NEDO-22290-A
SUPPLEMENT 2
DRF L12-00581
CLASS I
OCTOBER 1985

SAFETY EVALUATION OF THE GENERAL ELECTRIC ADVANCED LONGER LIFE CONTROL ROD ASSEMBLY

GENERAL ELECTRIC

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

July 1, 1985

Mr. J. F. Klapproth
Principal Licensing Engineer
Nuclear Technologies and Fuel Division
General Electric Company
175 Curtner Avenue
San Jose, California 95125

Dear Mr. Klapproth:

SUBJECT: ACCEPTANCE FOR REFERENCING OF LICENSING TOPICAL REPORT NEDE-22290, SUPPLEMENT 2, "SAFETY EVALUATION OF THE GENERAL ELECTRIC ADVANCED LONGER LIFE CONTROL ROD ASSEMBLY"

We have completed our review of the subject topical report submitted by the General Electric Company (GE) by letter dated February 20, 1985. We find the report to be acceptable for referencing in license applications to the extent specified and under the limitations delineated in the report and the associated NRC evaluation, which is enclosed. The evaluation defines the basis for acceptance of the report.

We do not intend to repeat our review of the matters described in the report and found acceptable when the report appears as a reference in license applications, except to assure that the material presented is applicable to the specific plant involved. Our acceptance applies only to the matters described in the report.

In accordance with procedures established in NUREG-0390, it is requested that GE publish accepted versions of this report, proprietary and non-proprietary, within three months of receipt of this letter. The accepted versions shall incorporate this letter and the enclosed evaluation between the title page and the abstract. The accepted versions shall include an -A (designating accepted) following the report identification symbol.

Should our criteria or regulations change such that our conclusions as to the acceptability of the report are invalidated, GE and/or the applicants referencing the topical report will be expected to revise and resubmit their respective documentation, or submit justification for the continued effective applicability of the topical report without revision of their respective documentation.

Sincerely,

Cecil O. Thomas

Cecil O. Thomas, Chief
Standardization and Special
Projects Branch
Division of Licensing

Enclosure:
As stated

ENCLOSURE

EVALUATION OF TOPICAL REPORT ON ADVANCED LONGER LIFE CONTROL ROD (ALLCR) ASSEMBLY (TACS 56930)

By letter dated February 20, 1985, General Electric Company presented Supplements 1 and 2 to Topical Report NEDE-22290 for staff review. This evaluation is concerned with Supplement 2 which is entitled "Safety Evaluation of the General Electric Advanced Longer Life Control Rod Assembly, NEDE-22290, Supplement 2" and is dated January 1985. The Core Performance Branch has reviewed the report and prepared the following evaluation.

1. Summary of Report

The supplement describes a variant of the Hybrid I Control Rod (HICR) Assembly which has been generically approved (See Reference 1 for a copy of approval letter). The design improvements described in the supplement are intended to extend the residence time for the control rods in the reactor. The significant design changes from the HICR are described in the report and are:

a. The addition of a hafnium absorber plate to the tip of each wing of the blade, and

b. Redesign of the velocity limiter to reduce its weight in order to compensate for the increased weight of the absorber blade.

The increase in residence time is obtained by replacing the B_4C with hafnium in that portion of the blade which is subjected to the greatest flux when the control rod is partially inserted into the core. The reduction in velocity limiter weight is required in order to minimize the impact of the design changes on rod drop and scram times.

ALLCR designs are described for BWR/2-4 D-lattice (ALLCR-D), BWR/4,5 C-lattice (ALLCR-C) and BWR/6 lattice (ALLCR-6) control blades. In addition to the major design changes described above, certain features of the BWR/6 blades (upper handle configuration and coupling release handle configuration) were incorporated into the ALLCR-D and ALLCR-C designs. These changes improve the ease of handling of the rods but do not impact safety.

