leaks.

While the cycle 1 refueling core shuffle was being conducted, fifteen (15) visual inspections were performed on 7 Batch "A", 4 Batch "B", and 4 Batch "C" assemblies. The results, were communicated to the NRC by telephone on May 12, 1981. After the reactor vessel had been closed, sixty (60) discharged Batch "A" assemblies were visually inspected.

Significant grid strap damage was found on three assemblies, AKA-042, AKA-106, and AKA-109; and some extremely minor grid damage was found on two assemblies AKA-023 and AKA-041. Based on the bright metal at the torn interfaces, it was concluded that the damage resulted from grid to grid interaction with adjacent fuel assemblies following the operation of the first cycle. These results were reported in reference 4. The measures that AP&L then decided to implement to prevent similar damage were described in reference 3.

A concern still existed over what grid strap damage might have occurred on the unexamined assemblies and gone into cycle 2 core. As Table IV shows, grid damage was detected at EOC 2 on five assemblies: AKB-032, AKB-T04, AKB-049, AKB-052, and AKC-303. In the case of the last two assemblies, the damage was minor. Only one of the assemblies, AKB-032, contained a leaking fuel rod. No bright metal surfaces were detected at the tears and, due to the generally corroded condition, it was believed the damage probably took place during the cycle 1 outage. All of the assemblies with grid damage, both major and minor; are shown on the cycle 1 core map presented in Figure 2. The faces on which the damage was found are also indicated. In one case, between assemblies AKB-032 and AKA-109, damaged grid to damaged grid contact can be observed. As noted in Table I, the grid strip damage to AKB-032 may have contributed to a failed rod in this assembly during cycle 2. In the eight other cases of grid damage shown in Figure 2, six of the facing assemblies were visually inspected either after cycle 1 or cycle

2, and no damage was found. In general, then, damage to the grid of one assembly does not usually mean that the grid of the facing assembly also incurred damage.

The increased awareness of the possibility of causing grid damage while handling the assemblies and the consequent caution of the operators appear to have resulted in a cycle 2 offload without incurring any new damage. Modifications were made to the refueling machine after the offload, but before the core was reloaded for cycle 3. These modifications should further assist in preventing future damage by improving the overload trip response.

6.0 CONCLUSIONS

Twelve (12) leaking assemblies have been found in two cycles of operation. In two of these cases, the cause appeared to be fretting from foreign material trapped by the bottom grid. In a third case, seven of the rods replaced in a reconstitution effort showed evidence of wear from foreign materials trapped by the bottom grid. In a fourth case, grid damage may have contributed to a rod perforation. No explanation has been found for the remaining eight cases. Neither core location nor fuel batch appear to have been a significant factor in causing rod perforations.

Although grid damage probably results from grid to neighboring assembly grid interaction, both grids have not usually sustained damage.

Analysis of the grid damaged assemblies locations shows that neither core location or proximity to the shroud have been a factor in causing the damage.

The corroded metal condition of the grid strip tears found at the end of cycle 2 indicates that the damage probably occurred during the cycle 1 refueling. Therefore, damage to the grids during the cycle 2 offloading was largely avoided.

REFERENCES

1 D.C. Trimble to Robert A. Clark, Docket No. 50-368, Letter No. 2CAN118106, dated November 25, 1981.

2. J.R. Marshall to Robert A. Clark, Docket No. 50-368, Letter No. 2CAN128207, dated December 10, 1982.

3. J.R. Marshall to Robert A. Clark, Docket No. 50-368, Letter No. 2CAN058209, dated June 2, 1982.

4. D.C. Trimble to Robert A. Clark, Docket No. 50-368, Letter No. 2CAN068104, dated June 4, 1981.

TABLE I

LEAKING ASSEMBLIES AND RECONSTITUTION ACTIONS

ASSEMBLY IDENTIFICATION	PERFORATED RODS	REPLACED RODS[1]	REMARKS
AKD-120	1	2	No visual anomalies observed. In reconstitution effort, the leaking interior rod separated and a new cage was required. Two rods were inadvertently interchanged in position with two other rods.
AKC-212	1	8	No visual anomalies observed. Seven rods removed for diagnostic samples.
AKC-401	1	10	Rod severed between Grids 7 and 8.[2] Found on visual inspection. Leaking rod replaced with SS filled Zircaloy rod. Seven of replaced rods showed evidence of debris-related O.D. wear in the region below the bottom Inconel Grid.
AKB-032	1 or 2 Estimated	Not Reconstituted	Visual detection of one failed rod. Damage to perimeter strip of Grid 4 may have contributed to rod perforation.
AKB-029	1 or 2 Estimated	Not Reconstituted	No visual anomalies observed.

[1]Replacement fuel rods from AKA-005.

