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INSIGHTS INTO IMPROVING THE EFFICACY OF NUCLEAR POWER PLANT INSPECTION PROCEDURES BASED UPON RISK ANALYSIS

Final Report

A. M. Plummer R. S. Denning
Battelle Columbus Laboratories

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Battelle Columbus Laboratories
505 King Ave.
Columbus, OH 43201

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ABSTRACT

A preliminary study was conducted to determine how the insights gained through the Reactor Safety Study(1) might be applied to improve the efficacy of nuclear power plant inspection activities. Abstracts of Licensee Event Reports and non-compliance citations for all operating plants for selected periods were reviewed to identify and classify performance deviations associated with risk-mitigating systems. Procedural deficiencies were observed to be an important factor in these deviations. Although no changes in the inspection program can be recommended as a result of this preliminary study, possible approaches to improving the efficiency of the inspection program were identified. Further study of the following areas is recommended.

(1) The allocation of inspection effort based on the relationship of each inspection activity to the control of risk

(2) The use of Licensee Event Reports and non-compliance citations to identify the causal factors in performance deviations or as the basis for the evaluation of the risk-related performance of plants

(3) The review of test and maintenance procedures for risk-mitigating systems to identify procedural inadequacies that lead to performance deviations.

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Introduction

This report describes a preliminary study, conducted in two phases, for the U.S. Nuclear Regulatory Commission to determine how the insights developed through the Reactor Safety Study (RSS)[1] might be applied to improve the efficacy of nuclear power plant inspection activities. Phase I was principally a familiarization phase in which the Inspection Manual of the Office of Inspection and Enforcement was reviewed to identify modules containing risk-related activities. Efforts during this phase were aided by discussions with members of the headquarters staff and included a plant visit with an inspector. The Phase II activities were divided into two tasks which examined: (1) The Sensitivity of Reactor Risk to Non-Compliance and (2) The Adequacy of Test and Maintenance Procedures.

Limitations of the Study

The intent of this study was to gain a sufficient understanding of the inspection process and its relationship to the mitigation of risk to determine whether insights obtained from the Reactor Safety Study could be of assistance in the orientation of inspection efforts. Although Battelle has attempted to relate the results of this review to possible changes in the inspection program, it was recognized that only the staff of the Office of Inspection and Enforcement has an adequate understanding of the inspection process to fully appreciate the implications of the material presented. Consistent with the preliminary nature of the study only the Operating Phase of the Inspection Manual was considered. In addition, the results were not expected to include, or be based on, extensive quantitative analysis or in-depth review of occurrences. The information sources used in the study contained brief summaries of citations and occurrences, from which the affected systems, their states of failure, and causes of failure were identified and categoized; the full reports of these deviations were not reviewed. Summaries of citations over a period of about one year, and those of occurrences over a period of about six months were reviewed.

Definition of Terms

Risk Mitigating Systems. For the purpose of this study risk mitigating systems were defined as those whose failure on demand can result in the important accident sequences identified in WASH-1400. These systems are listed in Table 1; note that no ranking by relative importance is intended. Risk mitigating systems are not the only systems in the plant that are risk related. Systems involved with accident initiators such as the primary coolant system or the plant control system also affect risk. In the Reactor Safety Study, accidents involving fuel melting, which exceed the design bases of the plant, were found to dominate the risk to the public. The functioning of the risk mitigating systems has a major effect on the avoidance of fuel melting or the reduction of the consequences of accidents involving fuel melting.

Common Cause or Common Mode. Common cause failures are failures of two or more components by the action of a single failure-inducing mechanism. The term "common cause" is preferred over "common mode", but both are used here with the same meaning. Common cause failures are particularly important in nuclear power reactor risk because redundancy is provided in the safety systems. The probability of the simultaneous failure of all of the redundant trains of a system can be much higher for a common cause fault than would be the case if the failures for each train were independent.

