Westinghouse Non-Proprietary Class 3

WCAP-12473-A
Addendum 1-A

BEACON
Core Monitoring and Operations Support System

Westinghouse Electric Company LLC
Nuclear Fuel Business Unit

WCAP-12473-A
Addendum 1-A

BEACON
Core Monitoring and Operations Support System (WCAP-12473-A) Addendum 1

Original Version: May 1996
Approved Version: January 2000

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Core Engineering

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Pittsburgh, Pennsylvania 15230

<u>Table of Content</u>

SECTION A

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 30, 1999

Mr. H. A. Sepp, Manager
Regulatory and Licensing Engineering
Westinghouse Electric Corporation
Post Office Box 355
Pittsburgh, PA 15230-0355

OCT 0 4 1999
H. A. SEPP, JR.

SUBJECT: ACCEPTANCE FOR REFERENCING OF LICENSING TOPICAL REPORT WCAP-12472-P-A, ADDENDUM 1, "BEACON--CORE MONITORING AND OPERATION SUPPORT SYSTEM"

Dear Mr. Sepp:

We have completed our review of the subject topical report submitted by the Westinghouse Electric Corporation on May 13, 1996. The report is acceptable for referencing in licensing applications to the extent specified and under the limitations delineated in the report and in the associated NRC safety evaluation, which is enclosed. The safety evaluation defines the basis for acceptance of the report.

We do not intend to repeat our review and acceptance of the matters described in the report 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 the Westinghouse Electric Corporation publish accepted versions of this report, proprietary and non-proprietary, including associated requests for additional information (RAIs), within 3 months of receipt of this letter. The accepted version 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.

If our criteria or regulations change so that our conclusions about the acceptability of the report are invalidated, Westinghouse and the licensees referencing the topical report will be expected to revise and resubmit their respective documentation, or to submit justification for the continued effective applicability of the topical report without revision of the respective documentation.

Sincerely,

Stephen Dembek, Chief, Section 2
Project Directorate IV and Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Enclosure: Safety Evaluation

SECTION B

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATING TO TOPICAL REPORT WCAP-12472-P-A, ADDENDUM 1

"BEACON--CORE MONITORING AND OPERATIONS SUPPORT SYSTEM"

WESTINGHOUSE ELECTRIC CORPORATION

1.0 BACKGROUND

The Best Estimate Analyzer for the Core Operations--Nuclear (BEACON) system was developed by Westinghouse to improve the operational support for pressurized-water reactors (PWRs). It is a core monitoring and support package that uses Westinghouse standard instrumentation in conjunction with an analytical methodology for on-line generation of three-dimensional power distributions. The system provides core monitoring, core measurement reduction, core analysis, and core predictions. The main Topical Report, WCAP-12472-P, "BEACON--Core Monitoring and Operations Support System," was approved by the NRC staff on February 16, 1994. Topical Report WCAP-12472-P, Addendum 1, extends the previously licensed BEACON power distribution monitoring methodology to plants containing fixed incore self-powered detectors (SPDs).

The key aspects of Topical Report WCAP-12472-P are (1) the methodology used to obtain the measured power distribution from the Westinghouse standard instrumentation system, that is, movable incore detectors, core exit thermocouples and excore detectors, and (2) the methodology for assessing uncertainties to be applied to the measured power distribution and technical specifications with BEACON as the source of the measured power distribution. Addendum 1 of WCAP-12472 describes additional features incorporated into the BEACON system:

(a) Use of fixed incore SPD, and

(b) Use of three-dimensional advanced nodal code (ANC) neutronic model code.

The current operating Westinghouse PWR plants are equipped with movable incore detectors to monitor core performance. The Babcock and Wilcox plants and the Combustion Engineering plants are typically equipped with the fixed self-powered neutron detectors. Westinghouse extends the BEACON methodology to SPD systems such that the BEACON methodology can be used in other PWR plants. Westinghouse stated that the only new aspect of the SPD BEACON methodology is how to predict the detector response, that is, the Rhodium (Rh) detector current. The Westinghouse methodology is chosen to predict the detector current or the Rh reaction rate by the licensed "PHOENIX-P" methodology. In order to qualify the Westinghouse methodology, the plant measurement data acquired from operating plants that have the SPD system were analyzed by the BEACON system and the measured and predicted detector currents were compared. Westinghouse has concluded that the BEACON SPD methodology is generally consistent with the methodology of the detector behavior observed in the operating plants.

Use of the advanced nodal code (ANC) neutronic model code in the BEACON system was a desirable option since the beginning of development of BEACON. Due to computational power limitation of the early vintage workstations, a simplified diffusion equation code was used in the existing BEACON system. Recent workstation advancements, coupled with the improvement in numerical solution techniques has permitted the use of the three-dimensional ANC neutronic model code in the BEACON system.

The primary function of the BEACON core monitoring system is the determination of the three-dimensional core power distribution (Ref. 1). In BEACON, this calculation is performed with the NRC-approved Westinghouse SPNOVA nodal method. SPNOVA employs a single effective fast group (EFG) calculation to determine the global flux solution and then uses a local correlation to determine the thermal flux and power distribution. The SPNOVA data libraries and core models are consistent with the NRC-approved Westinghouse PHOENIX/ANC design models and have been extensively benchmarked against operating reactor measurements.

2.0 TECHNICAL EVALUATION

Westinghouse submitted Addendum 1 to Topical Report WCAP-12472 in order to seek implementation of additional features (Ref. 1). The features are the SPD system and the use of the three-dimensional ANC.

The SPD system has been widely used by the nuclear industry. It is used in place of the moveable incore detectors, incore exit thermocouples and excore detectors. However, the primary function of the BEACON methodology, which is to determine the core power distribution, remains the same.

Until now, the BEACON monitoring system utilized the SPNOVA neutronic methodology, employing a one-node-per-assembly (radial) representation to achieve the rapid running times required by hardware platforms available in the late 1980s (Ref. 2). The decision to extend the BEACON monitoring capability to utilize incore detectors, enables Westinghouse to use the NRC-approved PHOENIX/ANC methodology (Ref. 3). This option was available to Westinghouse at the time of the initial BEACON approval, but inadequate computational capabilities at the time necessitated the development of simplified diffusion equation methods in order for the BEACON system to function properly. However, recent workstation advancements, coupled with improvements in numerical solution techniques of the nodal expansion method, have permitted the optional use of the ANC neutronic engine in the BEACON system while maintaining BEACON functionality.

The PHOENIX/ANC is a proven and licensed methodology that is supported by many critical experiments and plant data. The method is based on basic neutron physics and avoids (as much as possible) the use of empirical correlations and data. Another advantage of utilizing the PHOENIX/ANC methodology is that the method can be applied to a wider range of design/operating conditions.

2.1 Westinghouse Monitoring Methodology

The BEACON system determines the detector current I_p as a function of the microscopic cross section. The microscopic cross section is a function of the Rh number density and is obtained from the PHOENIX code. The instrumentation thimble flux is determined by the pin power reconstruction methodology of the ANC solution code.

The electron escape probability plays an important role in detector sensitivity. Detector sensitivity is also dependent on Rh depletion. The electron escape probability used in the BEACON system reproduces the experimental Rh depletion data from the Oconee Rh detector study (Ref. 4) as a function of Rh number density. The Rh number density is depleted by the BEACON system. Once the BEACON system predicts the power distribution and the detector currents are calculated, the power distribution inference can be performed by using the existing BEACON flux map power distribution methodology (Ref. 1).

BEACON determines the measured power distribution by monitoring the predicted power distribution and multiplying it by the ratio of measured to predicted currents. The current ratio is indicative of the flux distribution, as such. The best estimate measured power distribution is obtained by adjusting the predicted power distribution by the current ratio.

In this methodology, after each radial node is determined, the 3-D power distribution is normalized to unity. The ratio of the measured to predicted power in each node is defined as the incore calibration constant for that node. This constant is then multiplied by the node fluxes and the node peak powers to generate the adjusted values of these parameters.

2.2 Qualifications of the SPD Model and Measurement Variability

To qualify the BEACON system methodology, plant measurement data were obtained from operating plants and analyzed (Ref. 4). Data provided in tabular form in this submittal compare measured and predicted detector currents and indicate the plants involved in the qualification process, the Rh detector design features, and the history of the SPD flux maps used for the analysis. Westinghouse conducted analyses to verify that the proposed SPD model is capable of predicting the magnitude of the detector current and of determining the detector measurement variability in the operating detector system.

SPD qualification analysis procedures were used to determine the ratio of the core average predicted currents to the core averaged measured currents for all of the SPD maps. Westinghouse pointed out that the averaging process eliminates detector-to-detector variation and provides accurate evaluation of the overall SPD model. Results of the analysis showed that the SPD model is very capable of predicting the magnitude of the detector currents with acceptable accuracy.

2.3 Detector Monitoring Uncertainty

Since the BEACON monitoring system is statistical in nature, the determination of the measured peaking factor is affected by such things as the detector measurement variability, the number and layout of detectors, interpolation techniques, and any differences between predicted and true power distribution. Consequently, Westinghouse analyzed the BEACON system uncertainty using a statistical method in which the detector behavior is simulated on the basis of measurement variability statistics. The details of the simulation methodology is described in Topical Report WCAP-12472-P-A (Ref. 2).

The simulation methodology consists of defining the monitoring uncertainty for a given set of detector configurations as a function of the detector measurement variability and the fraction of inoperable detectors. A bounding uncertainty value is determined from a series of simulation analyses, leading to a bounding 95/95 upper tolerance limit in the assembly power and peak node power. The total uncertainty is obtained by a convolution of components, such as the uncertainty in the power-to-reaction rate ratio and the uncertainty in the hot rod power-to-assembly average evaluation (Ref. 1). Review of the analyses conducted by Westinghouse, indicates that the SPD methodology can be integrated with the existing BEACON system to provide power distribution monitoring capability for SPD plants. The staff agrees with the analysis and the results obtained by Westinghouse.