In addition to a description of the ALLCR assemblies, the design bases, materials evaluation, design evaluation and safety evaluation are described. The design bases for the ALLCR rods are the same as that for the HICR rods and includes requirement for mechanical, thermal, and hydraulic compatibility with the existing rods. Nuclear performance should equal or exceed that of standard rods. The materials used in the manufacture of the ALLCR rods--including B_4C cladding materials, hafnium, sheath material and rollers--are the same as those for HICR rods.

The design evaluation of the ALLCR rods includes a mechanical evaluation of the rods, hafnium absorber plate, handles, and the new velocity limiter. The nuclear evaluation considers the reactivity worth and fluence limitations on the rods. The thermal-hydraulic evaluation considers the effect of the new hafnium plates on the performance of the rods.

The safety evaluation considers the response of the rods to off normal conditions in the core and compares that response to that for the all-B_4C rods.

2. Summary of Evaluation

The design bases for the ALLCR rods are the same as those for the HICR rods (See Reference 1) which have been reviewed and approved. We conclude that the design bases are acceptable. The materials for the ALLCR rods are the same as those approved in Reference 1 and are acceptable. The thermal expansion and irradiation growth characteristics of the hafnium rods have not changed from those of the HICR rods and are acceptable.

Extensive tests were performed on the new velocity limiter to assess its performance in combination with the ALLCR designs. Compared to the present B_4C control rod-limiter combination, the new design is less heavy for the ALLCR-D and slightly heavier for the other designs. The effect of these differences on scram and rod drop speeds has been evaluated. The results show that rod drop speeds increase slightly for the heavier rods but are still well below the design value for this quantity. With respect to scram speeds, the slight increase in weight has no effect on the scram speed for the ALLCR-6. For the ALLCR-C, the increase in scram time is a small fraction of 1 percent. The generic Technical Specification (safety analysis) value of the scram time is significantly greater than the increased value so that the small increase has no effect on safety analyses.

Analyses have been made to obtain the reactivity worth difference between the all-B_4C and ALLCR rods. The same analysis methods were used as those for the HICR rods (Reference 1). These methods were verified by comparison with experiments, including some in which hafnium rods were substituted for B_4C. The results show that the ALLCR rods had the same reactivity worth as all-B_4C rods to within the uncertainty in the calculations.

Because the reactivity worths of the ALLCRs are essentially the same as those of the control assemblies which they are to replace and because their scram speeds and rod drop speeds are only insignificantly different from the all-B_4C rods, we conclude that they may be substituted for the B_4C rods without further analysis.

The mechanical design adequacy of the ALLCR blades has been investigated by General Electric. The effect of the weight increase is negligible in view of the large margins to design limits in the blade structure. The velocity limiter has been subjected to extensive testing to confirm its ability to meet all performance and design requirements.

The surveillance program described in Reference 1 has been updated to include additional irradiations. This program, approved in Reference 1, continues to be acceptable for the ALLCRs.

3. Conclusions

Based on our review, which is described above, we conclude that Supplement 2 to Report NEDE-22290 is acceptable as a reference to the description and safety evaluation of the Advanced Longer Life Control Rod (ALLCR) Assemblies. We further conclude that the ALLCR rods may be used in BWR reactors without further analysis beyond that performed for all-B_4C rods.

General Electric has requested that the ALLCR control rod assemblies be exempted from the requirements of IE Bulletin 79-26, "Boron Loss from BWR Control Blades", except that for maintaining records of the exposure of the individual rods. (Letter from J. Klappoth, GE, to R. Lobel, NRC, May 24, 1985). Bulletin 79-26 was issued in response to the discovery of boron loss from high exposure B_4C rodlets in the control rod assemblies. The ALLCR rods have solid hafnium in the parts of the control blades subject to the highest exposure and the cladding on the remaining B_4C rodlets has been replaced by a material less vulnerable to the stress corrosion cracking which led to the B_4C loss. Further the requirrment for replacement of the blades prior to a ten percent loss in reactivity worth will remain. We therefore conclude that the ALLCR rod designs satisfy the requirements of IE Bulletin 79-26 and that individual licensees may reference this SER as a basis of demonstrating compliance with the requirements of this bulletin.

