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collaborative agreement to jointly develop breeder reactor fuel-reprocessing technology.

The development of the data-base structure is the crucial first step. A format similar to that used by the Centralized Reliability Data Organization[2] for liquid-metal reactors was used as a guide to develop the structure and data-entry screens for the dissolution system reliability data base. The dissolution system is divided into nine subsystems: acid feed, auxiliary, control, condensate return, dissolver, dissolver off-gas, fuel feed, hulls removal, and product withdrawal. These nine subsystems cover every part of a typical dissolution system and can provide a large variety of reliability, availability, and maintainability information. The identification of generic dissolution components follows the establishment of the framework or structure of the data base.

The data base is designed to work at the equipment component level. The definition of a component can be a cause of debate. For example, in an automobile a component could be a gear in the transmission or be the entire transmission. The definition of a component depends on a number of factors: the desired level of detail for retrieval of reliability information and the economic feasibility and value of collecting the storing information at that level. In a spent-fuel dissolution system, repair of failed equipment is usually accomplished by removing and replacing the failed item with a spare. Returning to our analogy of the automobile transmission, if the transmission were a component in a reprocessing plant, upon failure, the transmission would be replaced with a spare transmission; the transmission would not be disassembled and the faulty gear replaced in the hostile environment of the process cell. A component is therefore defined at the level at which a part is to be replaced. For the dissolution system data base, 18 generic components (e.g., motors, pumps, valves, etc.) have been identified as constituents of the reliability data base.

The data base utilizes three separate files: the engineering data file, the operating data file, and the event data file. The event data file is perhaps of most interest to the plant operator. This file records narrative descriptions of the failure, the root cause of the failure, and the corrective action that resulted from the failure. Keyword entries describe event modes, causes, etc. Repair or maintenance time to correct the failure and other useful information are also available. The operating data file stores the operating history of the system so that failure rates can be calculated. The engineering data file defines the components for which data are collected. Engineering data fall into two categories, component descriptors (manufacturer, model numbers, etc.) and design parameters (design and operating temperatures, pressures, etc.).

Reliability information is entered directly onto an entry screen. The data entry screens contain memo fields (i.e., narratives) for a description of failure and repair events in addition to keyword entries that promote rapid information retrieval. The PC monitor displays templates of the various data forms, and the data collector simply fills in the blanks with various failure and repair information. On-screen prompts and on-screen help capabilities assist the data collector in completing the forms. For example, if a data form requires a keyword and the data collector does not know it, a "help" key retrieves a listing of permitted keywords for the specific data block in question. A keyword search-and-retrieval capability is available. If a control room operator needs the operating, failure, and repair history of some specific equipment in developing some diagnosis analysis or in planning a repair, the operator simply searches the data file for historical information. This capability aids in diagnosing a failure and in projecting repair and downtimes by evaluating previous events. In the near future, dissolution data may undergo mathematical and statistical analyses to calculate failure and repair rate and failure and repair density distributions.

This data base is being installed in Oak Ridge National Laboratory's (ORNL's) integrated equipment test facility, where operations data are being collected on a prototypical rotary, continuous dissolver. Although the data base is established for the specific system in place at ORNL, the data base is flexible and can be tailored to other nuclear fuel dissolution systems.

In summary, a reliability data base has been developed for a nuclear fuel dissolution system. The data base resides on a PC, includes narrative descriptions of failure and repair events, and has keyword search-and-retrieval capabilities. These features enable the plant operator to plot failure trends for specific equipment, subsystems, and systems. It allows the retrieval of historical data for use in diagnosing faults and projecting maintenance requirements. It provides a record of root causes of failure and the resulting corrective actions. The designer can use the data base to calculate failure and repair rates and failure and repair density distributions for use in the probabilistic design of followup facilities.

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1. *Federal Register*, **56**, *132*, 31306 (July 10, 1991).
2. J. J. MANNING et al., "A Guide for Completing Input Data Forms for CREDO – A Centralized Reliability, Availability, and Maintainability Analysis Center for Liquid Metal Cooled Reactor and Test Facility Components," ORNL/TM-9892, Oak Ridge National Lab. (Nov. 1986).

3. Expert System for Maintenance Management of a Boiling Water Reactor Power Plant, *Hong Shen, Luen W. Liou, Samuel Levine, Asok Ray (Penn State), Michael Detamore (PP&L)*

An expert system code has been developed for the maintenance of two boiling water reactor units in Berwick, Pennsylvania, that are operated by the Pennsylvania Power and Light Company (PP&L). The objective of this expert system code, where the knowledge of experienced operators and engineers[1] is captured and implemented, is to support the decisions regarding which components can be safely and reliably removed from service for maintenance. It can also serve as a query-answering facility for checking the plant system status and for training purposes. The operating and maintenance information of a large number of support systems, which must be available for emergencies and/or in the event of an accident, is stored in the data base of the code. It identifies the relevant technical specifications and management rules for shutting down any one of the systems or removing a component from service to support maintenance. Because of the complexity and time needed to incorporate a large number of systems and their components, the first phase of the expert system develops a prototype code, which includes only the reactor core isolation coolant system, the high-pressure core injection system, the instrument air system, the service water system, and the plant electrical system. The next phase is scheduled to expand the code to include all other systems. This paper summarizes the prototype code and the design concept of the complete expert system code for maintenance management of all plant systems and components.