2.4 Plant and Cycle-Specific Applications

The BEACON power distribution accuracy is dependent on the accuracy and reliability of both the calculation models and the plant instrumentation system. The BEACON uncertainty analysis includes components that are typically constant and are considered generic, such as the model calibration and the thermocouple cross-flow, as well as plant-cycle-specific components that depend on the condition and performance of the instrumentation systems.

In response to Question 1 (Ref. 5), it is indicated that the plant-cycle-specific components will be determined on a plant-specific basis and confirmed each cycle. It is also concluded that in order to ensure that the assumptions made in the BEACON uncertainty analysis remain valid, the generic uncertainty components may require reevaluation when BEACON is applied to plant or core designs that differ sufficiently to have a significant impact on the WCAP-12472-P and the WCAP-12472-P-A, Addendum 1, data bases.

3.0 CONCLUSION

The staff has reviewed the analyses presented in WCAP-12472-P-A, Addendum 1, "BEACON--Core Monitoring and Operations Support System," and concludes that, on the basis of the application of the licensed PHOENIX-P/ANC code for the prediction of the SPD currents, the qualification analysis performed against multiple operating plant data, and observed detector behavior consistent with operating plants data, WCAP-12472-P-A, Addendum 1, is acceptable for licensing applications, subject to the pertinent restrictions imposed on WCAP-12472-P-A; WCAP-12472-P-A, Addendum 1; and the associated responses to requests for additional information provided in Reference 5.

4.0 REFERENCES

1. Letter from N. J. Liparulo to the U.S. Nuclear Regulatory Commission submitting WCAP-12472-P-A, Addendum 1, May 13, 1996.

2. Beard, C. L., Morita, T., "BEACON--Core Monitoring and Operations Support System," WCAP-12472-P-A, August 1994.

3. Nguyen, T.Q. et al, "Qualification of the PHOENIX-P/ANC Nuclear Design System for Pressurized Water Reactor Cores," WCAP-11596-P-A, June 1988.

4. Warren, H. D. et.al, "Rhodium in-core Detector Sensitivity Depletion, Cycles 2-6," EPRI-NP-3814, December 1984.

5. Letter from H.A. Sepp, Acting Manager, to the U.S. Nuclear Regulatory Commission, entitled "Responses to Request for Additional Information on WCAP-12472-P-A, Addendum 1, "BEACON--Core Monitoring and Operation Support System," June 14, 1999.

Principal Contributor: A. Attard

Date: September 30, 1999

SECTION C

Westinghouse Electric Corporation
Energy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

May 13, 1996
NSD-NRC-96-4720

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

ATTENTION: R. C. Jones, Chief
Reactor Systems Branch
Division of Systems Safety and Analysis

Subject: Transmittal of "BEACON Core Monitoring and Operation Support System (WCAP-12472-P-A) Addendum 1"

Dear Mr. Jones:

At the request of the NRC Staff, enclosed are:

(1) Fifteen (15) copies of "BEACON Core Monitoring and Operation Support System (WCAP-12472-P-A) Addendum 1" [Proprietary].

(2) Twelve (12) copies of "BEACON Core Monitoring and Operation Support System (WCAP-12473-A) Addendum 1" [Non-Proprietary].

Also enclosed are:

(1) One (1) copy of the Application for Withholding, AW-96-965 with Proprietary Information Notice and Copyright Notice,

(2) One (1) copy of Affidavit, AW-96-965.

A topical report on "BEACON Core Monitoring and Operations Support System," WCAP-12472-P-A was submitted to the NRC in April 1990 and was licensed in February 1994. The key features of this topical included:

(1) the methodology used to obtain the measured power distribution from the Westinghouse standard instrumentation system, i.e., the movable incore detectors, core exit thermocouples and excore detectors, and

(2) the methodology for assessing uncertainties to be applied to the measured power distribution and Technical Specificaiton with BEACON as the source of the measured power distribution.

Addendum 1 extends the previously licensed BEACON power distribution monitoring methodology to plants containing Self-Power Fixed Incore Detectors (SPDs). A qualification analysis was performed for the plant measurement data acquired from operating plants with SPDs and indicated that the Addendum 1 methodology was generally consistent with the detector behavior observed in the operating plants.

This methodology was previously discussed with your staff (E. Weiss/L. Kopp/H. Richings) in November 1995. Operating SPD plants with BEACON are intending to use this methodology shortly and a timely review and approval of Addendum 1 is requested.

This submittal contains Westinghouse proprietary information of trade secrets, commercial or financial information which we consider privileged or confidential pursuant to 10 CFR 9.5(4). Therefore, it is requested that the Westinghouse proprietary information attached hereto be handled on a confidential basis and be withheld from public disclosure.

Correspondence with respect to any Application for Withholding should reference AW-96-965 and should be addressed to N. J. Liparulo, Manager of Regulatory and Engineering Networks, Westinghouse Electric Corporation, P. O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

N. J. Liparulo, Manager
Regulatory & Engineering Networks

cc: K. Bohrer, NRC (12H 5)
E. Weiss, NRR/SRXB (8E 23)
L. Kopp, NRR/SRXB (8E 23)

/ssh

Westinghouse Electric Corporation **Energy Systems**

Box 355
Pittsburgh Pennsylvania 15230-0355

May 13, 1996
AW-96-965

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

ATTENTION: R. C. Jones, Chief, Reactor Systems Branch
Division of Systems Safety and Analysis

Reference: Letter from N. J. Liparulo to R. C. Jones, NSD-NRC-96-4720, dated May 13, 1996

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: Transmittal of "BEACON Core Monitoring and Operation Support System (WCAP-12472-P-A) Addendum 1"

Dear Mr. Jones:

The application for withholding is submitted by Westinghouse Electric Corporation ("Westinghouse") pursuant to the provisions of paragraph (b) (1) of Section 2.790 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10 CFR Section 2.790, Affidavit AW-96-965 accompanies this application for withholding, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-96-965 and should be addressed to the undersigned.

Very truly yours,

N. J. Liparulo, Manager
Regulatory & Engineering Networks

cc: Kevin Bohrer / NRC (12H5)

Proprietary Information Notice

Transmitted herewith are proprietary and non-proprietary versions of documents furnished to the NRC. In order to conform to the requirements of 10 CFR 2.790 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.790(b)(1).

Copyright Notice

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Nicholas J. Liparulo, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Corporation ("Westinghouse") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

N. J. Liparulo, Manager
Regulatory & Engineering Networks

Sworn to and subscribed
before me this 14th day
of May, 1996.

Notarial Seal
Denise K. Henderson, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Oct. 28, 1996
Member, Pennsylvania Association of Notaries

Denise K Henderson

Notary Public

(1) I am Manager, Regulatory & Engineering Networks, in the Nuclear Services Division, of the Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Energy Systems Business Units.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by the Westinghouse Energy Systems Business Units in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in the document, "BEACON Core Monitoring and Operation Support System (WCAP-12472-P-A) Addendum 1," for submittal to the Commission, being transmitted by Westinghouse Electric Corporation (W) letter (NSD-NRC-96-4720) and Application for Withholding Proprietary Information from Public Disclosure, Nicholas J. Liparulo, W, Manager Regulatory & Engineering Networks to the attention of R. C. Jones, Chief, Reactor Systems Branch. The proprietary information as submitted by Westinghouse Electric Corporation is an addendum to the previously licensed BEACON Topical WCAP-12472-P-A to provide additional optional features to the core monitoring system methodology.

This information is part of that which will enable Westinghouse to:

(a) Improve core monitoring methodology

(b) Assist customers to obtain license changes resulting from the improvements

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the modified BEACON system features for purposes of improving core monitoring techniques

(b) Westinghouse can use this information to further enhance their licensing position with their competitors.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar licensing programs for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC licensing requirements without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for developing the improved fuel design.

Further the deponent sayeth not.

BEACON

Core Monitoring and
Operation Support System
(WCAP-12473-A)
Addendum 1

May 1996

Toshio Morita

Approved:

A. L. Casadei, Manager
Core Engineering

R. W. Miller, Manager
Advanced Software Development

Westinghouse Electric Corporation
Commercial Nuclear Fuel Division
P.O. Box 355
Pittsburgh, PA 15230

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 BACKGROUND

A topical report on "BEACON Core Monitoring and Operations Support System," was submitted to the USNRC in April, 1990 and was approved in February, 1994.(1) The key aspects of the report are 1) the methodology used to obtain the measured power distribution from the Westinghouse standard instrumentation system, i.e., the movable incore detectors, core exit thermocouples and excore detectors, and 2) the methodology for assessing uncertainties to be applied to the measured power distribution and Technical Specifications with BEACON as the source of the measured power distribution.

The BEACON system utilized the SPNOVA neutronic methodology employing a one node per assembly (radially) representation to achieve rapid running times required by hardware platforms available in the late 1980's.

2.0 NEW FEATURES ADDED TO BEACON

The purpose of this addendum is to summarize the following additional optional features implemented into the BEACON system.

(a) Use of Fixed Incore Self-Powered Detector System

The self-powered neutron detector (SPD) has been widely used as the fixed incore detector system for power distribution monitoring, which can be used in place of the movable incore system, thermocouple and excore detector systems.

The basic principle of power distribution inference of the BEACON system is unchanged, i.e., the measured power distribution can be obtained by adjusting the predicted power distribution by the amount of difference between measured and predicted detector responses.

