August 17, 2005

Mr. James A. Gresham, Manager
Regulatory Compliance and Plant Licensing
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

SUBJECT: DRAFT SAFETY EVALUATION FOR TOPICAL REPORT (TR) WCAP-12472-P, ADDENDUM 3, "BEACON CORE MONITORING AND OPERATION SUPPORT SYSTEM" (TAC NO. MC4958)

Dear Mr. Gresham:

By letter dated October 22, 2004, and its supplement dated February 21, 2005, Westinghouse Electric Company (Westinghouse) submitted Topical Report (TR) WCAP-12472-P, Addendum 3, "BEACON Core Monitoring and Operation Support System" to the Nuclear Regulatory Commission (NRC) staff for review. The objective of this addendum is to provide the information and data necessary to approve an upgraded core monitoring system that merges three existing products, Best Estimate Analyzer for Core Operation - Nuclear (BEACON) core monitoring system, Core Operating Limit Supervisory System (COLSS), and the thermal hydraulic analysis computer code CETOP-D, into one, and an uncertainty analysis methodology that will be applied to this new product, BEACON-COLSS.

The NRC staff has concluded that the BEACON-COLSS core monitoring system and its uncertainty analysis methodology are acceptable for use in Combustion Engineering (C-E) designed plants currently using COLSS. Enclosed for Westinghouse review and comment is a copy of the NRC staff's draft safety evaluation (SE) for the TR.

Pursuant to 10 CFR 2.390, we have determined that the enclosed draft SE does not contain proprietary information. However, we will delay placing the draft SE in the public document room for a period of ten working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects. If you believe that any information in the enclosure is proprietary, please identify such information line-by-line and define the basis pursuant to the criteria of 10 CFR 2.390. After ten working days, the draft SE will be made publicly available, and an additional ten working days are provided to you to comment on any factual errors or clarity concerns contained in the SE. The final SE will be issued after making any necessary changes and will be made publicly available. The NRC staff's disposition of your comments on the draft SE will be discussed in the final SE.

To facilitate the NRC staff's review of your comments, please provide a marked-up copy of the draft SE showing proposed changes and provide a summary table of the proposed changes.

If you have any questions, please contact Brian Benney at 301-415-3764.

Sincerely,

/RA/
Robert A. Gramm, Chief, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 700

Enclosure: Draft Safety Evaluation

cc w/encl:
Mr. Gordon Bischoff, Manager
Owners Group Program Management Office
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

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DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT WCAP-12472-P, ADDENDUM 3,

"BEACON CORE MONITORING AND OPERATION SUPPORT SYSTEM"

WESTINGHOUSE ELECTRIC COMPANY

PROJECT NO. 700

1.0 INTRODUCTION AND BACKGROUND

By letter dated October 22, 2004 (Agencywide Document Access Management System (ADAMS) Accession No. ML043000292 (Addendum 3)), as supplemented by request for additional information (RAI) responses dated February 21, 2005 (ADAMS Accession No. ML050560235), Westinghouse Electric Company LLC (Westinghouse) submitted Addendum 3 to WCAP-12472-P/WCAP-12472-NP, "BEACON Core Monitoring and Operation Support System," to the Nuclear Regulatory Commission (NRC) for review and approval. The objective of this addendum to the approved topical report (TR) is to provide the information and data necessary to approve an upgraded core monitoring system that merges three existing products, Best Estimate Analyzer for Core Operation - Nuclear (BEACON) core monitoring system, Core Operating Limit Supervisory System (COLSS), and the thermal hydraulic analysis computer code CETOP-D, into one, and an uncertainty analysis methodology that will be applied to this new product, BEACON-COLSS.

2.0 REGULATORY EVALUATION

There are no specific regulatory requirements for the review of TR revisions, supplements, or addendums. The NRC staff review was based on the evaluation of the technical merit of the submittal and compliance with any applicable regulations associated with reviews of topical reports, including NUREG-0800.

3.0 TECHNICAL EVALUATION

BEACON, COLSS, and CETOP-D have been functionally merged to create an upgraded core monitoring system for Combustion Engineering (C-E) designed plants. All three codes have been previously approved by the NRC and have been in use by Westinghouse.