The expert system code is structured with two major interacting modules: (a) system and component data base and (b) rule base, along with appropriate user interfaces. PROLOG was chosen as the computer language to program the code because its backtracking features are ideal for searching data bases, using such data (i.e., facts) to modify the system status, and for obtaining relevant technical specifications.[2] The program is menu driven and user-friendly, starting with the main menu, which allows determination of plant or system status, maintenance of components, putting components back into operation, and disabling or activating electrical components.

The code utilizes the concept of a relational model where the data base and associated operations are presented in the form of tables for both system and component levels. The plant data base at the system level stores the status and relevant information for all systems. This information is implemented as lists because of the availability of fast searching techniques in the PROLOG environment. At the component level, each entry in the table of the respective system represents one component and has multiple attributes to represent all relevant characteristics of the component. To access the data quickly, each system is provided with its own data base, which consists of different types of components. The electrical system components are stored separately in a tree structure because they operate under different rules; i.e., if an electrical component is deactivated, then all components within the subtrees are disabled because they are connected to this electrical component.

The rule base is build on the following major rules: If a component is scheduled for maintenance or reinstatement into operation, then the expert system determines whether there is a change in the respective system status. If removing a component from the system shuts it down, then the component type is *cut 1*. If two components are required to shut the system down, then they are both of *cut 2* type. The rule base must recognize cut 2 pairs. Other rules and regulations have been imposed to judge whether the maintenance can be performed under certain conditions. Also, a change in the system status may alter the relationship (e.g., contingent, high risk, operating, nonoperating, full capacity, or reduced capacity) of this system with others. Since the data base and the rule base are written separately for each system, the code has the capability to call a part of the data and rules, make the decision, and then change the relationship between the systems. This makes the algorithm faster and more effective in utilizing the computation time and memory space. It is especially efficient for automatic tracing of all relevant components that are affected by the disabling of an electrical component.

The prototype code is being expanded to include all of the pertinent systems and incorporate PP&L's related computer program and management techniques. In the future, a more friendly user interface will be developed by using the PROLOG tool provided to access PP&L's programs and increase program flexibility and reliability.

The program is being developed under the supervision of PP&L plant and engineering personnel to ensure that the terminology and operational characteristics of the expert system are consistent with current PP&L operational procedures and techniques.

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1. J. A. BERNARD, T. WASHIO, *Expert Systems Applications Within the Nuclear Industry*, American Nuclear Society (1989).

2. D. MERRITT, *Building Expert Systems in PROLOG*, Springer-Verlag, New York (1989).

4. Testing Program Overview: What Does a Good Program Look Like? *Andrew S. Hegedus (PECo, Delta)*

INTRODUCTION

A good testing program is vital to the safe, reliable, and efficient operation of a nuclear facility. A testing program consists of more than scheduling, performing, and reviewing results. It includes seven interrelated critical elements, all of which are necessary to provide complete control over a station's testing program.

The personnel at Peach Bottom atomic power station wanted to evaluate their testing program. The result was a report that described the framework for a complete testing program. Once the framework was developed, an implementation team was formed to develop the specific plan and schedule for modifying the existing program to conform to the framework. This implementation is ongoing.

TESTING PROGRAM EVALUATION

The report was generated by first defining the visions and objectives for our testing program. Once bounded, a data gathering phase was started by asking the following questions:

1. What do we do now?
2. How does Philadelphia Electric Company senior management view a testing program?
3. What do other plants do?
4. What constitutes an excellent testing program to regulators and industry oversight groups?
5. What are appropriate standards for an excellent testing program?
6. Where are the project "givens" leading us?

TESTING PROGRAM CRITICAL ELEMENTS

All these data were assembled and reduced to define the seven critical elements of a testing program:

1. Identify tasks from source documents.
2. Include tasks in the tests.
3. Identify need to perform test.
4. Inform work group of need and schedule test.
5. Perform test.
6. Review completed test.
7. Update data base, log completion, and send to storage.

The most visible elements of this program are Nos. 3 and 5 because the failure of these elements for technical-specification-related testing results in a licensee event report to the U.S. Nuclear Regulatory Commission. An especially challenging area is the control of situational or event-based testing (rather than periodic). Specific controls are necessary to ensure that all events are captured by tests and that appropriate triggers exist to cause the test to be performed. Weaknesses are difficult to discover, and the root causes can also be difficult to fix.

Another vital component of the process is a feedback mechanism to monitor the performance in each of the critical elements. Performance indicators are being developed, including management performance expectations, to monitor the processes.

Along with the critical program elements, an organizational structure was defined that facilitates program oversight, work group involvement, ownership and accountability, document flow path, and documentation.

Although not process necessities, the need for several new information resources was also defined by the study. Once generated, some of the cross references will save considerable post-maintenance test planning time and will improve the control of limiting-conditions-for-operation testing.

CONCLUSION

This framework has helped to define and clarify all aspects of a testing program that are vital to its ability to continue satisfying its intent. This framework can also provide a basis for others to evaluate their programs to determine the performance of their processes. The implementation of the improvements at Peach Bottom will lead to excellence in the testing area.