[2]Spacer grids are numbered from the bottom to the top of the assembly with the Inconel Grid designated as "0".

TABLE II

ASSEMBLIES MODIFIED TO INCREASE SHOULDER GAP

AKC 101[4]	AKC 206	AKC 312
AKC 104	AKC 207	AKC 401[1,2]
AKC 105	AKC 208	AKC 403[1]
AKC 106[2]	AKC 210[5]	AKC 406[1]
AKC 107	AKC 211	AKC 410
AKC 108[2]	AKC 212[2]	AKC 411[1]
AKC 201	AKC 302	AKC 412
AKC 202[1]	AKC 309	AKC 415[4]
AKC 203	AKC 310	AKC 416
AKC 204[3]	AKC 311	AKC 504[1]

[1]Shoulder gap would have been acceptable in final statistical analysis.

[2]Initial procedure of pulling and replacing stainless steel sleeves used.

[3]Final procedure followed, cutting off sleeve flares, but center sleeve then pulled and not replaced. No CEA or detector to be inserted for cycle 3.

[4]As in 3, but the center tube was resleeved, and a CEA used in cycle 3.

[5]The north-east (near S/N) corner post modified to facilitate insertion.

TABLE III

ANO-2 FUEL ASSEMBLIES EXAMINED AT EOC-2

(Extracted from Combustion Engineering, Inc., System Integrity Services Report TR-SIS-030; Dated February 3, 1983)

ASSEMBLY SERIAL NUMBER	NUMBER OF FACES EXAMINED	EXAMINATION PURPOSE
All 60 Batch B Assemblies	4	General Fuel Inspection
AKD022	4	Examined for possible handling damage
AKD004	4	
AKD035	4	
AKD006	4	
AKD003	4	
AKD029	4	
AKD109	4	
AKD105	4	
AKD114	4	
AKD112	4	
AKD119	4	
AKC311	4	
AKC302	4	
AKC103	4	
AKC303	4	
AKD120	4	Failed Fuel Exam
AKC212	4	
AKC401	4	
AKD039	4	DOE sponsored R&D Program
AKD040	4	
AKD037	1	R&D Program investigating assembly grid/core shroud interaction
AKD031	1	
AKD016	1	
AKD006	1	
AKD025	1	

TABLE IV
VISUAL INSPECTION OBSERVATION

AKB032
A perforated fuel rod and perimeter strip grid damage were observed on the South[1] face of this assembly. The peripheral fuel rod was number 4[2], and it contained a mature hydride blister ~ 2-3 inches above Grid #3.[3] Perimeter strip damage was observed on the bottom of Grid #4 between Rods 3 and 5. The perimeter strip tab between Rods 3 and 4 was torn and folded under toward Fuel Rod 4. The tab between Rods 4 and 5 was also folded under toward the fuel rods. The damage on Grid #4 may have contributed to the perforation of Rod 4 on the same face. In addition, the location of the grid damage on AKB032 corresponds with grid damage observed on adjacent assembly AKA109 at EOC-1. Due to the oxidized appearance of the damage on AKB032 and the fact that an adjacent assembly face had damage at EOC-1, it is concluded that the damage to AKB032 was a result of handling during the EOC-1 fuel shuffle.

AKBT04
Perimeter strip grid damage was observed on the West Face at Grid 8. The torn region extended from the lower left corner of the grid to Rod 4. Approximately one-third of the perimeter strip width was missing. Little to no distortion of the grid was discernable. The torn region and fracture surface appeared crudded and oxidized indicating the damage was a result of handling during the EOC-1 fuel shuffle.

AKB049
Perimeter strip grid damage was observed on Grid 2 of the West face. The upper left corner of the perimeter strip was torn from the grid corner to Rod 2. Approximately 25% of the perimeter strip width is missing. The damaged area appears crudded and oxidized indicating the damage was a result of handling during the EOC-1 fuel shuffle.

AKB052
Perimeter strip damage was observed on the North face of Grid 9. The tab at the top of the grid between Fuel Rods 12 and 13 is missing (torn away). No other damage was observed on this grid.

AKBT03
A small piece of foreign debris was observed lodged between Rods 9 and 10 approximately 2 inches above Grid 8. The sources or type of debris could not be identified. No damage was observed as a result of the lodged debris.

AKB013
A perforated poison rod was observed in this assembly. The rod was number 16 on the South face (Southeast corner), and it was observed to be heavily hydrided approximately midway between Grids 6 and 7. The hydriding has resulted in the clad being fractured completely around the circumference of the rod. No other anomalies were detected on this rod.

AKC401

A perforated fuel rod was observed on the East face of this assembly. The peripheral fuel rod, number 8, was heavily hydrided approximately 5-1/2 inches below the centerline of Grid 8. The hydrided region extended axially approximately 3/4 to 1 inch and 360° circumferentially. The rod was completely separated into two pieces at the damaged region. No apparent cause of the rod perforation was discernable. This assembly was reconstituted and re-inserted into the core for Cycle 3 exposure.