Performance Deviation. The term performance deviation is used in this study to represent system faults that are the direct result of human error. Human errors that are citable or must be reported in Licensee Event Reports (LER's) are examples of performance deviations. The definition is intended to include all human errors that can reduce the availability of risk mitigating systems.

TABLE 1. RISK MITIGATING SYSTEMS*

Auxiliary Feedwater (PWR)
Consequence Limiting Control (PWR)
Containment Heat Removal (PWR)
Containment Leakage
Containment Spray Injection (PWR)
Containment Spray Recirculation (PWR)
Electric Power Systems
Emergency Coolant Injection
Emergency Service Water (BWR)
High-Pressure Recirculation (PWR)
High-Pressure Service Water (BWR)
Low-Pressure Recirculation (PWR)
Reactor Protection
Safety Injection Control (PWR)
Sodium Hydroxide Addition (PWR)
Vapor Suppression (BWR)

*Risk mitigating systems are defined as those whose failure on demand can result in the important accident sequences identified in WASH-1400.

Review of Inspection Modules

The initial task of the study was a review of the inspection modules for the purposes of (1) becoming familiar with the inspection process, (2) identifying the modules which are used to monitor risk-related activities, and (3) evaluating the degree to which the inspection program is oriented toward factors that influence risk. Familiarization activities included discussions with IE headquarters staff and the observation of a portion of a plant inspection.

The inspection process is guided by procedures or modules, as they are called, contained in the Inspection Manual.[2] These modules provide detailed instructions and guidance for the inspection of all types of licensed facilities. Each inspection activity is included in a module. The modules form the basis of a tracking system used to ensure the timely inspection of various activities. The scope of the present study was restricted to the review of the Manual Chapter covering the operations phase of light water power reactors. This chapter is comprised of nearly 100 modules that range from the conduct of meetings with plant management to the technical review of in-service inspection test results. About 30 of these modules are completed annually on a routine basis at an operating plant. These were reviewed to identify the ones directly involving the inspection of risk mitigating systems. The purpose of this review was to determine the extent to which risk mitigating systems were examined in plant inspections.

The eight modules listed in Table 2 were judged to have a direct relationship to the risk mitigating systems identified in Table 1 and include those modules that have specific inspection requirements for these systems. For inspection purposes, plant systems are generally grouped by the categories used in the standard Technical Specifications: Reactivity Control and Power Distribution, Instrumentation, Reactor Coolant, Emergency Core Cooling, Containment, and Plant and Electric Power. It should be noted that each of the risk mitigating systems identified from WASH-1400 is included in these more general categories. These important systems will therefore be reviewed periodically by the inspector at some level of frequency in the current inspection program.

TABLE 2. ROUTINE INSPECTION MODULES WITH DIRECT RELATIONSHIP TO RISK MITIGATION SYSTEMS

Module Number	Title
42700	Procedures
56700	Calibration (Technical Specification Requirements)
56701	Calibration
61700	Surveillance
61701	Surveillance (Complex Systems)
62700	Maintenance
71710	Review of Plant Operations
71720	Review of Safety Limits, Limiting Safety System Settings, and Limiting Conditions for Operation

A relatively small fraction of modules, 8 out of 40, was judged to have a direct association with risk mitigating systems. This fraction does not accurately represent the extent to which the inspection program is oriented to the control of risk, however. First, the various modules do not involve the same levels of inspection; some are done more frequently or require more time than others. Secondly, some of the more general modules may not have direct association with risk mitigating systems but have high significance to risk. Training of plant personnel, for example, is a general activity which is very important to risk. Thirdly, some fraction of the inspection effort involves auditing of the plant surveillance program which has the intent of reducing the likelihood of accident initiating events. Finally, the modules noted are completed on a routine annual basis; there are similar (and generally more complex) modules scheduled for refueling periods and non-routine modules that are used to follow-up occurrence reports.