References

1. Safety Evaluation of the General Electric Hybrid I Control Rod Assembly, NEDE-22290-A, September, 1983.

CONTENTS

TABLES

*General Electric Company Proprietary Information has been deleted.

ILLUSTRATIONS

1. INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

This supplemental report describes the design and safety evaluation of General Electric's Advanced Longer Life Control Rod (ALLCR). This new control rod assembly has been designed in three distinct configurations to be compatible with General Electric's three BWR core configurations. Therefore, the appropriate configuration of the new control rod is intended to be a direct replacement for the current control rod assemblies in the General Electric BWR/2-4 D-lattice plants, BWR/4,5 C-lattice plants and BWR/6 plants. The ALLCR designs for the BWR/2-4 D-lattice, BWR/4,5 C-lattice and BWR/6 lattice are designated ALLCR-D, ALLCR-C and ALLCR-6, respectively. The ALLCR's form (i.e., envelope), fit and function are identical to those of the control rod it replaces.

The ALLCRs are designed to increase control rod assembly life and to eliminate cracking of absorber tubes containing boron carbide (B_4C). The essential differences between the new ALLCRs and the conventional all-B_4C control rod assemblies currently in use are as follows:

a. Improved B_4C absorber rod tube material to eliminate cracking during the lifetime of the control rod assembly;

b. Some B_4C absorber rods are replaced with solid hafnium absorber rods to increase blade life;

c. A hafnium absorber plate is added at the top of each wing to further increase blade lifetime and

d. A lighter weight velocity limiter is used to minimize control rod weight and maintain performance.

The essential differences between the new ALLCRs and the Hybrid I Control Rod (HICRs)[1,2] are described in preceding Items c and d.

These and other minor design differences are described in detail in this report.

1.2 SUMMARY

The design description and analyses presented in this report and in Reference 1 demonstrate that the ALLCR satisfies the performance and safety requirements for use as a direct replacement for the conventional control rod assemblies. The design basis for the ALLCR is given in Section 3.

Described in Section 4 are the physical, chemical and irradiation properties of the ALLCR materials. Set forth in Section 5 is the ALLCR design evaluation including mechanical, nuclear, thermal hydraulic performance and prototypical tests.

Contained in Section 6 are evaluations showing that scram speed, scram reactivity, linear heat generation rate (LHGR), minimum critical power ratio (MCPR) and maximum average planar linear heat generation rate (MAPLHGR) design limits are not affected when the ALLCR is used in BWR cores.

2. DESIGN DESCRIPTION

2.1 CONFIGURATION

The ALLCR configurations differ from the HICR control rod configuration (Reference 1) in the areas of the velocity limiter and the use of hafnium absorber plates. The configuration of the ALLCRs is shown in Figures 2-1 and 2-2. The new velocity limiter dimensions lie within the envelope of the previous velocity limiter and are, therefore, compatible with all the Nuclear Steam Supply System (NSSS) hardware.

The basic design differences between the ALLCR (all configurations) and the HICR are as follows:

a. A hafnium absorber plate ______________ is added to the tip of each wing (Figures 2-1 and 2-2); *

b. the B_4C absorber rods were reduced ________ in length to accommodate the _____ hafnium plate; and

c. the new lighter weight velocity limiter offsets the weight of the hafnium absorber plates.

All other features of the HICR are retained, such as the high purity Type-304 stainless steel B_4C absorber rod tubing, three full length hafnium rods at the edge of each wing (Figure 2-3), and the new pin and roller materials. Shown in Table 2-1 is a comparison of the current all-B_4C control rods, the HICRs and the ALLCRs for the three General Electric BWR core configurations.

The following subsections provide details of additional changes on each specific configuration of the ALLCR. A summary of changes is provided in Table 2-2.

*General Electric Company Proprietary Information has been deleted.