AKD039 & AKD040

These two assemblies were examined as part of the DOE sponsored Improved Fuel Utilization Demonstration Program being conducted at ANO-2. The shoulder gaps on three (3) of the test rods in each assembly (6 rods total) were observed to be less than adjacent rods of standard design. These test rods all contain large grain size fuel pellets of either standard or annular geometry. The smallest measured shoulder gap for these six test rods was 1.455 inches. The shoulder gap of standard peripheral rods in the same area of the assembly range from 1.635 to 1.688 inches.

AKC303

Perimeter strip damage was observed on the South face of Grid 2. A tab at the top of the grid between Fuel Rods 14 and 15 is missing (torn away). No other damage was observed on this grid.

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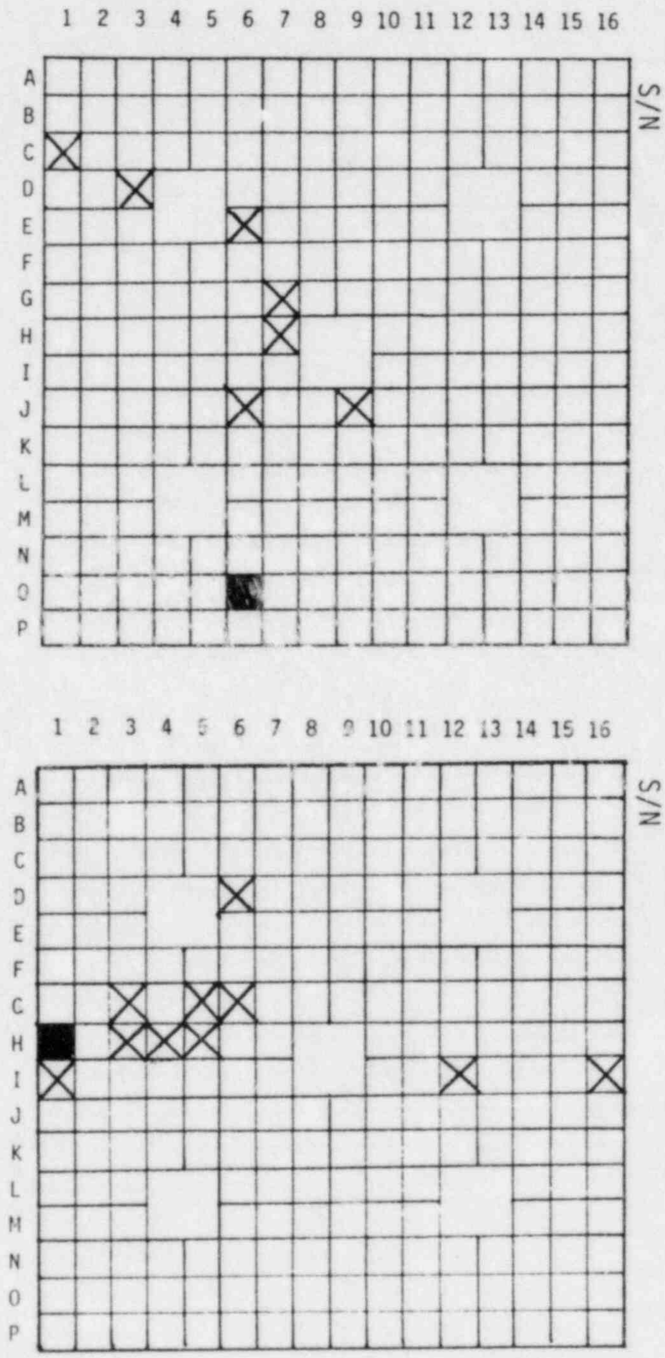
[1]The faces of each assembly are identified North, South, East or West relative to the location of the assembly serial number taken to be the Northeast corner of the upper end fitting holddown plate.

[2]Rods are numbered 1-16 from left to right across the face of the assembly.

[3]Spacer grids are numbered from the bottom to the top of the assembly with the Inconel Grid designated as Grid 0.

FIGURE 1a.

REPLACED FUEL RODS



Assembly AKC 212

Assembly AKC 401

■ Perforated Rod

⊠ Replaced Rods

FIGURE 1b.

