The computerized expert system: An innovative approach to an easily customized plant maintenance tool

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1 INTRODUCTION

One critical aspect of nuclear power plant operation is plant maintenance. Its rapid and efficient performance ensures maximum plant availability at the required safety level. While computerized expert systems can provide cost effective solutions to plant maintenance needs, the wide range of individual plant design requirements and installation environments emphasizes the need for a rule-based expert system whose components can be easily customized to respond to plant specific design and maintenance requirements. This paper discusses the techniques employed in the recent development of a microcomputer-based expert system called PbSHIELDING. Designed for the evaluation of the use of temporary lead shielding on nuclear power plant piping, PbSHIELDING will be used to illustrate how a versatile expert system can be easily adapted to suit individual power plant needs.

2 THE EXPERT SYSTEM

An expert system is designed to make decisions and perform evaluations commonly associated with persons having expertise in a particular area. These decisions are made utilizing the same tools and information, collectively called the knowledge base, available to the human expert. To perform these functions an expert system must contain three primary elements: the data base, the rule set, and the rule interpreter. The data base contains factual information which will be used at all levels of input. The rule set contains the domain-specific or expert knowledge which will be applied to particular functions or calculations within the program. The rule interpreter is the general reasoning program which defines the appropriate bounding assumptions, makes the required model decisions and performs the necessary analytical calculations. The rule interpreter, therefore, must be able to recognize the level of input the user is able to provide and obtain from the data and rule set sufficient information to perform the analysis. The following paragraphs will discuss how each of these elements was implemented in the PbSHIELDING system to develop a versatile, easily customized plant maintenance tool.

3 THE PbSHIELDING EXPERT SYSTEM

In 1983 the United States Nuclear Regulatory Commission expressed a concern in IE Information Notice 83-64 (Reference 1) with regard to the use of lead shielding on piping systems. The Commission encouraged efforts to minimize workers' exposure to radiation through the use of shielding, but re-emphasized the need to perform evaluations to determine the weight effects of the shielding on the piping's ability to perform its intended safety function. In order to continue to use shielding effectively, plant personnel needed a method to quickly and easily evaluate the effects of shielding loads on piping.

This need formed the basis for the development of the PbSHIELDING expert system. While the IE Notice had emphasized the need to evaluate temporary lead shielding loads, it was clear that the industry also had a need to rapidly evaluate other loads, both permanent and temporary, on piping systems. Some examples were loads due to placement of permanent shielding, temporary scaffolding, and temporary rigging and hoisting equipment on piping systems.

The effectiveness of PbSHIELDING as a plant maintenance tool was dependent on the level of versatility which could be achieved in its design. The primary function of the system was to allow plant maintenance personnel to rapidly evaluate temporary loads on piping. To effectively do this throughout the nuclear power industry, it was required that the system function for a variety of power plant designs, be used by personnel with varying levels of expertise, and operate on various plant unique computer hardware.

Along with advances in reactor pressure vessel (RPV) technology came changes in the design basis for the power piping systems. The PbSHIELDING system design had to be applicable to piping systems utilized in Boiling Water Reactors (BWR) or Pressurized Water Reactors (PWR). This meant that the temporary loads which would be evaluated had to be considered in conjunction with any or all of the loads which form the design basis for the particular reactor pressure vessel. This could, for example, consist of LOCA related loads which have been postulated for the G.E. Mark II BWR.

The versatility of the software system had to accomodate the plant design basis not only in terms of design loadings but also in terms of the design code which forms the plant licensing basis. This code could, for example, be 1967 ANSI B31.1 with AISC used for the design of piping supports or it could be ASME including NF design of supports.

Another factor which was considered in the versatility requirements for the design of the PbSHIELDING system as a maintenance tool was the end user. As a maintenance tool it would be used predominately by plant personnel including not only engineers, but also health physics, radiation protection, and maintenance personnel.

Unique plant operational and maintenance procedure specifications indicated a requirement for additional flexibility in the PbSHIELDING expert system. Commitments, both internal and to the USNRC were made by the operating utilities to use specific procedures to control and track the placement of temporary loads on piping.

Finally, the computer hardware used or accepted at individual plants varies significantly. The effectiveness of PbSHIELDING as a maintenance tool was partially dependent upon the ease with which the software could be installed on the wide range of computers and operating systems found within the industry.