2.1.1 ALLCR-D

The additional changes made to the ALLCR-D and the reason for each are as follows:

2.1.1.1 Upper Handle Configuration

A new handle of one-piece construction similar to one-half of the BWR/4,5 and BWR/6 handles will be used in the ALLCR-D. (See comparison of Figures 2-1 and 2-2.) This change was made to improve producability of the upper handle by eliminating fabrication costs and welding operations required for the old configuration. The handle is completely compatible with all existing handling equipment and NSSS hardware.

2.1.1.2 Coupling Release Handle (Lower Handle) Configuration

The BWR/6 control rod coupling release handle design was incorporated into the ALLCR-D design. This handle provides self-centering of the tool used to release the control rod from the control rod drive (CRD). This design is compatible with all existing handling equipment and NSSS hardware.

2.1.2 ALLCR-C

An additional change made to the ALLCR-C was in the coupling release handle described in Subsection 2.1.1.2. No other changes were made for this design.

2.1.3 ALLCR-6

No other changes were made for this design.

2.1.4 Summary

All of the ALLCR configurations are directly interchangeable with the existing control rod assemblies and are compatible with existing NSSS hardware.

2.2 MATERIALS

2.2.1 Pin and Roller Material

The materials to be used for the pins and rollers will be the same as those described for the HICR in Subsection 2.2.1 of Reference 1.

2.2.2 Absorber Rod Tubing Material

The material to be used for absorber rod tubing material will be the same as the high purity Type-304 stainless steel described for the HICR (production version) in Subsection 2.2.2 of Reference 1.

2.2.3 Absorber Material

As in the production version of the HICR, three of the B_4C absorber rods per blade (12 in each control rod assembly) will be replaced with solid hafnium rods. These replacements rods are located at the three outside positions of each blade (Figure 2-3).

In addition to the three hafnium rods in each blade, a ________ plate of hafnium absorber material will be installed in the tip of each blade. The position of this absorber material is shown in Figures 2-1 and 2-2.

Table 2-1

(General Electric Company Proprietary Information)

Table 2-2

ALLCR CONFIGURATION COMPARISON

Attribute	ALLCR-D	ALLCR-C	ALLCR-6
Hafnium edge rods (3/wing)	Yes	Yes	Yes
Hafnium absorber plate (1/wing)	Yes	Yes	Yes
New velocity limiter[a]	Yes	Yes	Yes
New upper handle[b]	Yes	No[c]	No[c]
BWR/6 type uncoupling handle[d]	Yes	Yes	Yes

[a] Described in Subsection 5.1.2

[b] Described in Subsection 5.1.4

[c] Handle design same as current all-B_4C control rods

[d] Described in Subsection 5.1.5

Figure 2-1. (General Electric Company Proprietary Information)

Figure 2-2. (General Electric Company Proprietary Information)