The only new aspect of SPD BEACON methodology is how to predict the detector response, i.e., the Rhodium detector current. The Westinghouse methodology is chosen to predict the detector current or Rh reaction rate by the licensed PHOENIX-P methodology.(2)

The benefits of this approach are:

(i) Proven and licensed PHOENIX-P/ANC methodology, which is supported by many critical experiments and plant data, is used

(ii) The method is based on basic neutron physics and avoids the use of empirical correlations and data to the maximum extent possible

(iii) The method can be applied to a wider range of design/operating conditions, including a higher Rh depletion stage

(b) Use of 3-D ANC Code

Use of ANC in place of SPNOVA in the BEACON system has been a desirable option since the beginning of the BEACON development. However, computational power of early vintage workstations necessitated the development of a simplified diffusion equation code for the required functionality of the BEACON system. Recent workstation advancements, coupled with the improvement in numerical solution technique of the nodal expansion method has permitted the optional use of the ANC neutronic engine in the BEACON system while maintaining BEACON functionality.

3.0 WESTINGHOUSE MONITORING METHODOLOGY

The BEACON system has the capability of predicting the Rh-SPD current, which is given by:

a,c

The microscopic cross section is a function of Rh number density and is obtained from the PHOENIX code. Instrumentation thimble flux is determined by the pin power reconstruction methodology of the nodal neutronic solution.

The change in detector sensitivity as a function of Rh depletion is one of the key parameters for the detector current prediction. The electron escape probability plays an important role in this sensitivity. The electron escape probability used in the BEACON system reproduces the experimental Rh depletion data from the Oconee Rh detector study (Ref. 3) as a function of Rh number density. The Rh number density is depleted by the BEACON system.

Once the predicted power distribution and detector currents are calculated, the power distribution inference can be performed by using the existing BEACON flux map power distribution methodology.[1] The monitored power distribution determined by BEACON is defined by:

a,c

[ ]

The ratio of I_M/I_P indicates the difference between the measured and predicted flux distribution. The best estimate measured power distribution is obtained by adjusting the predicted power distribution by the I_M/I_P current ratio.

a,c

[ ]

After each radial node power has been interpolated, the 3-D power distribution will be normalized to unity. The ratio of the measured to predicted power in each node is defined as the incore calibration constant for that node. This constant is then multiplied by the node fluxes and node peak powers to generate the measured values of these parameters.

4.0 QUALIFICATION OF SPD MODEL AND MEASUREMENT VARIABILITY

In order to qualify the Westinghouse methodology, the plant measurement data acquired from operating plants were analyzed by the BEACON system and the measured and predicted detector currents were compared. Table 1 shows the qualification plants, Rh detector design features and the history of the SPD flux maps used for the analysis.

The purpose of this analysis is two fold, i.e.,

(i) To verify that the proposed SPD model is capable of predicting the magnitude of the detector current

(ii) To evaluate the detector measurement variability in the operating detector system

Figure 1 shows the flow of the SPD Qualification Analysis Procedures. The ratio of the core average predicted currents to the core averaged measured currents were determined over all SPD maps. The averaging process eliminates detector to detector variation and provides accurate evaluation of the overall SPD model. The results are shown in Figure 2 and Figure 3. The detector currents are proportioned to the reactor thermal power, therefore the accuracy of the thermal power measurement directly affect these results. Considering this inherent uncertainty, it is seen that the proposed SPD model is capable of predicting the magnitude of the detector currents (item i) with acceptable accuracy.

For the detector measurement variability (item ii), comparisons were made between measurement and prediction for individual detectors. The measured and predicted currents are normalized to eliminate the difference due to the thermal power measurement uncertainty. The standard deviation of the measurement variability, σ_m, is shown in Table 2.

a, c

Thus, it is concluded that the BEACON SPD methodology is generally consistent with the detector behavior observed in the operating plants.

5.0 POWER PEAKING FACTOR MONITORING UNCERTAINTY

The uncertainty of the BEACON "measured" peaking factor is affected by

- Detector Measurement Variability
- Number and Layout of Detectors and their Availability
- Interpolation Technique
- Differences between Predicted and True Power Distribution

The BEACON monitored power distribution is inherently statistical in nature and a range of reactor conditions addressed as the above effects need to be considered for the determination of its uncertainty. For this reason, the BEACON uncertainty has been determined using a statistical simulation analysis in which the detector behavior is simulated based on measurement variability statistics. The BEACON monitored power distribution is generated from these detector responses. The simulation methodology is described in detail in the BEACON Topical Report.[1]

The monitoring uncertainty will be defined for a given detector configuration, as a function of the detector measurement variability and the fraction of inoperable detectors. The bounding uncertainty is defined from a series of simulation analyses.

The bounding 95/95 upper tolerance limit in the assembly power and peak node power can be expressed by:

a,c

[ ]

The total uncertainty can be obtained by convolution of the following components (Ref. BEACON Topical Report)[1]

a,c

[ ]

The total hot channel $F_{\Delta H}$ and local F_Q measurement uncertainty of a typical plant are shown in Figure 4 and Figure 5 respectively, as a function of the detector measurement variability and the detector availability.The methodology is applicable to any required peaking factor parameter, for example, F_{xy}.

6.0 CONCLUSION

Westinghouse has applied the licensed PHOENIX-P/ANC Code System for the prediction of the Rh Self-Powered Detector (SPD) currents. The qualification analysis has been performed for the plant measurement data acquired from multiple operating plants. The results indicated the proposed methodology is consistent with the detector behavior observed in the operating plants.

The qualified SPD methodology has been integrated with the existing BEACON System to provide the power distribution monitoring capability for SPD plants.

In conjunction with the addition of the SPD methodology, an option to use the ANC neutronic model instead of the SPNOVA has been added.

REFERENCES

1. Beard, C. L., Morita, T., "BEACON -- Core Monitoring and Operations Support System," WCAP-12473-A, August 1994.

2. Nguyen, T. Q. et al, "Qualification of the PHOENIX-P/ANC Nuclear Design System for Pressurized Water Reactor Cores," WCAP-11597-A, June 1988.

3. Warren, H. D. et al, "Rhodium In-Core Detector Sensitivity Depletion, Cycles 2-6," EPRI-NP-3814, December 1984.

Table 1

SPD Measurement Data for BEACON Qualification

Plant ID	Maker of Reactor	# of Fuel Assy	Detector Configuration	Cycle	Age of Detector at BOC	# of SPD MAPS Analyzed	Max BU GWD/MTU
Plant A	B&W	177	57 x 7 12.5 cm	7	2 Cy	24	14.0
				8	3 Cy	24	15.9
				9	Fresh	23	19.5
				10	1 Cy	8	6.4
Plant B	CE	217	45 x 4 40 cm	12	Fresh	27	12.3
				13	1 Cy	14	4.6

N x N and L denotes M Detector Strings: each made of N Detectors of L cm length

Table 2

Statistics of $\left(\frac{I_p^N(I,J,K)}{I_m^N(I,J,K)} = 1 \right)$ Standard Deviation in Percent

Plant	Cycle	Detector Length (cm)	Age of Detector at BOC	# of Data Points	Measurement Variably σ_m

a,b, c

Figure 1

SPD QUALIFICATION ANALYSIS PROCEDURE

a,c

4849e-c3.fmk(960516):50

Figure 2

Core Ave. Detector Current
Ratio of Prediction to Measurement
Plant A through Cy 10