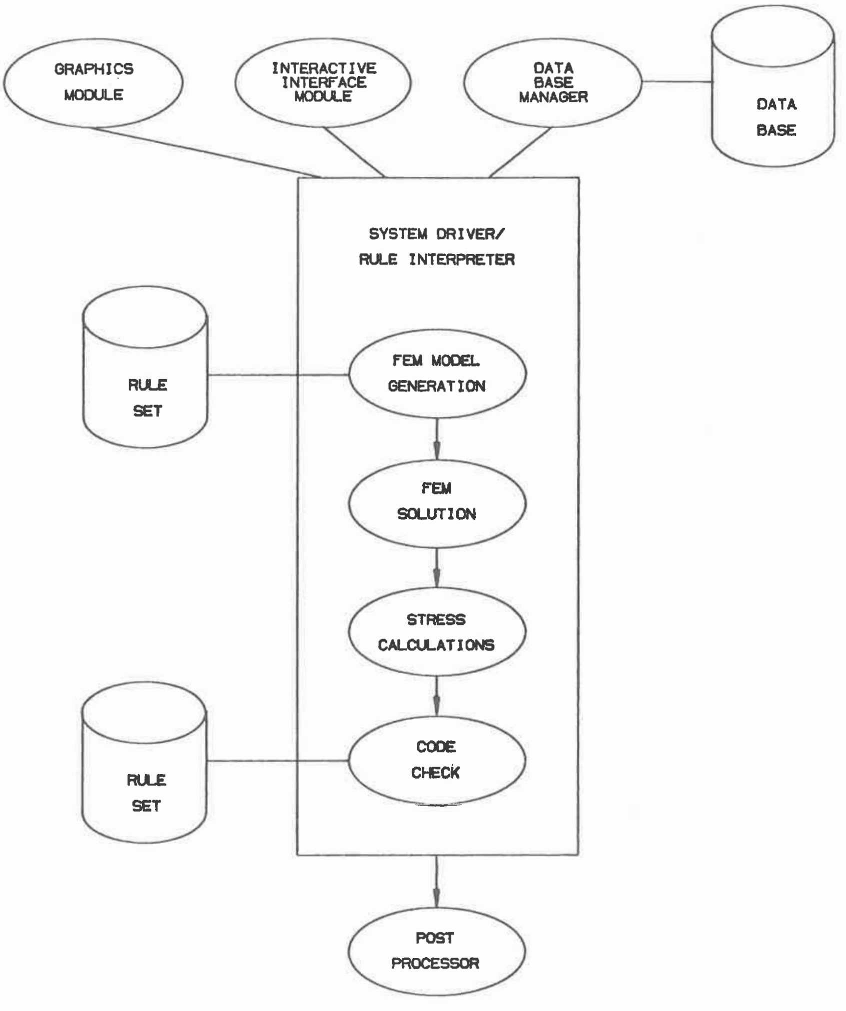

FIGURE 1. COMPONENTS OF THE PbSHIELDING EXPERT SYSTEM

4 DESIGN OF PbSHIELDING

The development of PbSHIELDING as an easily customizable plant maintenance tool was facilitated by the use of a modular program structure. As shown in Figure 1, the PbSHIELDING system driver or rule interpreter is the core of the PbSHIELDING expert system. The solution technique employed by the rule interpreter is the generation and solution of a finite element piping model, calculation of piping stresses and support loads, and determination of allowable additional system loading based on design stress allowables (Reference 2). Since this solution technique for evaluating loads on piping systems remains the same regardless of the specific application, the rule interpreter does not change from one installation to another.

The program modules which PbSHIELDING's system driver accesses, however, are designed to be easily tailored to site-specific characteristics and requirements. The system driver first accesses the program's interactive interface and graphics modules, from which all user input is defined interactively through menu-driven input sequences and color graphics. Because of the wide range of potential users of the PbSHIELDING system, the interactive and graphics modules of the program were designed to accomodate users at varying levels of piping analysis expertise. As a minimum, the user is required to know only the system and line on which lead shielding will be placed, as well as the operating status of the plant. No knowledge of the plant's design parameters or the system's configuration is required. At the second level of expertise, the user must be able to supply additional information about the local piping/support configuration of the system being evaluated. At the third level of expertise, the user is provided the opportunity to overide or supplement some of the existing data base information. This capability is particularly useful for evaluations with special system requirements, but use of PbSHIELDING at this level requires considerable expertise in piping analysis techinques.

The program's graphics module was designed not only for ease of user input at all levels of expertise, but also for easy program installation on a wide range of computer hardware environments. Although PbSHIELDING is a microcomputer-based software system, it has been successfully installed on VAX 11/780 and Prime miniframe computers as well as on an IBM mainframe computer systems. PbSHIELDING's graphics routines were designed to contain all system-dependent code within several subroutines so that program conversion for use on different operating systems requires modification of only those routines.