BEACON core monitoring 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 TR, WCAP-12472-P-A, BEACON Core Monitoring and Operations Support

(WCAP-12472-P-A), was approved by the NRC staff on February 16, 1994. WCAP-12472-P-A, Addendum 1-A (Addendum 1), extended the previously licensed BEACON power distribution monitoring methodology to plants containing fixed incore self-powered detectors (SPDs) that use rhodium. "BEACON - Core Monitoring and Operations Support System," WCAP-12472-P-A Addendum 2-A, April 2002 (Addendum 2), extended the previous NRC approval to plants containing SPDs that use platinum or vanadium.

COLSS was developed to help maintain a C-E supplied (PWR) within its Limiting Conditions for Operation (LCOs). It was also developed as a core monitoring system that uses data from plant instrumentation along with an analytical methodology for on-line generation of core power level, synthesized power distribution, and power operating limits.

The uncertainty determination report, CEN-356(V)-P-A Revision 01-P-A, "Modified Statistical Combination of Uncertainties," was approved by NRC staff in May 1988. COLSS has also been described in CEN–312-P Revision 02-P, "Overview Description of the Core Operating Limit Supervisory System (COLSS)," and approved by the NRC in November 1990.

CETOP-D is a thermal hydraulic analysis computer code for all C-E designed plants. It has been approved for design analysis in each plant's safety evaluation report. An example is NUREG-0712 Supplement 4 for San Onofre Generating Station Units 2 and 3, Docket Nos. 50-361 and 50-361, Section 4.4.6.1. In response to Question 2 of the RAIs, this design analysis code applies to an on-line core monitoring system as well because the same benchmarking will be used and the same adjustment factors included when CETOP-D is used in BEACON-COLSS. Also, the inputs that would be used in a design analysis are consistent with the inputs from BEACON-COLSS under corresponding conditions.

3.1 BEACON-COLSS Product

Approval of BEACON-COLSS will allow the current C-E plants, which use COLSS to take advantage of the additional BEACON predictive and analysis capabilities. Also, BEACON employs a more sophisticated three-dimensional power distribution methodology than the synthesis method used in COLSS. This will give the current C-E COLSS plants a more accurate on-line core monitoring tool.

BEACON-COLSS will monitor the same LCOs and Technical Specification limits as COLSS. COLSS currently monitors core flow and power, linear heat rate (LHR) power operating limit (POL), departure from nucleate boiling ratio (DNBR) POL, core power margin to the licensed power limit, Axial Shape Index (ASI), and azimuthal power tilt. BEACON-COLSS will use COLSS power and flow inputs, LHR POL, core power margin to licensed power limit, LHR POL, and DNBR POL. The DNBR POL will be calculated by CETOP-D, instead of the modified version of CETOP currently used by COLSS or the BEACON DNBR calculator. ASI and azimuthal power tilt will be calculated by BEACON with its three-dimensional power distribution methodology because the COLSS power distribution synthesis method will be replaced by the BEACON methodology for all COLSS modules requiring a power distribution input. Both ASI and azimuthal power tilt are calculated from the core power distribution module. Therefore, the BEACON-COLSS product level merges only existing functions that will be unchanged in functionality.

BEACON-COLSS will not experience any adverse effects due to the merging of the two codes because the COLSS core power, flow, DNBR, and power margin functions will be rewritten as dynamic library functions that will be called and executed by BEACON for core monitoring and predictive function purposes when needed. Therefore, the COLSS modules will perform their calculations as they currently do, except they will be executed by BEACON and use BEACON 3D power distribution information instead of COLSS power distribution. By rewriting the COLSS functions as separate libraries, they can be accessed through the BEACON system by simply executing them with the appropriate thermal hydraulic and power distribution information.

In response to Question 3 of the RAIs, CETOP-D is being used instead of the DNBR calculator from BEACON for the following reasons: 1) The BEACON DNBR calculator does not contain any empirical DNBR correlations for C-E fuel types. The DNBR algorithm is benchmarked to the thermal hydraulic code, THNC4. This generates a set of coefficients that ensure the relative DNBR results are conservative and bounding compared to the THNC4 results. Therefore, the results of the DNBR calculator do not represent an actual DNBR but a conservative and bounding DNBR result. 2) The CETOP-D code contains empirical DNBR correlations for C-E fuel types and is benchmarked to the TORC thermal hydraulic code to give DNBR results that are consistent with this code. It is benchmarked every cycle to ensure that the results continue to represent the TORC code. Also, CETOP-D is a multi-channel code so it will stay representative of the TORC results over a wider range of fuel thermal hydraulic conditions than the single channel BEACON DNBR calculator. Therefore, CETOP-D will give the current C-E COLSS plants upgrading to BEACON-COLSS a more accurate DNBR calculating tool.