REPLACED FUEL RODS

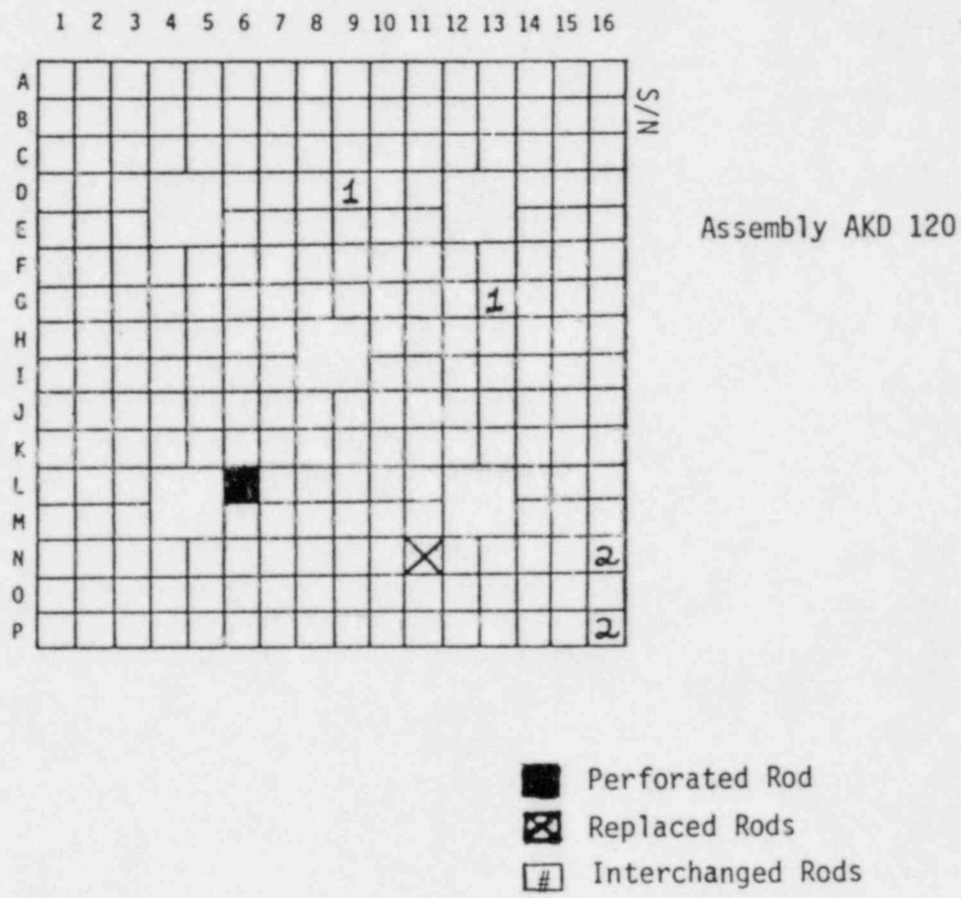


FIGURE 2

ANO-2 CORE LOADING PLAN

CYCLE 1

FUEL TRANSFER CANAL →

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
1						C409	C308 67	C311	C307 68	C411					
2				C413	C202	C106 57	B006	A044 52	B003	C103 56	C211	C412			
3			C503 66	C213	A041 45	B031	A050 33	B001	A101 34	B053	A102 46	C214	C501 69		
4		C408	C215	A006 39	B017	A048 25	B0[illegible]0	A103 C	B032	A030 26	BT06	A043 40	C204	C410	
5		C216	A021 44	B041	A047 F	B009	A015 17	BT03	A109 18	B021	A004 G	B029	A043 47	C203	
6	C407	C104 56	B043	A104 24	B011	A024 11	B023	A107 8	B049	A003 12	B035	A110 27	B002	C107 59	C404
7	C306 65	B042	A007 32	B033	A010 16	BT01	A019 3	B050	A042 4	B010	A046 19	B037	A023 39	B013	C310 70
8	C303 S01	A014 51	B007	A001 B	B020	A009 7	B026	A005 1	B027	A037 9	B048	A038 D	B045	A011 53	C305 S02
9	C312 64	BT04	A040 31	B034	A028 15	B038	A039 2	B008	A034 5	B025	A008 20	B015	A031 36	B005	C304 71
10	C414	C108 55	B039	A022 23	B051	A106 10	B028	A033 6	B024	A016 13	B036	A020 28	B012	C105 60	C401
11		C205	A026 43	B054	A018 E	B052	A012 14	B022	A036 21	B019	A017 H	BT02	A051 48	C210	
12		C416	C206	A002 38	B016	A013 22	BT05	A035 A	B014	A106 29	B018	A027 41	C201	C402	
13			C502 63	C207	A029 42	B046	A032 30	B040	A105 37	B044	A045 49	C208	C504 72		
14				C415	C209	C102 54	B004	A025 50	B047	C101 61	C212	C403			
15						C405	C302 62	C309	C301 73	C406					

Leaking Assembly EOC1

Grid Damage Found EOC1

Grid Damage Found EOC2

Side of Grid Damage

NORTH

FIGURE 3

ANO-2 CYCLE 2 CORE LOADING PLAN