a, b, c

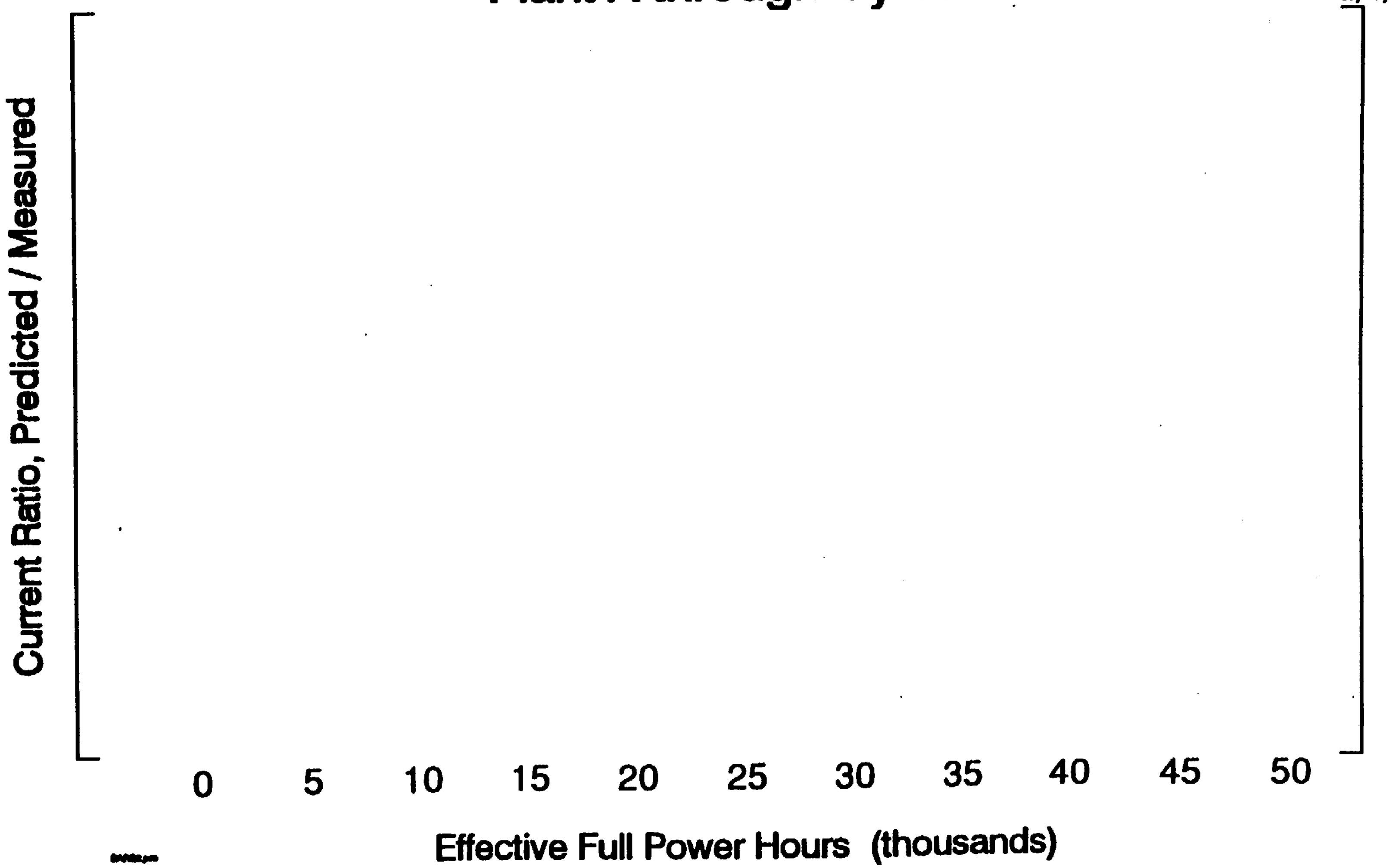


Figure 3

Plant B
Core Ave. Detector Current
Ratio of Prediction to Measurement

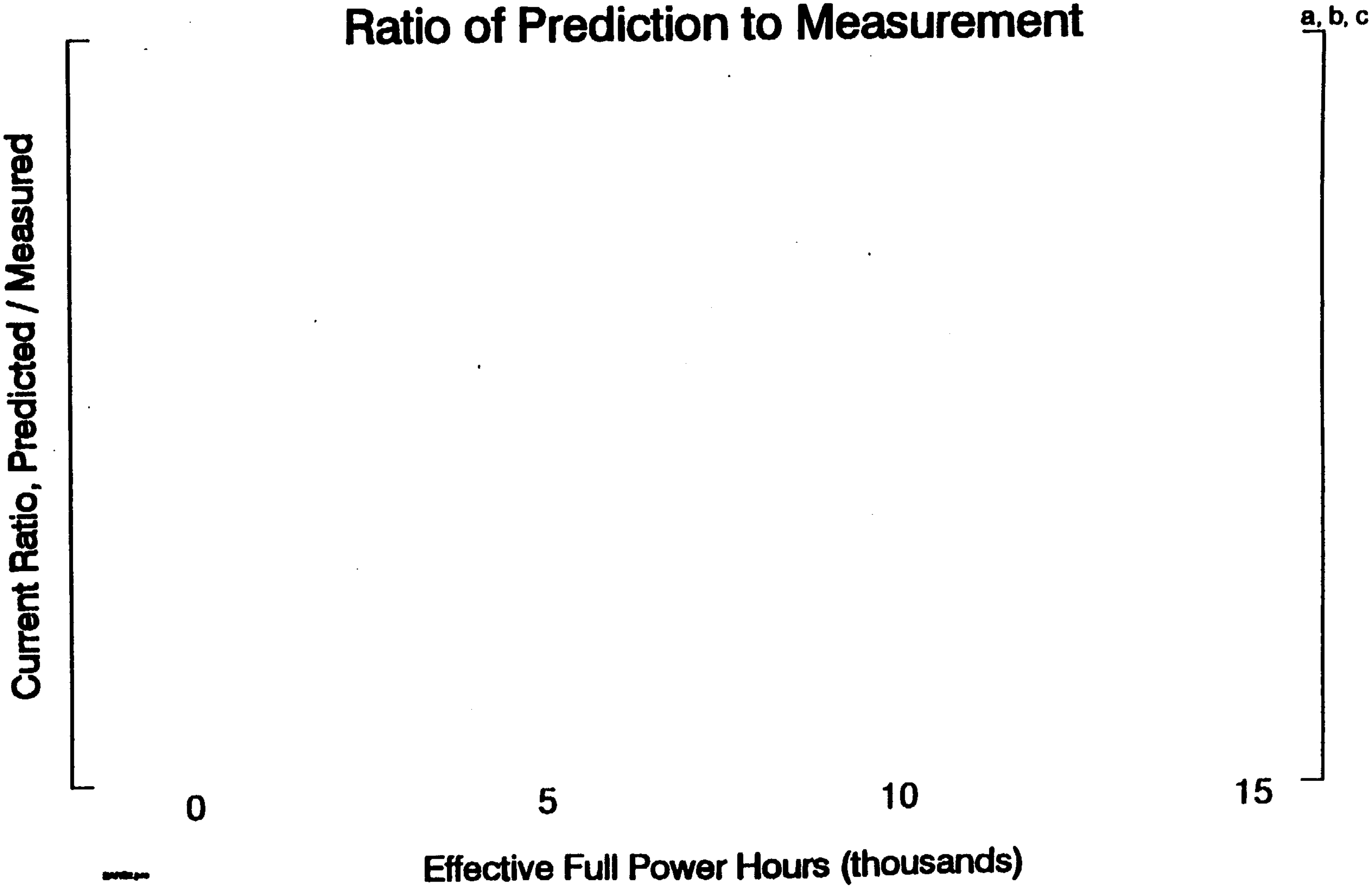


Figure 4

$F_{\Delta H}$ Uncertainty vs SPD Variability at different levels of detector loss

a, c

95/95 Upper Tolerance Limit (%)

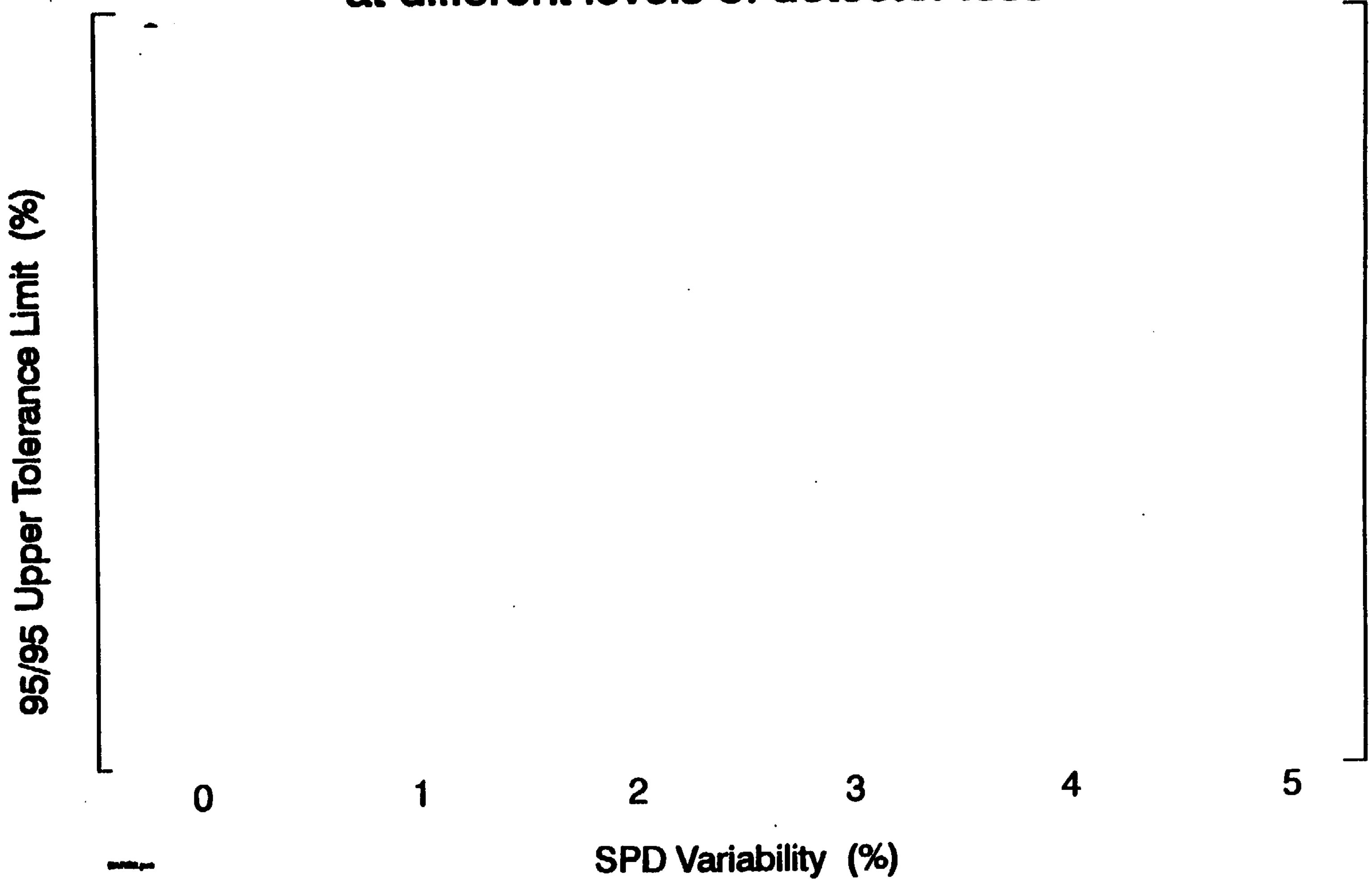
0 1 2 3 4 5

SPD Variability (%)

Figure 5

F_Q Uncertainty vs SPD Variability at different levels of detector loss

a, c



SECTION D

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 18, 1999

Mr. Henry A. Sepp, Manager
Regulatory and Licensing Engineering
Westinghouse Electric Corporation
Mail Stop ECE 4-07A
Post Office Box 355
Pittsburgh, Pennsylvania 15230-0355

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION FOR WESTINGHOUSE TOPICAL REPORT WCAP-12472-P-A, ADDENDUM 1, "BEACON CORE MONITORING AND OPERATING SUPPORT SYSTEM" (TAC No. MA3494)

Dear Mr. Sepp:

By letter dated May 13, 1996, Westinghouse submitted topical report WCAP-12472-P-A, Addendum 1 for NRC review. The staff has reviewed the report and determined a need for additional information. The enclosure to this letter identifies the information required. Please address your response to the NRC Document Control Desk.