In order to investigate more closely the risk orientation of these modules, the periodic surveillance requirements of the standard Technical Specifications for a specific plant were tabulated according to the systems identified for review in the modules. The results of this comparison are shown in Table 3 where the total number of requirements and number of requirements for risk mitigating systems (for one year and one reactor) are listed for each system category. Hourly and refueling requirements are not included in this tabulation. Note that individual test and channel checks have been counted, i.e., a check that is performed once each shift contributes 1095 requirements to the tabulation. There are no requirements involving risk mitigating systems in the Reactivity Control and Reactor Coolant categories. These categories are more closely associated with possible accident initiators rather than risk mitigating systems.

Table 3 indicates that the surveillance requirements for risk mitigating systems are not evenly distributed among the categories. Since the module guidance generally directs the inspector

TABLE 3. APPROXIMATE NUMBER OF SURVEILLANCE REQUIREMENTS PERFORMED PER YEAR*

System Category**	Risk Migitating Systems	Total
Reactivity Control & Power Distribution	0	6,190
Instrumentation	27,260	37,720
Reactor Coolant	0	5,030
Emergency Core Cooling	4,750	4,750
Containment	50	1,710
Plant & Electrical Power	2,610	4,700

* Tests performed during refueling are not included.
** Typical categorization used in inspection modules.

to review at least one test from each category, the auditing effort may be evenly distributed with respect to system categories but not necessarily with respect to risk-related surveillance activities. Based on these observations, it is concluded that the potential exists for improving the efficacy of inspection by weighting the sampling of tests to be audited to obtain a representative selection of risk-related activities.

An additional observation is that the number of risk-related tests is too large to make complete review practicable, without a significant increase in inspection effort. However, from a risk perspective the complete audit of each of the activities of the plant operator is not necessary. The principal purpose for reviewing tests in the NRC inspection program appears to us to be to assure that the management controls of the plant are effective rather than to cross check the results of each test. In fact, occasional failure to perform a test has very little effect on the unavailability of safety systems or on plant risk. By examining a sample of tests, however, the inspector should be able to evaluate how well the plant procedures are being followed. It is recommended that a study be undertaken to develop a quantitative basis for the frequency of auditing surveillance tests.

It was not possible within this effort to determine the amount of inspection time that is presently allocated to different inspection activities or to evaluate the degree to which these activities have a risk relationship. It is our general impression, however, that an undertaking of this type would be beneficial and could lead to an approach to the allocation of inspection time that could be more efficient from the viewpoint of controlling public risk. It should not be inferred that based upon risk analysis, the inspection effort can be optimized in a rigorous sense. The relationship between the NRC inspection effort and the risk to the public from nuclear power plants is too complex. A critical evaluation of the various inspection activities from a risk perspective, should lead to a better understanding of the merits and limitations of the existing inspection program, however. The allocation of the inspection efforts might then be established on a more quantitative basis while recognizing that considerable judgment will be required in the quantification.

The Sensitivity of Reactor Risk to Non-Compliance

In the role of enforcement, the inspection staff reviews the activities of the owner/operator to assure that the nuclear power plant is operated in comformity with applicable regulations and commitments. Recognizing that acts of non-compliance will occur in the operation of nuclear plants, the intent of this task has been to evaluate the impact of non-compliances on public risk. Although a very difficult subject to address quantitatively, the relationship between risk and non-compliance is a very important one for the NRC to explore. It is important to understand this relationship not only for assessing the manner in which a utility is operating a plant but also in evaluating the effectiveness of the NRC's own inspection program.