Once all user input has been obtained, the system driver accesses the data base manager module which, based on information provided by the user, extracts the required plant specific information required to perform the evaluation (Reference 3). This information includes data which is based on the plant's code-of-record or design basis. For example, stress intensification factors and stress allowables to be used in the evaluation must be part of the plant-specific data base since they depend on whether the plant was designed to ASME or ANSI standards. In addition, material and insulation properties and response spectra data are part of the data base since they are established in the plant's FSAR requirements.

The versatility of the PbSHIELDING expert system is further evidenced by the inclusion of system/line data specific to each plant in the program's external data base. The number and types of systems which may be evaluated by the PbSHIELDING program vary widely from one nuclear plant to another; for example, a BWR plant will typically place shielding in 15-20 systems within the plant. A PWR plant, however, will typically place shielding in less than 10 systems (Figure 2). PbSHIELDING has been designed to accomodate as many systems and lines as required for each installation. In addition, since the evaluation of piping is required for design basis loads (LOCA, SRV, postulated break loads) which may differ at each plant, the external data base is designed to accomodate input data for these requirements.

Once all user input and data base information has been collected, the PbSHIELDING rule interpreter formulates the finite element model and determines piping stresses and support loads. Determination of the modelling parameters is made by access to PbSHIELDING's rule set. In

BWR SYSTEMS	PWR SYSTEMS
Main Steam	Chemical and Volume Control
Extraction Steam	Drainage
Feedwater	Primary Water
Condensate	Reactor Coolant
Heater Drains	Residual Heat Removal
Reactor Recirculation Piping	Spent Fuel
Reactor Water Cleanup	Safety Injection
Fuel Pool Cooling and Cleanup	Waste Disposal
Off-Gas	
Radioactive Drains	
Radwaste	
Residual Heat Removal	
Reactor Core Isolation Cooling	
Low Pressure Core Spray	
High Pressure Core Spray	
Pressure Suppression Piping	
Core Spray Piping	
Low Pressure Coolant Injection	
Shutdown Reacotr Cooling Piping	
High Pressure Coolant Injection	

Figure 2. BWR vs. PWR Systems Which Typically Require Shielding

addition, the stress and code check performed by the rule interpreter extracts coefficients for the governing stress equations from the rule set, since these again may be different for each installation. This use of the rule set allows for additional versatility of the PbSHIELDING expert system. For example, PbSHIELDING was originally developed for the evaluation of temporary lead shielding on piping systems. However, by changing several parameters of the external rule set, PbSHIELDING was easily modified to evaluate the placement of permanent lead shielding on piping systems. With another modified application of the rule set, PbSHIELDING was adapted to evaluate scaffolding and hoisting/rigging equipment loads in addition to distributed lead shielding loads.

Once allowable shielding quantities are determined, the PbSHIELDING system driver processes the results through the program's post-processor module. Because the documentation or record-keeping requirements may vary in format for each PbSHIELDING installation, the post-processor was designed to be easily customized.

5 THE EFFECTIVENESS OF MAINTENANCE EXPERT SYSTEMS

The development of expert systems for use in nuclear power plant maintenance has revealed advantages in the replacement of the human expert with a computerized expert.

The advantages of a computerized expert system are seen in terms of time and cost savings. Because an expert system is readily available, delays in unscheduled maintenance activities are minimized. In addition, the use of an expert system will ensure the quality of technical decisions and ensure that the high level of plant safety is maintained.

When compared to alternative methods of lead shielding evaluation, the PbSHIELDING system demonstrates the significant time and cost savings provided by this type of maintenance expert system. Simple hand calculations or use of generic charts or tables to determine allowable lead shielding quantities are very conservative. PbSHIELDING provides high lead shielding allowables, thereby reducing worker exposure. The cost savings associated with this alone is significant. The accuracy of rigorous piping analysis is high and will result in lead shielding quantities higher than those provided by PbSHIELDING, but the time required to perform this type of analysis could result in extended down time and high evaluation costs. The use of this and other maintenance expert systems can be extremely cost effective and can help ensure maximum plant availability while maintaining a high level of plant safety.

6 REFERENCES

1) USNRC, IE Information Notice No. 83-64, "Lead Shielding Attached to Safety-Related Systems Without 10CFR50.59 Evaluations", September 1983.
2) Impell Corporation, "PbSHIELDING Control Manual", Version 2B, July 10, 1985.
3) Impell Corporation, "PbSHIELDING Theoretical Manual", Version 2B, July 10, 1985.