

## APPLICATION OF RISK-BASED METHODS TO OPTIMIZE INSPECTION PLANNING FOR REGULATORY ACTIVITIES AT NUCLEAR POWER PLANTS\*

S.M. Wong, J.C. Higgins, G. Martinez-Guridi  
Brookhaven National Laboratory  
Engineering Technology Division  
Building 130  
Upton, New York 11973  
(516)282-2111

J. W. Chung  
U.S. Nuclear Regulatory Commission  
Office of Nuclear Reactor Regulation  
Washington, DC 20555  
(301)415-1071

### INTRODUCTION

As part of regulatory oversight requirements, the U.S. Nuclear Regulatory Commission (USNRC) staff conducts inspection activities to assess operational safety performance in nuclear power plants. Currently, guidance in these inspections is provided by procedures in the NRC Inspection Manual and issuance of Temporary Instructions defining the objectives and scope of the inspection effort. In several studies sponsored by the USNRC over the last few years, Brookhaven National Laboratory (BNL) has developed and applied methodologies for providing risk-based inspection guidance for the safety assessments of nuclear power plant systems.<sup>1-3</sup> One recent methodology integrates insights from existing Probabilistic Risk Assessment (PRA) studies and Individual Plant Evaluations (IPE) with information from operating experience reviews for consideration in inspection planning for either multi-disciplinary team inspections or individual inspections. In recent studies at BNL, a risk-based methodology was developed to optimize inspection planning for regulatory activities at nuclear power plants. This methodology integrates risk-based insights from the plant configuration risk profile and risk information found in existing PRA/IPE studies.

### APPROACH AND METHODOLOGY

Typically, NRC inspection programs provide an audit function to assure compliance with regulatory requirements. The inspection process in these

programs are largely based on deterministic engineering approaches. Due to increased emphasis toward performance-based regulations, it has been recognized that the deterministic inspection process could be enhanced through the application of PRA methods and technology in regulatory activities.<sup>4</sup> Thus, the development of a risk-based methodology to enhance the inspection process could provide a framework for optimizing inspection resources and help to focus on risk significant areas of plant design and operational practices. As shown in Figure 1, the major elements of the methodology include:

1. definition of the plant configuration risk profile,
2. insights from PRAs and plant-specific IPE on the role of important systems in dominant accident sequences, potential severe accident vulnerabilities, and resolution of plant safety issues,
3. risk-based input augmented with information gleaned from evaluation of the plant risk profile to select and rank components for inspection emphasis, and
4. identification of risk significant areas of licensee safety performance that require increased inspection attention.

The first element of the methodology is centered on the development of a plant configuration risk profile. Based on review of actual plant records of

---

\* Work performed under the auspices of the U.S. Nuclear Regulatory Commission.

## DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

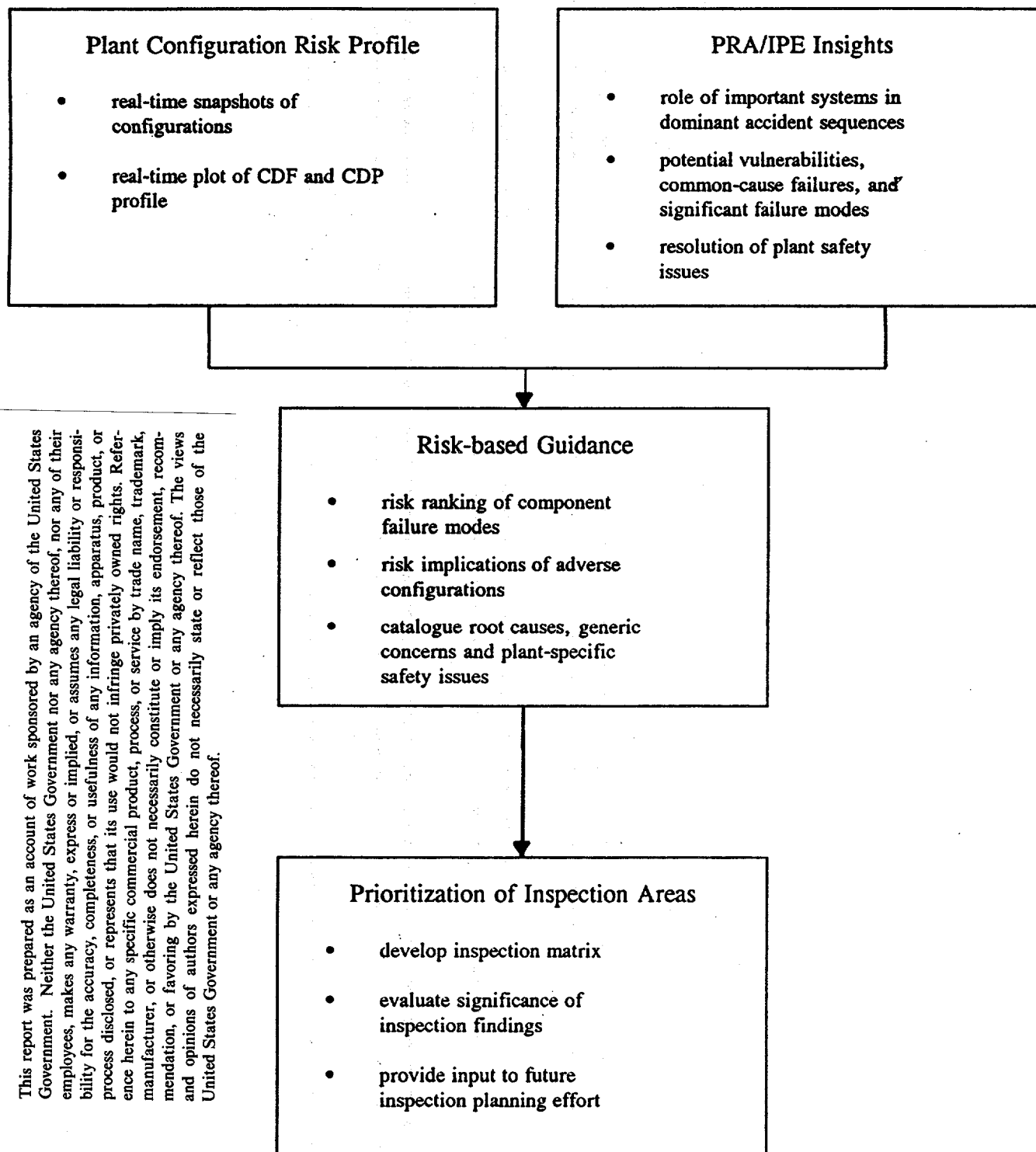


Figure 1. Risk-based methodology for optimizing inspection planning of regulatory activities at nuclear power plants.

## **DISCLAIMER**

**Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.**

equipment outages, the real-time snapshots of equipment outage configurations are systematically identified to allow risk calculations to be performed subsequently. Each configuration is a combination of equipment outages (e.g., single, double, or multiple components) occurring within a specific time interval or "time window". Results of risk impact calculations for the identified configurations are then used to develop the real-time plots of core damage frequency (CDF) and core damage probability (CDP) profile.

The second element of the methodology is well defined for LWR nuclear power plants. Additional risk insights from the plant PRA/IPE studies can be used to complement the insights from the plant configuration risk profile for inspection planning purposes. The PRA/IPE insights provide a risk perspective of the role of important systems in accident mitigation purposes, risk important human performance actions, potential severe accident vulnerabilities, and licensee actions to resolve plant safety issues.