In order to characterize the various types of non-compliances, a number of citations were reviewed. The Enforcement Text for all operating reactors for the approximate period of July, 1976, to July, 1977, was provided by the NRC for the study. This portion of the text contains 1269 citations issued to operating power reactors. Each citation in the Text is identified by a code that associates the deviation with regulatory and licensing requirements and with inspection procedures covering all of the various aspects of plant operation. These codes provided a convenient means of locating citations that might be risk-related. The codes identifying citations related to (1) operating license conditions, (2) technical specification requirements, and (3) safety analysis report commitments were judged to be the only ones that would be of interest to this study. Further, within these three general areas it was possible to eliminate a number of specific codes dealing with areas that obviously are not risk-related: non-radioactive waste release, for example. Through the process of elimination the list of applicable codes was narrowed as much as possible, but without eliminating items of possible interest.

Risk-related citations were selected by first scanning the citation identification codes for the particular requirement codes that indicated a possible relationship to risk mitigating systems.

Each entry so selected (there were about 350) was read and its relationship to risk judged by its content. In making this final selection, only those citations having a direct influence on the availability of risk mitigating systems were considered; administrative deviations, for example, were not included even though they may have involved risk mitigating systems indirectly. A summary of the citations by broad requirement categories is given in Table 4. Of the 1269 citations, 57 were identified as risk-related; these citations are listed in Appendix A.

The risk-related citations fall into two general categories: (1) those having a direct contribution to unavailability in that components or systems were found to be in an inoperable state, and (2) those having a potential contribution in that they involved activities that could either cause an inoperable state or fail to assure operability. These categories are listed in Table 5; the number of citations in each category is also shown.

It is interesting to note that a large fraction (1212 of 1269) of citations were not identified as having a direct relationship to risk. If citations which relate to potential accident initiators had been included, the fraction identified as having a direct risk relationship would have been greater. However, most citations involve administrative control failures such as failure to report an occurrence within a specified time. Although many of these citations appear to have negligible significance to risk, a failure in any aspect of management control could be indicative of a general laxness affecting the safety of the plant. In the preliminary review of citations performed in this effort, however, there was no apparent correlation between the total number of citations received by a particular plant and the number of citations that we have identified as risk related. The total number of citations may not, therefore, be a reliable measure of the risk to the public from a plant.

TABLE 4. REQUIREMENT CATEGORIES AND NUMBER OF CITATIONS

Code	Requirements	Number of Citations*
A	10CFR20	115
B	10CFR30, 31, 32, 33, 34, 35, 36	2
C	10CFR40	0
D	10CFR50	25
E	10CFR50 Appendix B	280
F	Facility Lic. Conditions & Tech. Specs.	802(57)
G	10CFR50 Appendix J	1
H	10CFR19	17
J	10CFR55	6
K	10CFR70	2
L	10CFR71	4
M	Materials Lic. Conditions	4
N	10CFR73	2
P	10CFR150	5
R	Safeguards Lic. Conditions	7
S	Safety Analysis Report Commitments	0
T	10CFR21	0
V	Vendor Program Deviations	5

* Risk-related citations in parenthesis.

TABLE 5. NON-COMPLIANCE CATEGORIES

Direct Contributors:	
	Operation with Inoperable Systems or Components (15)*
	Valves Improperly Aligned (5)
	Improper Calibration (1)
Potential Contributors:	
	Post-Maintenance Test Not Performed (3)
	Maintenance Performed Without Procedures (2)
	Test Performed Without Procedures (2)
	Calibration Performed Without Procedures (1)
	Maintenance Procedures Inadequate (8)
	Valves or Circuit Breakers Not Locked (7)
	Test or Calibration Interval Exceeded (13)

* Number of citations in parenthesis.

Source: Enforcement Text for Operating Reactors, 7606 to 7707.

In reviewing the risk-related non-compliance categories, it is apparent that many of the types of faults that underlie non-compliance citations are the same kinds as considered in the fault trees in WASH-1400 to be human error contributors to system unavailability. If we use the term performance deviations to represent human errors in plant operations (including testing, maintenance and management function), the acts that result in non-compliance citations can be considered to be a special class of performance deviations.