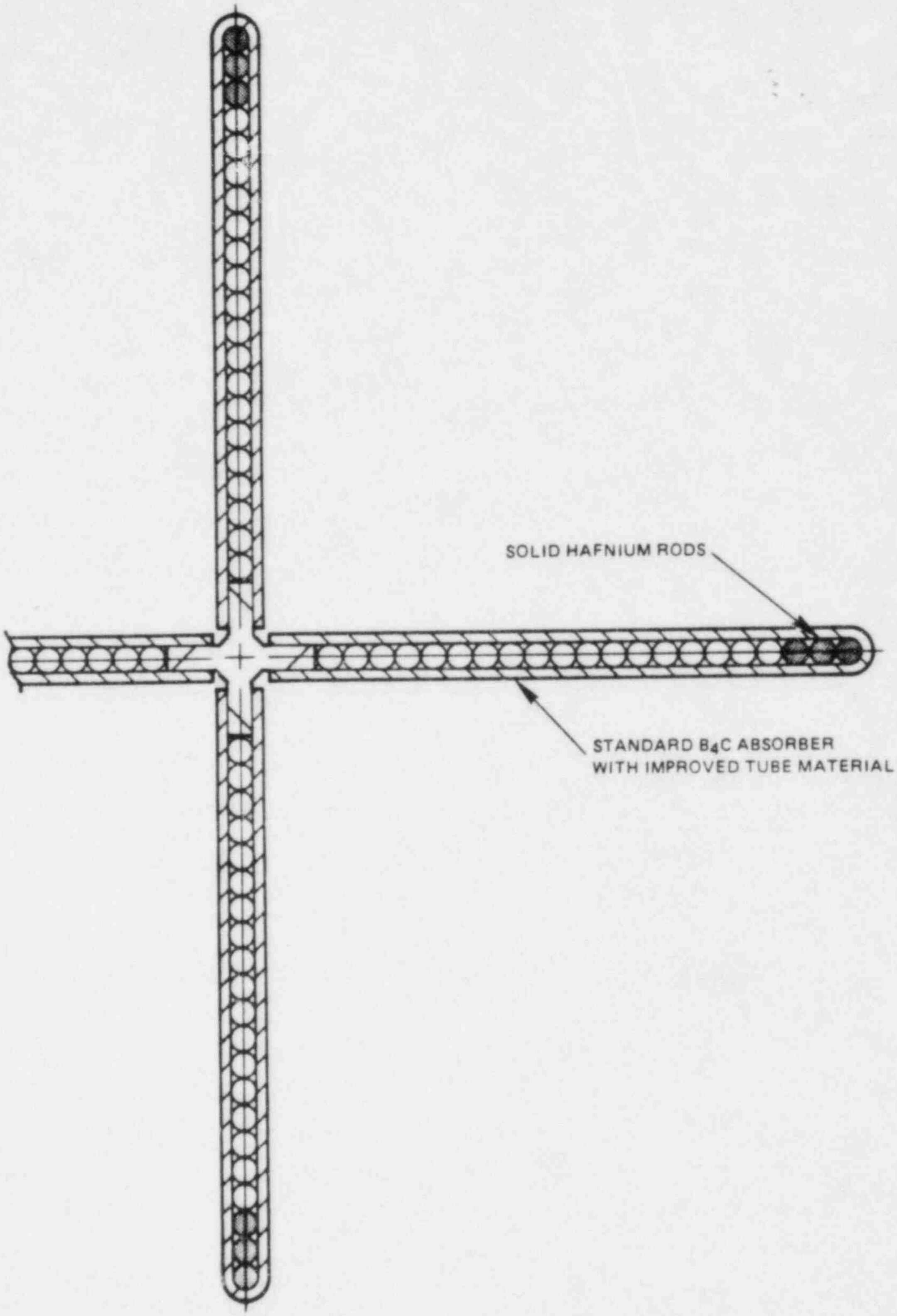

Figure 2-3. Location of Hafnium Absorber Rods for all the ALLCRs (ALLCR-D shown)

3. DESIGN BASES

The ALLCR-D, ALLCR-C and ALLCR-6 are designed to the same design basis as the HICR. The bases for the HICR design are described in Section 3 of Reference 1.

4. MATERIALS EVALUATION

The materials for the ALLCRs are the same as the materials for the production version of the HICR. The materials evaluation presented in Section 4 of Reference 1 is applicable to all ALLCR configurations.

5. DESIGN EVALUATION

5.1 MECHANICAL EVALUATION

5.1.1 Thermal Expansion and Irradiation Growth of Hafnium Rods

Subsection 5.1.1 of Reference 1 describes the thermal expansion and irradiation growth of the solid hafnium rods for the HICR. This evaluation is also applicable to the ALLCR-D, ALLCR-C, and ALLCR-6.

5.1.2 New Velocity Limiter Design

The replacement of boron carbide (B_4C) absorber material with hafnium metal results in an increase in control rod weight. To compensate for such weight increases, a new lightweight velocity limiter was incorporated into the design of the ALLCR. The new velocity limiter design bases are as follows:

a. Reduced weight without compromising structural performance.

b. Increased drag efficiency in the drop direction.

c. Maintain the same (or reduced) flow resistance in scram direction.

d. Maintain interchangeability with present design.