A key third element in this risk-based methodology for optimizing inspection planning is the rationale for selection and ranking of plant components to focus the inspection effort. In this study, the rationale is based on augmenting the risk importance of plant components with insights from evaluation of the plant configuration risk profile. The importance of component failures are traditionally prioritized by PRA-derived risk importance measures (e.g. risk achievement worth, etc). In addition to PRA and operational considerations, the importance ranking of plant components for inspection focus are determined by including implicit considerations of potential challenges due to high risk configurations, and conditional failures to identify the less obvious but risk significant failure modes, that merit increased inspection attention at the particular plant. In addition to risk ranking of component failure modes to focus inspection planning efforts, the risk-based guidance includes insights on the risk implications of adverse configurations, and a catalogue of identified root causes, generic concerns, and plant-specific safety issues. This approach to risk-based guidance assures that the risk perspective is adequately addressed in the inspection planning process.

The fourth element of the risk-based methodology is centered on the prioritization of inspection areas. Once the prioritized list of components is obtained, an inspection matrix can be developed to identify the inspection focus on licensee

performance in various functional areas such as operations, engineering, and maintenance. An important aspect of the risk-based methodology is to determine the risk significance of inspection findings during and after the inspection. A suitable approach for evaluating the relative importance of an inspection finding must include consideration of the risk implications on plant safety and changes in system performance reliability levels due to the suspect problem. The insights gained from the analysis of risk significance of each particular inspection finding can also be used for future inspection planning. Such feedback would help to focus attention on prioritized concerns in future regulatory activities on the next assessment cycle.

## RESULTS

Pilot tests of the new risk-based methodologies have been conducted over the past year. In addition to PRA/IPE insights to identify vulnerable plant design features, risk-based guidance included insights from the evaluation of the plant configuration risk profiles to provide an overview of significant component or system failures and recurrent problems. The catalogue of these risk-based insights on licensee performance in functional areas such as operations, engineering, and maintenance was found to be useful in prioritizing inspection activities, as well as a key element in identifying risk significant inspection findings.

Previous applications of this risk-based methodology have been shown to be workable in the planning for regulatory activities such as the electrical distribution system functional inspections (EDSFI<sup>3</sup>) and inspections of selected safety systems (e.g., high pressure coolant injection and high pressure core spray systems) in BWR plants.<sup>2</sup> In the EDSFI activities, risk-based insights on electrical distribution system (EDS) functionality was found to be useful in prioritizing inspection activities as well as a key element in identifying risk significant inspection findings. In the case of safety system inspections, insights on risk significant failure modes of the system provide the flexibility for inspectors to utilize their own field inspection experience to optimize the inspection planning process.

## CONCLUSIONS

On the basis of lessons learned from actual application of the risk-based insights to optimize inspection planning activities, some of the key benefits include:

- a) optimized inspection strategies and possible reduction inspection planning times,
- b) a rational basis for the selection of safety significant inspection items and subsequent evaluation of inspection findings, and
- c) enhanced communication of possibly "hidden" safety concerns to plant management responsible for maintaining safe and reliable operation of the nuclear power plant.

Finally, potential applications of risk-based methods for other regulatory activities such as operator licensing, event assessment and resolution of generic issues are being explored. The application of PRA technology in these various NRC regulatory activities is a supplement to the traditional deterministic methods which are continued to be utilized.

## REFERENCES

1. S. Wong, et al., "Application of Risk-based Methods for Inspection of Nuclear Power Plant Systems," PSAM II - International Conference Devoted to the Advancement of System-based Methods for the Design and Operation of Technological Systems and Processes, San Diego, CA, (1994).
2. S. Wong, A. DiBiasio, and W. Gunther, "High Pressure Coolant Injection (HPCI) System Risk-based Inspection Guide - Browns Ferry Nuclear Power Station," NUREG/CR-6022, BNL-NUREG-52370, Brookhaven National Laboratory, Upton, NY (1993).
3. S. Wong, "Risk/Reliability Methodology for Evaluation of Electrical Distribution Systems in Nuclear Power Plants," BNL Technical Report L-2065/6-23-92, Brookhaven National Laboratory, Upton, NY (1992).
4. USNRC Policy Paper SECY-94-219, "Proposed Agency-wide Implementation Plan for Probabilistic Risk Assessment (PRA)," memorandum from EDO J. Taylor, Washington, D.C. (1994).