An additional source of data on performance deviations can be found in the Licensee Event Reports (LER's). LER's published in Nuclear Safety[3] and having report dates from August, 1976, to February, 1977, were reviewed under the same selection criteria used for citations. The LER's with a direct relationship to risk mitigating systems are listed in Appendix B. Relative numbers of risk-related citations and LER's are summarized in Table 6. No extensive effort was made to correlate these citations and LER's because of the somewhat disparate time intervals involved and the brevity of the descriptions used. From a cursory review it appeared that, while several citations were associated with LER's, the two compilations are generally independent. The tabulations in Table 6 indicate that there are significantly more LER's than citations issued. This difference is understandable when the reasons for both types of reports are considered. It might be expected that non-compliance citations would be more severe from a risk viewpoint than the occurrences that result in a Licensee Event Report. For example, the violation of a Technical Specification limit which would result in a non-compliance citation might reduce the level of redundancy of a system below what was considered acceptable when the limit was established. On the other hand, the occurrences in the LER's appear to have the same basic causes as the non-compliances and are probably as good an indicator of deficiencies in plant management control as the non-compliances. The relatively greater number of LER's suggests that they form a broader source of information on performance deviations.

TABLE 6. RELATIVE NUMBERS OF CITATIONS AND EVENT REPORTS RELATED TO RISK MITIGATING SYSTEMS

Contribution	Number of Reports*	
	Citations	LER's
Direct	21	51
Potential	36	20
TOTAL	57	71

Definition of "Contribution"

Direct: A condition of inoperability existed

Potential: Deviations that could produce a condition of inoperability

* Selected from listings of approximately 1200 each of citations (1-year period) and LER's (6-month period).

Contribution of Performance Deviations to Risk

In order to evaluate the impact of performance deviations on risk, the contribution to system unavailability of various types of human errors was examined within the context of the fault trees which had been developed for WASH-1400. In the quantification of the WASH-1400 fault trees, system unavailabilities were considered to be comprised of the following general contributions:

- Hardware failures
- Test and maintenance unavailabilities
- Common cause failures.

These three categories include contributions from human errors, which differ both in nature and importance in each case. At this point we will explore how the various types of performance deviations within these categories can influence system unavailabilities. As defined in WASH-1400 hardware failures are comprised of failures that are independent of any others that might occur. Both equipment failures and human errors were included as hardware failures in the WASH-1400 analysis and both contributed quantitatively to system unavailability in the same way. The performance deviations we have identified as being related to hardware failures are of two types: (1) those that contribute directly and appear explicitly as human errors in the WASH-1400 fault trees; and (2) those that contribute in a more subtle way as a degrading influence on equipment operating or demand failure probabilities. The following are examples of the first type:

Valves improperly aligned

Instruments improperly calibrated

Bistable switches in the test position.

Functionally, these failures which are the result of human error are the same, respectively, as the equipment failures: (1) a valve that does not operate due to a mechanical or control circuit component failure, (2) an instrument that does not respond properly due to an electronic component failure, and (3) a logic train that does not operate properly due to a faulty relay coil or contact. It should be noted that other types of important human error contributions were considered in the Reactor Safety Study: these can be categorized generally as errors committed under emergency conditions, i.e., after the initiation of an accident. Such errors would not be likely to appear in the sources used in this study. In addition, this study has been concerned principally with performance deviations associated with normal test and maintenance activities, as would be audited in the course of routine inspections.

Examples of the second type of performance deviation that influence equipment failure probabilities in a more indirect manner are:

Surveillance test interval exceeded or not performed

Post-maintenance test not performed

Maintenance performed without procedures

Test performed without procedures

Calibration performed without procedures

Inadequate test or maintenance procedures.

The contributions of deviations of this type do not appear explicitly in the fault trees, although they can contribute to the failures that do appear. They also have the potential to cause or allow a component to be in a degraded state of operability because of improper and undetected mechanical or electrical adjustment, for example. The observable result of this type of performance deviation is a higher-than-normal component failure rate.