To meet these requirements, a configuration incorporating an optimized ________________ was designed and tested. The new velocity limiter, illustrated in Figure 5-1 is approximately ___ pounds lighter, while keeping the drop velocity below the design basis of ____ ft/sec.

All the interfacing dimensions between the velocity limiter and the guide tube and CRDs are the same for the present design. Therefore, the new velocity limiter is interchangeable with the current design.

5.1.2.1 Velocity Limiter Testing

Extensive tests were performed at room and operating temperature and pressures to confirm the drop velocity and scram performance of the new velocity limiter design, using an assembly weight which bounds the ALLCR-6 configuration. Analyses and tests have been performed to confirm the structural adequacy of the velocity limiter for all operational, accident, and handling conditions. Tests performed at operating conditions (1050 psi, 550°F) have resulted in average drop velocities of less than ____ ft/sec. By comparison, the average drop velocity for the all-B_4C control rod (______ ______________________________) is ____ ft/sec. (Reference 3) The drop velocity for the ALLCR configuration fully meets the design basis drop velocity requirements.

During this test series, the velocity limiter (and control rod) was subjected to worst case scram loads, including failed CRD buffer conditions, with no degradation of structural integrity.

5.1.3 Hafnium Absorber Plate Installation

The hafnium absorber plate is ____ ____, as shown in Figure 2-1 and 2-2. In this manner, all acceleration (and deceleration) loads on the hafnium absorber plate will be transmitted ______________________________________ ____. This arrangement has been analyzed and meets all current design requirements. ____ ______________________________ from nuclear and mechanical considerations by a reduction of fabrication tolerances.

5.1.4 Upper Handle (ALLCR-D Only)

The design changes made to the upper handle of the ALLCR-D control rod reduce the potential for residual weld stresses, without affecting the interface compatibility between the handling and storage equipment and the core internals. Therefore, the upper handle design is bounded by the current HICR design evaluation.

5.1.5 Coupling Release Handle

The BWR/6 control rod coupling release (unlatching) handle design has been applied to the ALLCR-D and ALLCR-C. This design provides both increased handle strength and unlatching tool self centering. There have been no reported problems with this handle design at foreign operating reactors in over 3 years of service.

5.1.6 Increased Control Rod Weight (ALLCR-C and ALLCR-6 Only)

Substitution of hafnium as an absorber material for boron carbide results in a net weight ______________________________ offset by the new lighter weight velocity limiter. This weight increase has been evaluated to determine its effect on the sheath design margins. Since the actual increase in loading per wing (__________ distributed over a 12-ft length) is small, compared to the sheath strength and design margins, the increased weight has no significant effect on the mechanical design adequacy of the ALLCR-C and ALLCR-6.

5.2 NUCLEAR EVALUATION

5.2.1 Reactivity Worth

The ALLCR features a hafnium plate in the top ________ of the absorber column. By placing hafnium in the tip of the control rod, which experiences the largest power peaking when partially inserted in the core, the hafnium reduces the duty on the B_4C.

Reactivity worth calculations were performed with the _____ neutron transport Monte Carlo computer code (Subsection 5.2.1 of Reference 1) to demonstrate the nuclear interchangeability of the ALLCRs with their corresponding all-B_4C designs. The ALLCRs have two distinct axial absorber zones (see Figure 5-2): Zone 1 contains the stainless steel clad B_4C rods, and Zone 2 contains the hafnium absorber plate. Both absorber zones contain the three solid hafnium edge rods.

A two-dimensional _____ geometry model was generated to represent each of the two axial absorber zones. Each geometry model represents an infinite length control rod (i.e., no axial neutron leakage). The results of the reactivity worth calculations for absorber Zone 1 are contained in Table 5-1. _____ The results of the reactivity worth calculations for absorber Zone 2 for the ALLCR-D design are contained in Table 5-2. _____. Because of the similarity in the Zone 1 results for the three ALLCR designs (Table 5-1), Zone 2 was only analyzed for the BWR/2-4 D-lattice (ALLCR-D) design and will also represent the ALLCR-C and ALLCR-6 designs.