For current COLSS plants, the accuracy of COLSS DNBR and LHR POLs is dependent on the core design, primarily due to the power distribution methods utilized in COLSS. Using the BEACON 3D power distribution methodology in the BEACON-COLSS product will eliminate this dependency due to BEACON's measured hot pin power distribution capability that will be based on the core design neutronics model, which will be updated every cycle consistent with core design. Each time BEACON-COLSS is applied to a new plant, the generic uncertainty analysis will be performed for that specific plant and confirmed each cycle. These generic uncertainty components will be reevaluated when the core design differs sufficiently to have an impact on the data methods and assumptions in Addendum 3. These plant- and cycle-specific requirements are consistent with those in the WCAP-12472-P-A, Addendum 1, and Addendum 2.

3.2 BEACON-COLSS Models

3.2.1 Plants A and B

Westinghouse performed calculations for two C-E designed plants to show the application of the BEACON-COLSS methodology and the expected measurement uncertainties, and compare those to current COLSS values. The calculations were performed for peaking factors, LHR POL, and DNBR POL. The peaking factor and LHR uncertainty methodology is unchanged from the current approved methodology in Addendum 1, and will be defined as a function of SPD measurement variability and fraction of inoperable detectors. The DNBR uncertainty methodology is unchanged from the current approved methodology in "Modified Statistical Combination of Uncertainties," CEN-356(V)-P-A Revision 01-P-A, May 1988, except for the inherent changes from the neutronics and thermal-hydraulic improvements of CETOP-D. The two C-E designed plants used for the calculations, Plants A and B, are described in Table 2 of Addendum 3, and their SPD layouts are shown in Figures 4 and 5 of Addendum 3 as well. Each plant also contains the same axial SPD layout, which is shown in Figure 6 of Addendum 3.

Westinghouse gathered the necessary data from BEACON, pairs of simulated “true” and “predicted” power distributions in Plants A and B. In order to bound the calculations, power distributions were selected between the simulated model performed by BEACON and actual plant conditions. It is impossible to predict all potential variations in core conditions, so conservative data were also included in their calculations.

The conservative data include the following plant conditions from Addendum 3:

- Three different cycle burnup points at the beginning, middle, and end of cycle.
- Burnup mismatch between “true” and “prediction” cases as much as 1000 MWD/MTU.
- Rod Bank Position difference up to 30 percent of total rod travel.
- One CEA fully misaligned and inserted in the core.
- Reactor power difference of 20 percent.
- Large xenon oscillation, radially and/or axially, induced by asymmetric control element assembly (CEA) insertion or inlet temperature mismatch.

The power distribution calculation results can be found in Tables 3 and 4 of Addendum 3. In addition, these data will be evaluated at each plant on a case by case basis to make certain they are reasonable and bounding.

3.2.2 Comparison of BEACON-COLSS Results with Applicable COLSS Plant Results

To calculate the measurement uncertainties for the 3D peaking factor (Fq) and integrated radial peaking factor (Fr), Westinghouse took a simulated pair of “true” and “predicted” power distributions, an SPD variability, and a fraction of inoperable detectors, and calculated a measured power distribution. This was compared to the “true” distribution and a deviation was calculated for the peaking factors. One hundred trial cases were performed for each of the 20 combinations of detector variability and inoperable detector fractions in this analysis. These trial cases ensured good statistical accuracy. This was performed for all 29 pairs of “true” and “predicted” bounding power distributions.

The measurement uncertainty is defined by the 95/95 upper tolerance limit of the deviation calculated in the aforementioned trial cases. The data were collected where the power was within 5 percent of the peak value to ensure that all values were included that could possibly contain the maximum peaking factor for any reasonable core condition. The peaking factor uncertainties show a definite trend as a function of detector variability and fraction of inoperable detectors. The measurement uncertainty method for Fr and Fq (used in BEACON-COLSS as the uncertainty in LHR POL) is consistent with what was previously licensed in WCAP-12472-P-A. These uncertainties are shown in Figures 7 through 10 of Addendum 3.

Westinghouse compared the BEACON-COLSS LHR POL uncertainty to that of the standard COLSS methodology uncertainty values. These results are shown in Table 5 of Addendum 3 and are lower for BEACON-COLSS due to the improved power distribution predictions from the 3D model used in BEACON. These results are consistent with what should be expected due to the application of the improved power distribution model.