The WASH-1400 category "test and maintenance unavailabilities" is comprised of the unavailabilities caused by the intentional removal of systems from service for testing and maintenace. The deviations that contribute directly in this category are those related to operation under conditions exceeding the limits of Action Statements of the Technical Specifications. These performance deviations contribute to risk because systems operate with reduced redundancy during these outage time intervals, and because extension of these intervals beyond the prescribed bounds represents an increase in the normal unavailability.

The remaining category of risk contributors is that of common cause faults. Human error can be a major contributor to common cause faults because humans (operators and technicians) provide a common link between the separate pieces of equipment in the plant. For example, a poorly trained technician who miscalibrates one instrument may very well miscalibrate the same instrument in a redundant train if both instruments are his responsibility. Tables 7 and 8 illustrate the percentage of the unavailability of safety systems attributed to common cause faults in WASH-1400 for the PWR and BWR. In the comments column the source of the common cause is identified. From these tables it is evident that, for many safety systems, common cause faults can be the principal contributor to system unavailability. In the majority of these examples from WASH-1400, human errors were the source of the common cause faults identified. Performance deviations of this type, with the potential for common cause failures, should be of particular concern to the inspection program. In a poorly managed plant, the factors that could result in a strong common cause coupling between failures would be expected to exist, such as inadequate training, poor procedures or a general degradation of the quality assurance program. Thus it is reasonable to speculate that the common cause contribution to system unavailability could be significantly greater in a poorly managed plant relative to an average plant.

Thus far we have attempted to establish the relationships between performance deviations and risk by associating the various types of deviations with system unavailability. To summarize these briefly, performance deviations contribute to risk in two ways: (1) as direct contributions that produce an immediate state of component inoperability, and (2) as indirect contributions that tend to increase the probability of component failure. In addition, performance deviations can occur as independent events, much in the same manner as random hardware failures, or as coupled events that produce simultaneous common cause states of failure in two or more redundant components.

TABLE 7. COMMON MODE CONTRIBUTIONS TO BWR SYSTEM UNAVAILABILITIES

System	Contribution (%)	Comments
Reactor Protection	24	Sensor Miscalibrated
Vapor Suppression:		
Large LOCA		
Small LOCA		
Emergency Coolant Injection:		
Low-Pressure Coolant Injection		
Core Spray Injection		
Autodepressurization	100	Sensor Miscalibrated
High-Pressure Coolant Injection		
RCICS		
Containment Leakage:		
Large LOCA		
Drywell (>6 in.^{2})	98	
Drywell (1-4 in.^{2})	100	Equipment Failure
Wetwell (>6 in.^{2})	96	
Wetwell (1-4 in.^{2})	100	
Small LOCA		
High-Pressure Service Water:		
Required Within 30 Minutes	53	Emergency Procedures Not
Required Within 25 Hours	47	Followed and Valves Misaligne
LPCRS and CSIS Pump Cooling (ESW)	<1	
Secondary Containment		

Source: WASH-1400

TABLE 8. COMMON MODE CONTRIBUTIONS TO PWR SYSTEM UNAVAILABILITIES

System	Contribution (%)	Comments
Reactor Protection		
Auxiliary Feedwater:		
0-8 Hours After Small LOCA	86	Valves Misaligned
8-24 Hours After Small LOCA		
0-8 Hours Without Offsite Power	44	Equipment Failure
Containment Spray Injection	80	Sensors Miscalibrated and Valves Misaligned
Consequence Limiting Control:		
Hi; Single Train	4	
Hi; Both Trains	67	Sensors Miscalibrated or Damaged
Hi-Hi; Single Train	13	
Hi-Hi; Both Trains	92	
Emergency Coolant Injection:		
Accumulators		
Low-Pressure Injection	1	
High-Pressure Injection	1	
Safety Injection Control:		
Single Train	1	
Both Trains	68	Comparator Miscalibrated
Containment Spray Recirculation	37	Equipment Failure
Containment Heat Removal	14	Valves Misaligned
Low-Pressure Recirculation	68	Emergency Procedures Not Followed
High-Pressure Recirculation	75	Emergency Procedures Not Followed
Containment Leakage		
Sodium Hydroxide Addition	20	Valves Misaligned