_____.

_____

____

____

____

________________________________.

5.2.2 Experimental Results

The experimental results described in Subsection 5.2.2 of Reference 1 are applicable for benchmarking the _____ computer code used to perform the calculations described in Subsection 5.2.1.

5.2.3 Methods Qualification

The methods qualification described in Subsection 5.2.3 of Reference 1 describes the benchmark calculation performed to qualify the _____ computer code to perform the calculations presented in Subsection 5.2.1.

5.2.4 Fluence Limitations

The fluence limitations described in Subsection 5.2.4 of Reference 1 apply to the ALLCRs.

5.2.5 Summary

The current practice by General Electric in Standard Lattice Physics methods is to model the all-B_4C control rod assemblies as non-depleted. The effects of control rod depletion on core performance during any one fuel cycle are small and are corrected for by the critical eigenvalue normalization process performed for each fuel cycle. As demonstrated in Subsection 5.2, through the use of a benchmarked Monte Carlo code, a non-depleted ALLCR has direct nuclear interchangeability with a non-depleted all-B_4C control rod assembly. The ALLCR also has the same end-of-life reactivity worth reduction limit as the all-B_4C control rod assembly. As a result, the ALLCR can be used without change in the current lattice physics treatment of control rod assemblies and current design procedures.

5.3 THERMAL HYDRAULIC EVALUATION

The addition of the hafnium absorber plates at the tip of the control rod does not affect the thermal hydraulic performance of the control rod. The thermal hydraulic evaluation contained in Subsection 5.3 of Reference 1 conservatively modeled the hafnium absorber rods as a plate, bounded BWR/2-6 conditions, and is, therefore, directly applicable to the ALLCRs. Therefore, the temperatures reported in Subsection 5.3 of Reference 1 apply directly to the high fluence region of the ALLCR hafnium tip absorber plate.

5.4 SURVEILLANCE PROGRAM

The surveillance programs described in Subsection 5.4 of Reference 1 are directly applicable to the ALLCRs.

Contained in Table 5-3 is an updated listing of the surveillance programs that directly support General Electric's advanced control rod designs which include the ALLCR. The lead ALLCR assemblies will be visually examined during service and one control rod will be visually examined after it is discharged from service.

Table 5-1

(General Electric Company Proprietary Information)

I BWR/2-4 D-LATTICE, ALLCR-D

Condition	$\Delta k/k$ ($\pm 1\sigma$) Zone 1	All B_4C	Δ [$\Delta k/k$]
Cold			
Hot 0% voids			
40% voids			

II BWR/4,5 C-LATTICE - ALLCR-C

Condition	$\Delta k/k$ ($\pm 1\sigma$) Zone 1	All B_4C	Δ [$\Delta k/k$]
Cold			
Hot 0% voids			
40% voids			

III BWR/6 ALLCR-6

Condition	$\Delta k/k$ ($\pm 1\sigma$) Zone 1	All B_4C	Δ [$\Delta k/k$]
Cold			
Hot 0% voids			
40% voids			

Table 5-2

(General Electric Company Proprietary Information)

I BWR/2-4 D-LATTICE (ALLCR-D)[b]

Condition	Δk/k (± 1σ) Zone 2	All B_4C	Δ [Δk/k]
Cold			
Hot 0% voids			
40% voids			

[b]The results for the ALLCR-D bound the results for the ALLCR-C and ALLCR-6.