If you wish to meet with the staff to accelerate the information transfer, the staff would welcome such a meeting at a mutually convenient time. If you have any questions on this matter, I may be contacted by phone, 301/415-2832, or by e-mail, pxw@nrc.gov.

Sincerely,

Peter C. Wen

Peter C. Wen, Project Manager
Generic Issues and Environmental
Projects Branch
Office of Nuclear Reactor Regulation

Enclosure: Questions on topical report
WCAP-12472-P-A, Addendum 1

cc: See next page

Request for Additional Information for the Westinghouse BEACON Topical Report, WCAP-12472-P-A, Addendum 1.

1. Topical Report WCAP-12472-P-A, Addendum 1 extends the previously licensed BEACON power distribution monitoring methodology to plants containing self-power fixed incore detectors (SPD). The approved Topical Report WCAP-12472-P-A includes detailed Technical Specifications as discussed in Section 7 of the report. However, the Technical Specifications listed in Section 7 is based on the Westinghouse Standard Technical Specification (STS) Rev.5. Please provide the typical BEACON Technical Specifications for plants containing self-power fixed incore detectors that is based on Babcock and Wilcox plants (reference to NUREG-1430) or Combustion Engineering plants (reference to NUREG-1432).

2. Are the detector uncertainties, limits and restrictions for the fixed incores the same as those for the movable incore detector system?

3. The criteria for the movable incore neutron detectors, with BEACON operable, which are presented in the example of WCAP-12472 COLR Section 2.5, require at least 75-percent available at beginning of cycle, and a minimum of 50-percent at any time afterward, with a minimum of two per quadrant. Discuss the appropriate criteria for the self-power fixed incore detectors. The requirements should be included in the proposed Technical Specifications.

4. How are failed self-power fixed incore detectors identified? How will it be assumed in the BEACON analysis?

5. The typical fixed incore detector assemblies are to be top mounted and located within inches of the Control Rod Drive Mechanism coil stacks. A concern was raised that the small fixed incore detector signals may be affected by the potentially large electromagnetic field generated by the Control Rod Drive Mechanism coils. The Rod Position Indication Detector coils is also a potential source of electromagnetic interference. Please provide appropriate recommendations to address this concern.

6. It is the staff understanding that SPDs are required to be operable all the time, instead of part-time as in the Westinghouse case. What is the difference in the operability requirement between the present system (movable incore detector system) and the proposed system (fixed incore detector system)?

7. Will the excores/thermocouple system still be used as backup system on Westinghouse plants and non-Westinghouse Plants for incore monitoring?

8. WCAP-12472-P-A contains information pertaining to the detector system description and qualification for the movable incore detector system. Please provide similar information for the fixed incore detector system.

ENCLOSURE

cc:

Mr. Nicholas Liparulo, Manager
Equipment Design and Regulatory Engineering
Westinghouse Electric Corporation
Mail Stop ECE 4-15
P.O. Box 355
Pittsburgh, PA 15230-0355

Mr. Jack Bastin, Director
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Pittsburgh, PA 15230-0355

SECTION E

Westinghouse Electric Company LLC

Box 355
Pittsburgh Pennsylvania 15230-0355

June 14, 1999
NSD-NRC-99-5835

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Attention: J. S. Wermiel, Chief
Reactor Systems Branch
Division of Systems Safety and Analysis

Subject: Responses to Request for Additional Information on WCAP-12472-P-A Addendum 1, "BEACON Core Monitoring and Operation Support System"

Reference: (1) Letter from P. C. Wen (NRC) to H. A. Sepp (Westinghouse), Request for Additional Information for Westinghouse Topical Report WCAP-12472-P-A, Addendum 1, "BEACON Core Monitoring and Operation Support System" (TAC No. MA3494), March 18, 1999

Dear Mr. Wermiel:

Enclosed are copies of the Proprietary and Non-Proprietary versions of the Westinghouse responses to additional information requested in Reference 1.

Also enclosed are:

1. One (1) copy of the Application for Withholding, AW-99-1340 with Proprietary Information Notice and Copyright Notice.

2. One (1) copy of Affidavit, AW-99-1340.

This submittal contains Westinghouse proprietary information of trade secrets, commercial or financial information which we consider privileged or confidential pursuant to 10 CFR 9.17(a)(4). Therefore, it is requested that the Westinghouse proprietary information attached hereto be handled on a confidential basis and be withheld from public disclosure.

This material is for your internal use only and may be used solely for the purpose for which it is submitted. It should not be otherwise used, disclosed, duplicated, or disseminated, in whole or in part, to any other person or organization outside the Office of Nuclear Reactor Regulation without the expressed prior written approval of Westinghouse.

Correspondence with respect to any Application for Withholding should reference AW-99-1340 and should be addressed to H. A. Sepp, Acting Manager Westinghouse Quality, Westinghouse Electric Company LLC, P. O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

H. A. Sepp, Acting Manager
Westinghouse Quality

cc: P. C. Wen, NRR/DRIP/RGEB (10H5)

/cad

Westinghouse Electric Company LLC

Box 355
Pittsburgh Pennsylvania 15230-0355

June 14, 1999
AW-99-1340

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Attention: J. S. Wermiel, Chief, Reactor Systems Branch
Division of Systems Safety and Analysis

Reference: Letter from H. A. Sepp to J. S. Wermiel, NSD-NRC-99-5835, dated June 14, 1999

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: Responses to Request for Additional Information on WCAP-12472-P-A Addendum 1, "BEACON Core Monitoring and Operation Support System" [Proprietary]

Dear Mr. Wermiel:

The application for withholding is submitted by Westinghouse Electric Company LLC, a Delaware limited liability company ("Westinghouse"), pursuant to the provisions of paragraph (b)(1) of Section 2.790 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10 CFR Section 2.790, Affidavit AW-99-1340 accompanies this application for withholding, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-99-1340 and should be addressed to the undersigned.

Very truly yours,

H. A. Sepp, Acting Manager
Westinghouse Quality

cc: T. Carter, NRR/DISP/ (5E7)

Proprietary Information Notice

Transmitted herewith are proprietary and non-proprietary versions of documents furnished to the NRC. In order to conform to the requirements of 10 CFR 2.790 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.790(b)(1).

Copyright Notice

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Henry A. Sepp, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC, a Delaware limited liability company ("Westinghouse"), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Henry A. Sepp

Henry A. Sepp, Acting Manager
Westinghouse Quality

Sworn to and subscribed
before me this 14th day
of June, 1999.

Notarial Seal
Janet A. Schwab, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires May 22, 2000
Member, Pennsylvania Association of Notaries

Janet A. Schwab

Notary Public

JANET A. SCHWAB
COMMONWEALTH OF PENNSYLVANIA
NOTARY PUBLIC

(1) I am Acting Manager, Westinghouse Quality, in the Nuclear Services Division, of the Westinghouse Electric Company LLC, a Delaware limited liability company ("Westinghouse"), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Electric Company LLC.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by the Westinghouse Electric Company LLC in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in Westinghouse Electric Company LLC letter (NSD-NRC-99-5835) and Application for Withholding Proprietary Information from Public Disclosure, H. A. Sepp, Westinghouse, Acting Manager Westinghouse Quality to the attention of J. S. Wermiel, Chief, Reactor Systems Branch. The proprietary information as submitted by Westinghouse Electric Company LLC is in response to questions on WCAP-12472-P-A Addendum 1, "BEACON Core Monitoring and Operation Support System."

This information is part of that which will enable Westinghouse to:

(a) Improve core monitoring methodology

(b) Assist customers to obtain license changes resulting from the improvements

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of the information to its customers for purposes of improving core monitoring techniques

(b) Westinghouse can use this information to further enhance their licensing position with their competitors

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar licensing services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for developing the enclosed information.

Further the deponent sayeth not.

Attachment

Responses to NRC Request for Additional Information for WCAP-10472-P-A, Addendum 1

Question 1

Topical Report WCAP-12472-P-A. Addendum 1 extends the previously licensed BEACON power distribution monitoring methodology to plants containing self-powered fixed incore detectors (SPD). The approved Topical Report WCAP-12472-P-A includes detailed Technical Specifications as discussed in Section 7 of the report. However, the Technical Specifications listed in Section 7 is based on the Westinghouse Standard Technical Specification (STS) Rev. 5. Please provide the typical BEACON Technical Specifications for plants containing self-powered fixed incore detectors that is based on Babcock and Wilcox plants (reference to NUREG-1430) or Combustion Engineering plants (reference to NUREG-1432).

Response

The use of SPD to provide continuous core power distribution measurement input to the BEACON System eliminates the need to use core exit thermocouple, excore detector, and incore movable detector inputs in the BEACON core monitoring process. Each vendor has power distribution Technical Specifications that require surveillance of parameters related to hot rod power and local power density. BEACON can easily provide any required surveillance of these limits. There is no need to change the actual power distribution related Technical Specifications requirements if the BEACON System is used at Babcock and Wilcox and Combustion Engineering plants. It will be necessary, however, to include a BEACON Operability specification in the Technical Requirements Manual associated with either the NUREG-1430 or NUREG-1432 format Technical Specifications. This TR specification will address the minimum number and distribution, as applicable, of plant sensor inputs required for BEACON to properly monitor the core power distribution. The minimum number and distribution incore detectors required to insure that the core peaking factor measurement uncertainties remain bounded by the values assumed in the reactor design limits will be ascertained for the plant specific detector configuration as described in Section 5.0 of Addendum 1 to WCAP-12472-P-A. A sample TR addressing the BEACON System operability requirements is contained in Exhibit A of this response. Note that the name "BEACON System" is replaced by the term "Power Distribution Monitoring System" to avoid using a commercial product name in the Technical Specification. Any Technical Specification format changes required to more easily allow the use of the continuous core monitoring capabilities of the BEACON System at B&W or CE design plants will be handled on a plant specific basis.