Source: WASH-1400

In the context of this study, the important relationship is the one between risk and the inspection process. The characteristics of performance deviations that have been discussed suggest, first, the way their contributions to risk might be evaluated and, second, how their frequency might be controlled. The most important characteristic of performance deviations is, for a given reactor, the rate at which they cause safety-related components to be in an inoperable condition. These occurrences are generally reported in citations and LER's which are therefore a means to evaluate risk-related performance. The Nuclear Plant Reliability Data System (NPRDS)[4] would also provide valuable data for this purpose, if it were modified to include a description of the human error causes for failure, since it would include applicable failure data that, for various reasons, were not otherwise reportable.

Having examined the relationship between performance deviations and system unavailability or risk, we will now discuss the manner in which the underlying causes of performance deviations might be identified and the frequency of performance deviations controlled through the inspection program. In identifying the causes of system faults that result from human error it is helpful to note that all of the citations and LER's which we identified as risk-related are also procedure-related. As stated in the Inspection Manual,[2] "procedures guide the operation and maintenance of nuclear facilities". Each of the performance deviations that was reviewed could be related to a cause that is attributed to (1) failure to follow existing procedures, (2) performing activities without the use of required and available procedures, or (3) performir activities according to inadequate procedures. In cases where judgment was required to decide whether the cause was procedural, this judgment was based on the question: could this deviation have been prevented by the proper use of an adequate procedure?

The two principal sources of data on performance deviations available to the NRC are citations and LER's. The Nuclear Plant Reliability Data System (NPRDS)[4] would also provide valuable data for examining the frequency and causes of performance deviations if it were modified to include a description of the human error causes of failure. By collecting and categorizing data on performance deviations, it should be possible for the NRC to identify the principal underlying causes of these errors. It could be of particular value to trace back human errors to find the deficiencies in the applicable procedures that resulted in the error or permitted the error to occur. Having identified the causes of performance deviations, greater emphasis could be given in the inspection program to the audit of test and maintenance procedures to assure that these causal factors are not present. This increased effort could involve the review of a larger sample (or possibly all) of the test and maintenance procedures for risk mitigating systems during the Pre-operational Phase of the inspection program. Because the test and maintenance procedures change during plant life, a strong program of continued review of procedures also appears to be warranted. In the review of operating incidents, the inspection process can interface on a continuing basis with procedures. This review process may be the most effective way to locate and correct procedural inadequacies that allow risk-related performance deviations to occur. The normal follow-up review to abnormal occurrences includes the determination of causes and remedies; added emphasis should be given to the identification of risk-related deviations to assure that their causes are properly identified and that specific remedies are implemented through improved procedures.

In summary, WASH-1400 shows that human errors (performance deviations) are a significant contributor to reactor risk. Of primary importance to the NRC inspection program is the potential that could exist for a general degradation in the management control of plant operations and a resulting increase in human errors. Because of the significance of human errors to the total reactor risk, an increase in human errors would lead to an increase in the risk of the plant. For this reason, the continued evaluation of the management performance of plants should be an effective way for the NRC inspection program to control risk.

The occurrence of some performance deviations in operating a plant is unavoidable. Humans will make errors. It is important to note that the human errors identified in Tables 5 and 6 from a preliminary review of citations and LER's appear to be consistent with the types and frequencies of human errors assumed in WASH-1400. Nor are the observed errors in any sense more serious. Assuming that the risk from reactor accidents obtained in WASH-1400 is acceptable, this review has not therefore identified a need to reduce the rate of human errors. Because of the close relationship between human errors and risk, it is important, however, to understand the causes of performance deviations. To the extent that the rate of human errors can be reduced by practical measures, this would also be desirable.