Westinghouse also calculated the DNBR POL measurement uncertainty and compared it to the value produced by the standard COLSS methodology. In order to calculate the uncertainty for BEACON-COLSS, Westinghouse calculated the DNBR POL at “true” and “measured” core conditions. The “measured” was compared to the “true” and a deviation from the “true” value was calculated for each case using the 29 pairs of power distributions and the 20 combinations of detector variability and fraction of inoperable detectors. For each case, trial calculations were performed for up to 100 of the most limiting channels in the core to ensure all reasonable core conditions were included.

In this analysis, Westinghouse showed that the DNBR POL uncertainty dependence on detector variability and fraction of inoperable detectors mattered very little. Also, the BEACON-COLSS uncertainties compared to the standard COLSS uncertainties in Table 8 of Addendum 3 were similar and demonstrated that the methodologies of COLSS and BEACON-COLSS are consistent.

Both the peaking factor (Fr and Fq/LHR POL) and DNBR POL uncertainties will be applied to BEACON-COLSS as they are currently applied to COLSS.

4.0 LIMITATIONS AND CONDITIONS

The NRC staff accepts the methodology described in WCAP-12472-P, Addendum 3, subject to the following conditions:

1. A license amendment is required to incorporate this methodology into the license of each plant.

2. The BEACON and COLSS systems both have their own requirements and limitations. The NRC staff requested the combined limitations for the BEACON-COLSS methodology in Question 6 of the RAIs, (Ref. 8). Westinghouse will support licensees as they apply the BEACON-COLSS product at C-E COLSS plants under the following combined conditions:

    a. Movable fission chamber or fixed incore detector systems including rhodium and vanadium.

    b. Square or hexagonal PWR fuel types.

    c. With core power less than 20 percent, BEACON-COLSS are considered inoperable for alarms and surveillance.

    d. A minimum set of inputs from the plant computer is required for the BEACON-COLSS system to be considered operable. These include the following:

(1.) Lead control bank position and independent AO/ASI control bank position
(2.) RCS cold and hot leg temperatures
(3.) Reactor power level
(4.) A minimum of 13 detectors per core quadrant with at least 5 in the top half and 5 in the bottom half of each quadrant.
(5.) RCS pressure

These requirements are a combination of the power distribution methodology of BEACON and the core power, flow, thermal hydraulics, and operating limit methodology of COLSS.

5.0 CONCLUSION

The NRC staff has reviewed the analyses presented in WCAP-12472-P, Addendum 3, "BEACON Core Monitoring and Operations Support System." The NRC staff has considered the application of the merged BEACON-COLSS core system, the application of CETOP-D to perform its licensed function, and the qualification analysis performed against real plant data. Based on these considerations, the staff finds the BEACON-COLSS system acceptable for licensing applications, subject to the restrictions and limitations imposed on WCAP-12472-P, Addendum 3.

6.0 REFERENCES

1. Letter from J. A. Gresham to the U.S. NRC submitting Addendum 3 to WCAP-12472-P/WCAP-12472-NP, "BEACON Core Monitoring and Operation Support System," October 22, 2004.

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

3. Morita, T., "BEACON - Core Monitoring and Operations Support System," WCAP-12472-P-A Addendum 1-A, January 2000.

4. Boyd, W. A., "BEACON - Core Monitoring and Operations Support System," WCAP-12472-P-A Addendum 2-A, April 2002.

5. "Modified Statistical Combination of Uncertainties," CEN-356(V)-P-A Revision 01-P-A, May 1988.

6. "Overview Description of the Core Operating Limit Supervisory System (COLSS)," CEN-312-P Revision 02-P, November 1990.

7. Safety Evaluation Report, NUREG-0712 Supplement 4 for San Onofre Generating Station Units 2 and 3, Docket Nos. 50-361 and 50-361, Section 4.4.6.1.

8. Letter from J. A. Gresham, Manager, to the U.S. NRC, entitled "Responses to NRC Request for Additional Information on Addendum 3 to WCAP-12472-P, Rev. 0, "BEACON Core Monitoring and Operation Support System" (Proprietary/Non-Proprietary), February 21, 2005.

Principal Contributors: Tony Attard
Jeremy Tapp

Date: August 17, 2005