Question 2

Are the detector uncertainties, limits and restrictions for the fixed incores the same as those for the movable incore detector system?

Response

The basic concepts and methodologies used for determining the detector uncertainties and limitations are the same between a BEACON system for a typical Westinghouse plant and a plant that is using

SPDs. However, since the basic hardware is different, the actual uncertainties, limits and restrictions associated with fixed incore detectors are different from the corresponding values associated with the use of the incore movable detectors. The prime purpose of the BEACON system is to continuously measure the core peaking factors with high accuracy. In the standard Westinghouse BEACON plant, the incore movable detectors provide periodic (180 EFPD) calibration input to the BEACON System with thermocouple and excore detector readings providing data for continuous power distribution monitoring. The plant specific analysis used to determine the uncertainties is this measurement are described in Section 5 of WCAP-12472-P-A. The fixed incore detector functionality replaces the functionality of the core exit thermocouples, excore detector axial power shape information, and periodic incore movable detector inputs used by the BEACON System continuous monitoring process in Westinghouse design plants. The fixed incore detector uncertainties are analyzed for a specific plant detector configuration using the methodology described in Section 5.0 of Addendum 1 to WCAP-12472-P-A.

Generally speaking, the more fixed incore detectors that are installed, and the higher each detector's measurement accuracy is (smaller measurement variability), the smaller the measured core power peaking factor uncertainty becomes. As described in the response to Question 8, the SPD detector design and layout are different for the different NSSS vendors. Furthermore, the are some basic differences in the application of the SPD and moveable detector systems. These include:

- As plant operation continues, neutron irradiation depletes the detector sensor material and increases the measurement variability. The measurement variability of the incore movable detectors effectively does not change during operation because the movable detector measurements are not present in the core for sufficiently long times to undergo any appreciable depletion of the detector material.
- Some of the fixed incore detectors may fail during operation, which requires that the power distribution measurement uncertainty be adjusted during plant operation. If an individual incore movable detector fails, the core locations measured by the failed detector can be accessed using one of the other movable detectors, so no uncertainty adjustment is required.
- If an incore movable detector location access thimble becomes blocked, then the power distribution measurement uncertainty associated with the BEACON calibration data generated from the incore movable detector input is automatically adjusted by the BEACON System. Should the thimble become usable at a later time, BEACON automatically adjusts to this situation. If a FID string can not be inserted into the thimble during the refueling the entire string is left out of the core and the uncertainty is adjusted accordingly for the entire cycle.

The BEACON power distribution uncertainty methodology is designed to determine the power peaking factor measurement uncertainty for a wide range of the SPD detector operating conditions. The measured peaking factor uncertainty is defined as a function of the fraction of inoperable detectors and the detector measurement variability as given by Equation 3 and Equation 4 of Addendum 1 to WCAP-12472-P-A. The methodology of the power peaking factor uncertainty determination is described in Section 5 of Addendum 1 to WCAP-12472-P-A.

The constants, variabilities, and coefficients used in the equations described in Section 5 of Addendum 1 to WCAP-12472-P-A are specific for a given reactor core geometry, detector configuration, and installation layout, and can be obtained as described in Section 5. The equations are applicable for a wide range of detector conditions anticipated during the reactor operation.

The behavior of the measured peaking factor uncertainties as a function of the incore detector variability and composite random detector loss levels are shown in Figure 4 and Figure 5 of Addendum 1 to WCAP-12472-P-A for a representative plant. It is seen that the higher the SPD measurement variability and fraction of inoperable detector are, the higher the peaking factor measurement uncertainty becomes.

In most cases, the upper bound of the SPD measurement variability and fraction will be determined for a specified peaking factor measurement uncertainty. Alternatively, the BEACON methodology can be used to support an existing or requested availability requirement for a specific plant.

Question 3

The criteria for the movable incore neutron detectors, with BEACON operable, which are presented in the example of WCAP-12472 COLR Section 2.5, require at least 75 percent available at the beginning of cycle, and a minimum of 50 percent at any time afterward, with a minimum of two per quadrant. Discuss the appropriate criteria for the self-power fixed incore detectors. The requirements should be included in the proposed Technical Specifications.

Response

As discussed in Response to Question 2, the BEACON power peaking uncertainties are defined as a function of the detector measurement variability and fraction of inoperable detectors. Loss of operable detectors results in an increase of the uncertainty.

It should be mentioned that the BEACON measurement adjustment interpolation utilizes the surface spline fitting technique, as described in Section 3.0 of Addendum 1 to WCAP-12472-P-A. This method performs the interpolation by using all SPD measurement adjustment points simultaneously. Therefore, special requirements on the detector availability, such as minimum number of functioning detectors in a string or detector coverage requirement, are generally not necessary with the following exceptions.

i. Physics Test at Beginning of Cycle

In order to minimize the likelihood of a misloading, several means of proper core loading checking are employed, such as fuel assembly manufacturing procedures, adherence to the core loading plan, visual inspection of the as loaded core, and physics test. The physics testing is the final step to confirm the core is loaded consistent with the core design. Any significant core misloading can be detected by a deviation between measured and predicted rod worths at zero power, or deviations between measured and predicted assembly powers obtained from the flux symmetry and core power distribution measurements prescribed by ANSI/ANS-19.6.1, "Reload Startup Physics Tests for Pressurized Water Reactors". In order to maximize the capability to detect a core misloading ANSI/ANS-19.6.1 specifies that the incore detector locations measured be "well distributed throughout the core".

As a guideline for detector coverage requirements for the fuel misload detection, applicable during initial startup in each operating cycle, the Tech Specs associated with BEACON Operability included in WCAP- 2472-P-A require that measurements be obtained from at least 75% of the movable detector thimble locations, with at least 2 thimble measurements from each core quadrant. This measurement density has been shown to provide sufficient coverage for detecting fuel misloadings and other mislocated core components. Based on these past experiences, 75% SPD detector operability is specified in the Technical Requirement associated with BEACON Operability for the initial power ascension at the beginning of each operating cycle. After this time period, BEACON is considered operable as long as the detector requirements defined in the Response to Question 2 are satisfied..

ii. Detector Requirement in Quadrants

Except for the initial startup at the beginning of each operating cycle, BEACON supports operation with a reduced number of detectors as defined in the Response to Question 2. The deletion analysis presented in Section 5 of Addendum 1 to WCAP-12472-P-A presents the peaking factor uncertainty associated with the composite of many random deletion cases at the specified deletion level. The random deletions do not preserve any quadrant or axial coverage requirements (truly random). However, to insure adequate accurate quadrant tilt and the axial offset information is input to the BEACON System on a continuous basis, a minimum requirement of operable detectors is suggested for each quadrant. The quadrant and axial coverage recommendation is made consistent with the Westinghouse incore movable detector standard requirements as shown in the following table. Should an application at a specific plant have existing coverage requirements for the SPDs, the BEACON uncertainty can alternatively support that coverage, using an uncertainty value determined consistent with that specific requirement. There is no minimum requirement for the minimum number of operable detectors in a string or a minimum number of measured symmetric locations requirement

Table 3.1

SPD Minimum Recommendation for Quadrant Tilt and Axial Offset Monitoring

a,c

Question 4

How are failed self powered fixed incore detectors identified? How will it be assumed in the BEACON analysis?

Response

When BEACON is in operation, using information from the SPD to perform continuous core power distribution monitoring, detection of gross SPD element failure is performed automatically. The BEACON Plant Interface software module automatically examines each input SPD signal relative to the average of all detector signals at the same axial elevation. If the signal from any detector deviates significantly from the average of other corresponding detectors, then the data quality of the affected detector is degraded in the information output to the user, and the weight the detector information is given in adjusting the monitored core power distribution is automatically reduced. For larger deviations from the average signal for an SPD, the detector data quality is automatically set to BAD, and the input from the affected detector is not used by the BEACON continuous core monitoring process. The peaking factor uncertainties applied to the monitored core power distribution is then increased as required to account for the reduced number of operable detector elements using the methodology described in Section 5 of Addendum 1 to WCAP-12472-P-A.

In addition to the gross failure detection capabilities of the BEACON Plant Interface software, the BEACON System also provides the user with the capability to detect more subtle or gradual failures of SPD elements. This capability is provided through BEACON continuously tracking the RMS deviation between the measured and predicted SPD currents. If the user sees the RMS deviation value output changing in an abrupt fashion from one day to the next, then this will trigger the user to perform a more thorough evaluation of the SPD behavior, consistent with the current SPD signal validity evaluation methodology particular to that site and/or user.

The BEACON uncertainty analysis described in Section 5 of Addendum 1 to WCAP-12472-P-A assumes that all inoperable detectors are known to be inoperable. It is implicitly assumed that the combination of automatic and manual detector signal failure detection methodologies will insure that this assumption remains valid when BEACON is in operation. Also, since failed detector signals used as valid inputs will typically result in BEACON calculating higher than actual core peaking factors, conservative operation of the reactor will generally result from undetected failed SPD signal inputs.

Question 5

The typical fixed incore detector assemblies are top mounted and located within inches of the Control Rod Drive Mechanism coil stacks. A concern was raised that the small fixed incore detector signals may be affected by the potentially large electromagnetic fields generated by the Control Rod Drive Mechanism coils. The Rod Position Indication Detector coils is also a potential source of electromagnetic interference. Please provide appropriate recommendations to address this concern.

Response

BEACON does not process raw fixed incore detector signals. It only receives data from the plant process computer which in turn receives its data after any electronic processing has been made to the signals. The issue with electromagnetic interference (EMI) from the CRDMs and indication system coils is therefore not a BEACON issue but an issue related to the design of the fixed incore detector system itself, and most importantly, the cabling and electronics associated with getting that signal out of containment to the plant process computer. However, regardless of the actual process of getting the signal to the plant process computer, any electromagnetic interference that is presence in the signal output of the plant process computer will be observed as signal noise which will manifest itself as an increase in the detector variability determined during the BEACON uncertainty analysis. This in turn will result in a higher measurement uncertainty to be applied to the core power distribution measurement.