Table 5-3

SUMMARY OF CONTROL ROD IRRADIATION PROGRAMS

Plant	Type	Insertion	Quantity
Monticello	Pins and Rollers	2/80	2
Peach Bottom 2	Unclad Hf Test Rods	3/80	2
Millstone	Pins and Rollers	9/80	2
Quad Cities 1	High Purity Type-304 Production Rods	8/82	30
Peach Bottom 3	Hybrid Surveillance Rods	4/83	5
Additional Plant	Similar to PB 3	1985-1986	2
Monticello	Hybrid Production Rod Long-Term Surveillance	9/84	1
Additional Plant	similar to Monticello	1985-1986	1
Additional Plant	Advanced Longer Life Lead Surveillance Rods	1985	2

Figure 5-1. (General Electric Company Proprietary Information)

Figure 5-2. (General Electric Company Proprietary Information)

6. SAFETY EVALUATION

6.1 ACCIDENT EVALUATION

The mechanical and nuclear properties of the ALLCR-D, -C, and -6 do not differ from those of the all-B_4C assemblies in any manner that might be significant in a safety evaluation for normal or accident conditions.

Accordingly, the ALLCRs can be used to replace the all-B_4C control rods without additional considerations beyond those used in the safety analyses for the all-B_4C assemblies.

6.2 MECHANICAL EVALUATION

Except for the differences described in Section 2, the ALLCR-D, -C, and -6 assemblies are mechanically identical to control rod assemblies for which many reactor years of safe operating experience are available. The basic structure in the blade region, i.e., the sheath, tie rod, handle and velocity limiter attachment, has not been changed. The small increase in loads resulting from the additional of hafnium has no significant effect on the structural and functional adequacy of the control rod. Extensive analyses and testing has been performed on the new velocity limiter. These tests confirmed that the velocity limiter meets or exceeds all the design requirements, e.g., drop velocity, scram performance, envelope, and structural adequacy. The coupling between the control rod and the CRD mechanisms is identical to the all-B_4C design in all respects.

Thus, there are no significant differences between the mechanical safety analysis results for the ALLCRs and the all-B_4C control rods.

6.3 THERMAL EVALUATION

The thermal limits for the ALLCR-D, -C and -6 are bounded by the limits given for the HICR given in Section 6 of Reference 1.

6.4 REACTOR CORE RESPONSE EVALUATION

The ALLCRs have been evaluated against the all-B_4C control rods, for each of the three plant types, for comparison with LHGR, MCPR and MAPLHGR limits.

6.4.1 ALLCR-D

The ALLCR-D has slightly less weight (Table 2-1) and the same reactivity worth (Subsection 5.2.1) as the all-B_4C control rod in the D-lattice plant. Therefore, the scram speed and scram reactivity are the same. It follows that the LHGR, MCPR and MAPLHGR limits are not affected by the ALLCR-D.

6.4.2 ALLCR-C

The LHGR, MCPR and MAPLHGR limits scram time for the ALLCR-C are bounded by the all-B_4C rods for the following reasons:

a. ____
____.

b. ____
all-B_4C BWR/2-4 D-lattice control rod (Table 2-1).

c. ____

d. ____
____
________________________.

e. ____
____
____
____
____.

6.4.2.1 BWR/4,5 Performance Evaluation

For information, a scram speed evaluation was performed to quantify the effect of [redacted]

[redacted]

[redacted]

[redacted]

6.4.3 ALLCR-6

. The ALLCR-6 reactivity worth is equivalent to the all-B_4C control rod (Subsection 5.2.1). Therefore, the LHGR, MCPR and MAPLHGR limits are not affected by the application of ALLCR-6.

Table 6-1

(General Electric Company Proprietary Information)

% Insertion	Scram Time Increase (sec)		
5			
20			
50			
90			

7. REFERENCES

1. "Safety Evaluation of the General Electric Hybrid Control Rod Assembly," General Electric Company, September 1983 (NEDO-22290-A).

2. "Safety Evaluation of the General Electric Hybrid Control Rod Assembly (Supplement 1)," General Electric Company, October 1985 (NEDO-22290-A).

3. "Rod Drop Analysis for Large Boiling Water Reactors", General Electric Company, March 1972 (NEDO-10527).

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