Furthermore, it should be noted that the BEACON system uses one minute averages of detector signals. This one minute averaging serves as a filter to make BEACON less susceptible to any type of noise related issues. This is of prime importance in a thermocouple based BEACON system where signal noise can be rather large. In FID based plants, it also serves to mitigate the impact of EMI associated with the CRDM coil energizing as proposed in this question, especially since control rod motion is typically accomplished by moving the rods only a few steps at a time which only requires a few seconds to accomplish.

Question 6

It is the staff understanding the SPDs are required to be operable all the time, instead of part-time as in the Westinghouse case. What is the difference in the operability requirements between the present system (movable incore detector system) and the proposed system (fixed incore detector system)?

Response

BEACON is a continuous core monitoring system. As such, the input required for the continuous monitoring process must be available continuously. When the BEACON system is used in plants with movable incore detectors (MIDs), the incore thermocouples and excore detectors provide this continuous monitoring input function and are required to be operable at all times for the BEACON system to be considered operable. The MIDs are only used periodically to calibrate BEACON to the measured incore data. In plants with SPDs, the SPDs serve the purpose of the MIDs, excore detectors and the incore thermocouples. The SPDs provide the continuous data of the thermocouples/excores and the data needed for BEACON calibration. Therefore the SPDs are required to be operable at all times for the BEACON system to be considered operable. This is consistent with the BEACON operability requirements of the excore and thermocouple detectors in a plant with MIDs.

Question 7

Will the excores/thermocouple system still be used as backup system on Westinghouse plants and non-Westinghouse plants for incore monitoring.

Response

Although the BEACON system is able to use both excore/thermocouple and fixed incore system data for core monitoring it will not be setup to use the excore/thermocouple system as a backup to the fixed incore system. If excore/thermocouple data is available to the BEACON system it will only be used for inspection and display. The reason for this is that at a fixed incore plant the FID are the primary power distribution monitoring system and efforts are extended to ensure that system is operational. Therefore there is no value added in supporting extra excore/thermocouple data for a backup system that would never be used in plant operations.

Question 8

WCAP-12472-P-A contains information pertaining to the detector system description and qualification for the movable incore detector system. Please provide similar information for the fixed incore detector system.

Response

1. System Description

In pressurized water reactors using the fixed incore detector systems, rhodium (Rh) self powered detectors (SPD) are most widely used for power distribution monitoring. The reaction of rhodium when exposed to neutron flux is expressed by:

Rh(103) + n --> Rh(104) --> Pd + beta + energy

Capture of a neutron by rhodium-103 produces a radioisotope, rhodium-104, which decays to stable palladium by emitting a beta particle. Those beta particles that escape to the detector sheath create a charge deficiency that, in turn, produces a current flow which can be measured. The magnitude of the current, which is directly related to the neutron flux absorbed by the rhodium, is measured and sent to the plant computer.

The detector assembly contains the detector elements (Rh-wires) distributed in several axial locations. The detector assemblies are installed in the instrument thimble of selected fuel assemblies in a reactor core. Typically, about one third of the fuel assemblies are instrumented. The NSSS vendor defines detector locations to obtain the maximum information for a given number of detector assemblies. The following aspects are considered.

a. Uniform coverage over the entire reactor

b. Detectors at assemblies in selected symmetric positions

c. Detectors at assemblies on non-symmetric positions to maximize instrumentation coverage when collapsed to a symmetric sector

Actual detector configuration and layout in operating reactors varies by reactor vendors as shown in Table 8.1. For comparison, the corresponding information for the Westinghouse movable detector system is included.

As an example, the detector assembly and the detector layout of a typical 217 assembly CE plant is shown in Figure 8.1 through Figure 8.3.

Table 8.1

SPD Configuration

Plant	Rh length (cm.)	Rh wires*	Nasy**	Ndet***	Nasy/Ndet	
B&W	12.5	7	177	52	3.40	Plant A
CE	40.0	4	217	45	4.82	Plant B
CE	40.0	4	217	56	3.88	
VVER1000	25.0	7	163	64	2.55	
W(4-Loop)	Movable Detector		193	58	3.33	

*	Rh wires:	Number of Rh elements per detector string
**	Nasy:	Number of fuel assemblies in the core
***	Ndet:	Number of detector strings/thimbles

2. Qualification of BEACON Methodology

The qualification of the methodology, which is described in Section 3.0 of Addendum 1 to WCAP-12472-P-A, was performed by using actual measurement data from Plant A and Plant B of Table 1. The purpose of the qualification study is two fold, i.e.,

i. To verify that the proposed SPD model is capable of predicting the magnitude of the detector current, and

ii. To evaluate the detector measurement variability of the detector system.

The detector measurement variability, or accuracy, varies by the detector design and the depletion history of the detector. This is one of the important elements for the determination of the measured power peaking factor uncertainty by BEACON as described in Section 5.0 of Addendum 1 to WCAP-12472-P-A. Further discussion of related subjects can be seen in Response to Question 2.

Figure 8-1

In-Core Nuclear Detector Assembly

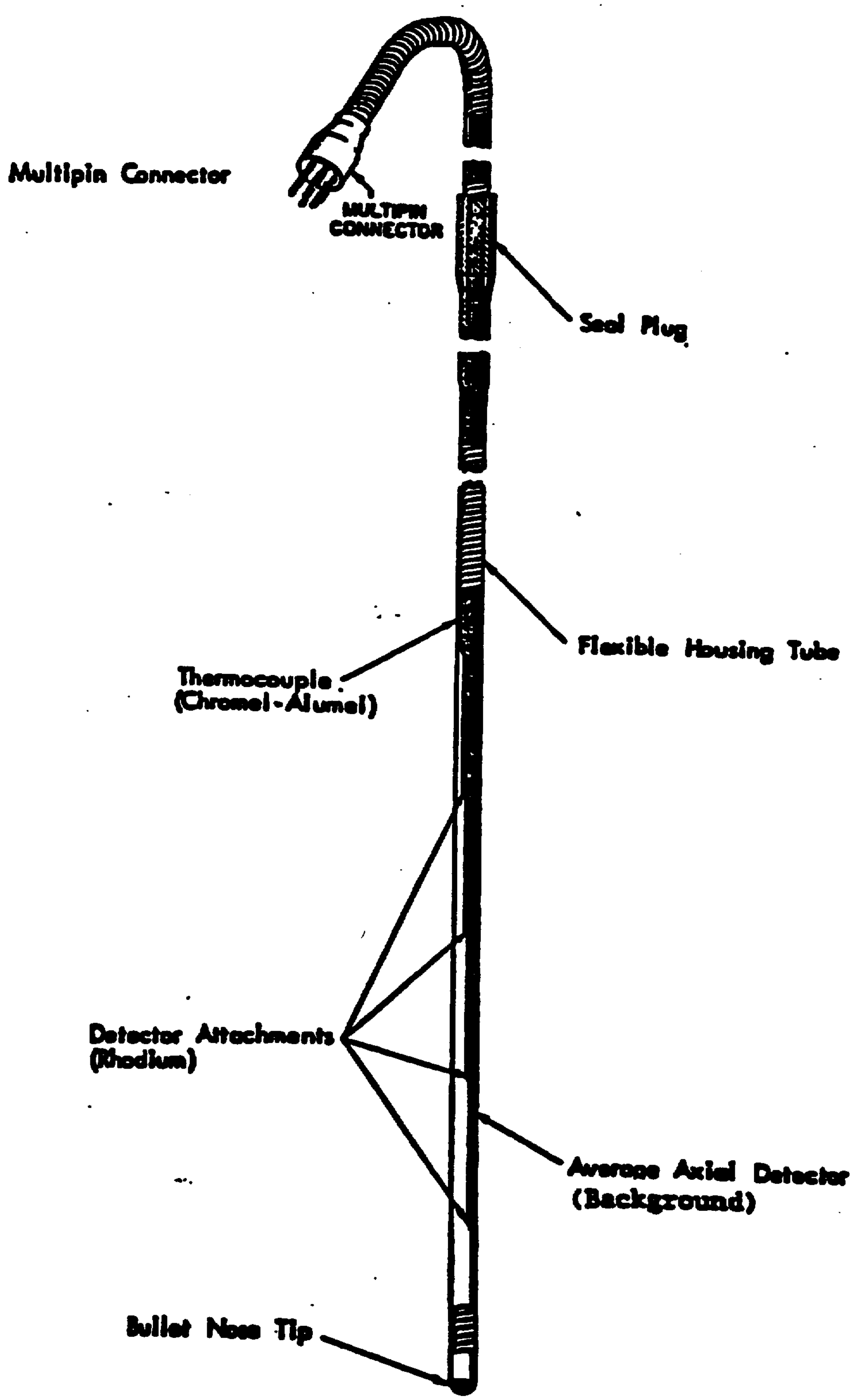


Figure 8-2

Plant B

Incore Detector Location

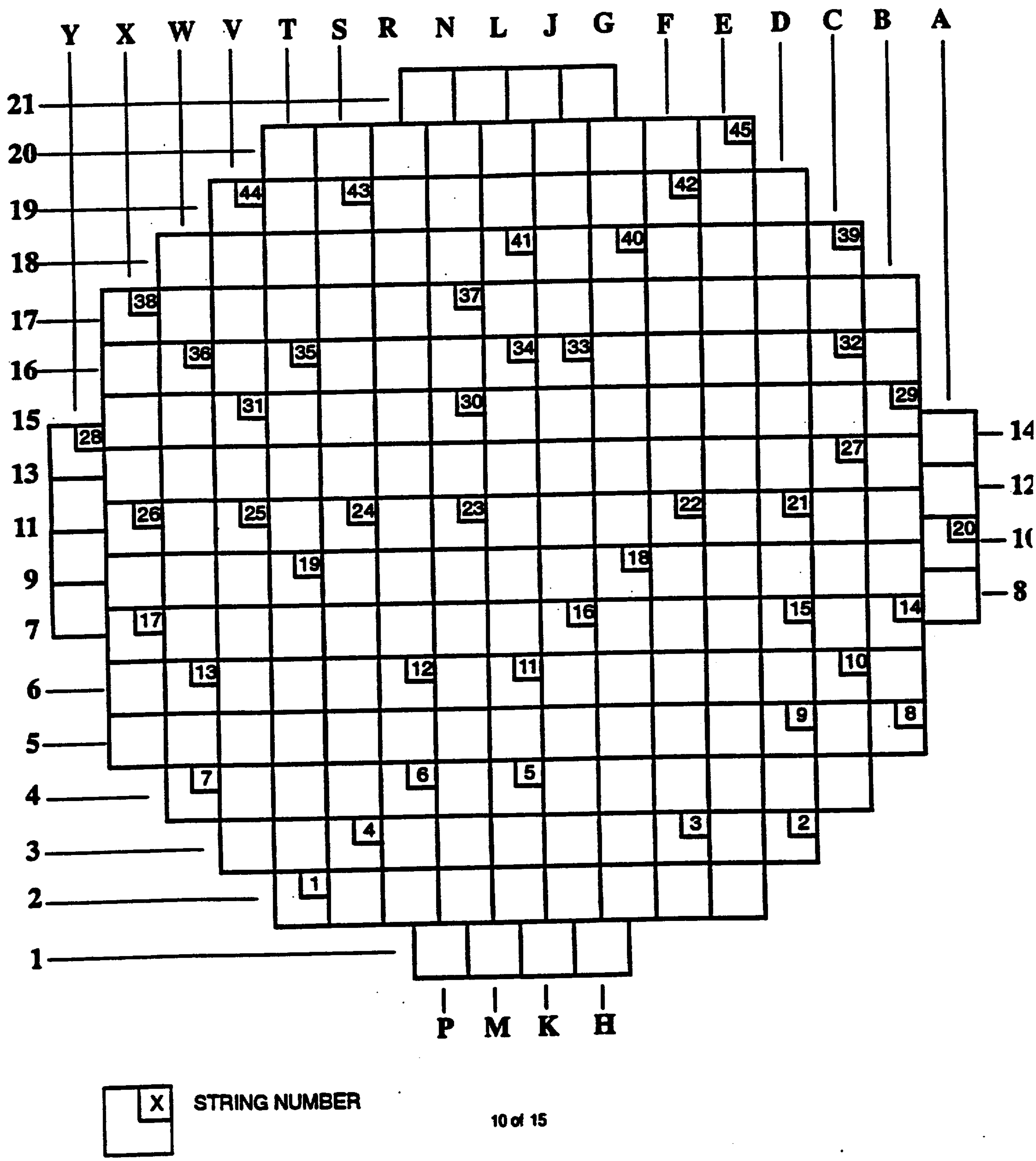
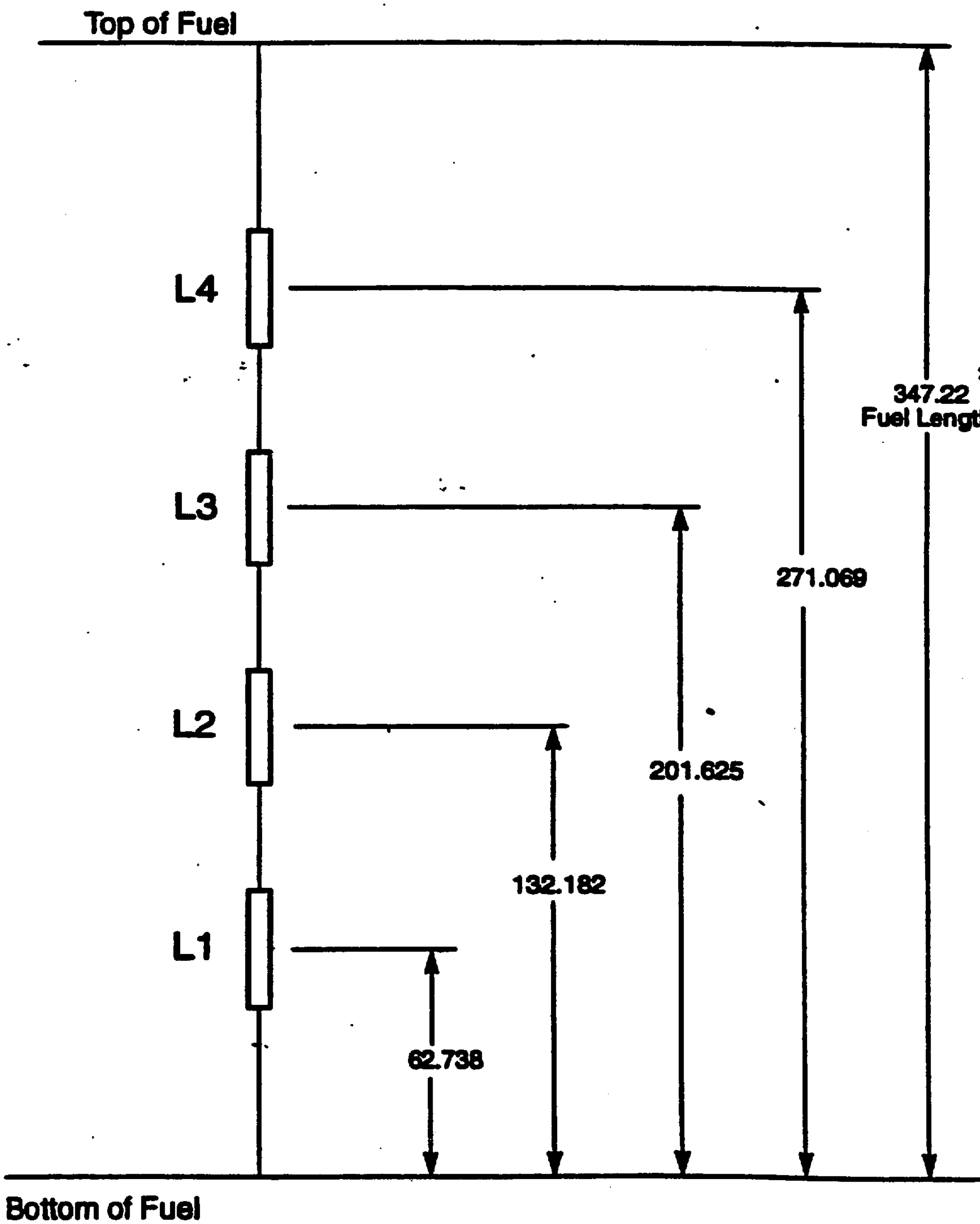


Figure 8-3

Plant B
Axial Detector Location



* Dimensions are in centermeters

Exhibit A

Sample Technical Requirement for BEACON Operability

3.3 INSTRUMENTATION

3.3.10 Power Distribution Monitoring System Instrumentation

TR 3.3.10 The Power Distribution Monitoring System (PDMS) shall be OPERABLE with:

a) Reactor THERMAL POWER is greater than or equal to 25% of RATED THERMAL POWER (RTP), and

b) The minimum type and number of valid inputs from the plant computer as defined in Table 3.3.10-1 shall be input to the PDMS.

c) The current value of (Tech Spec Requirement)output from the PDMS is available for review by the reactor operator in the Control Room on an essentially continuous basis.

APPLICABILITY: MODE 1

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. THERMAL POWER less than 25% of RTP	A.1 Declare the PDMS inoperable	15 minutes
B. One less than the minimum required type or number of valid inputs from the plant computer are input to the PDMS	B.1 Declare the PDMS inoperable	4 hours
C. The current value of (Tech Spec Requirement) is not available for review by the reactor operator in the Control Room	C.1 Declare the PDMS inoperable	4 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.3.10.1	Perform a CHANNEL CHECK of the PDMS instrumentation input specified in Table 3.3.10-1	Prior to use for core power distribution measurement purposes and every 24 hours thereafter
SR 3.3.10.2	Verify that the current value of (Tech Spec Requirement) available for review by the reactor operator in the Control Room.	Prior to use for core power distribution measurement purposes and every 24 hours thereafter
SR 3.3.10.3	---------------------------NOTE-------------------------- Neutron detectors are excluded from CHANNEL CALIBRATION. -- Perform CHANNEL CALIBRATION for each required instrumentation channel listed in Table 3.3.10-1.	Prior to use for core power distribution measurement purposes, and every 18 months thereafter.

Table 3.3.10-1
Power Distribution Monitoring System Instrumentation

FUNCTION	REQUIRED CHANNEL INPUTS
1. Control Bank Position	4[(a)]
2. RCS Cold Leg Temperature, T_{cold}	2
3. Reactor Power Level	1[(b)]
4. Incore Self Powered Detectors (SPD)	50%[(c)] with each core quadrant containing at least 5 operable SPD elements above the core mid-plane and 5 operable SPD elements below the core mid-plane

(a) Control bank position inputs may be bank positions from either valid Demand Position indications or the average of all valid individual RCCA positions in the bank determined from Rod Position Indication (RPI) System values for each Control Bank. A maximum of 1 rod position indicator may be inoperable when RCCA position indications are being used as input to the PDMS.

(b) Reactor Power Level inputs may be reactor thermal power derived from either a valid secondary calorimetric measurement, the average Power Range Neutron Flux Power, or the average RCS Loop ΔT.

(c) 75% of the SPD elements must be operable for the initial core power distribution measurement generated by the PDMS in each operating cycle.