Adequacy of Test and Maintenance Procedures

The second task outlined for this phase of the study was the review of plant procedures to learn how they are structured and how various inadequacies might cause or allow the occurrence of performance deviations. Two aspects of the procedures were reviewed: the degree to which the style of the procedures conformed to practices that would tend to minimize human errors and the technical adequacy of the procedures. From the inspection and enforcement standpoint, reviewing the technical adequacy of testing procedures is not as difficult as might be imagined. The standard Technical Specifications are quite specific in identifying the type and frequency of test to be performed. The review of the more difficult aspects of technical adequacy, such as the completeness and interval of tests, are therefore primarily a licensing function.

Pursuant to the conclusions reached in the previous task regarding the importance of procedures to the occurrence of performance deviations, test and maintenance procedures were reviewed to identify features that could contribute to the inoperability of components. ANSI N18.7-1976[5] the principal guide for the preparation of nuclear plant procedures, was also reviewed as part of this task. The ANSI standard appears to be an excellent guide for the writing of procedures and, if carefully followed, should result in procedures that tend to minimize the human error contribution to component failures. In particular, the standard stresses the importance of return-to-service and operability requirements. Our review of actual procedures, however, indicates that these elements, even when present, might have varying degrees of effectiveness depending on how they are incorporated. Our observations in this regard are discussed below.

Several maintenance and surveillance test procedures from two plants were made available for this study by the Probabilistics Analysis Staff. Although this represents a rather small sampling of existing procedures, we believe it was sufficient to gain some valuable insights. There was enough variation in similar procedures for a single plant to recognize the types of inadequacies that might lead to the deviations of interest. As noted earlier the deviations that have the greatest impact on risk are the ones that result in inoperable components. According to the guidance of the Inspection Manual, test, calibration, and maintenance procedures should include steps to assure that all equipment is properly returned to service, i.e., that it is operable following such activities. From the standpoint of risk, these appear to be the most important steps in procedures that guide the testing and maintenance of safety systems.

We are concerned here with three kinds of activities: testing, maintenance, and calibration. Each of these involves removing parts of systems from service, performing the activity, and returning the affected parts to service. The possible types of deviations and the preventative measures to avoid these deviations are therefore similar. Given the above observation, the appropriate way to reduce the frequency of performance deviations would be by improvement of procedures and their use.

Six types of procedural steps to return equipment to service were found in surveillance test procedures:

1. A precautionary note at the beginning of the procedure to return all switches to their original positions after completion of the test
2. Notes in the body of the procedure to return particular groups of switches to their original positions
3. A note near the end of the procedure to return all switches to their original position
4. Steps in the procedure to return particular switches or valves to a particular position
5. Steps in the procedure, as above, followed by a step requiring independent verification
6. Check lists, particularly for valves, that show the proper positions after testing.

No obvious inadequacies were noted in the calibration procedures. They include steps to return components to service and provisions for checking setpoints. Pressure instrumentation, for example, is checked by subjecting the sensor to a known pressure and observing the channel response.

In summary, our review of these relatively few procedures showed no obvious inadequacies, but did show variations in methods that could contribute to performance deviations. On the other hand, if some of these procedures were to be associated with activities that produced a high rate of performance deviations, potential procedural contributors should be easy to recognize.

Observations and Conclusions

The objective of the effort that has been undertaken was to review the inspection program of the NRC from a risk viewpoint in order to identify ways in which the program might be made more efficient or more effective. The task is a difficult one because the relationship between inspection and risk is very complex. For example, the mere presence of the inspector, with the implicit threat to the utility management of the discovery of non-compliance, has the effect of strengthening management efforts. The quantification of this effect in terms of improved plant safety is very difficult, however.

In the performance of this study a number of observations and conclusions have been made which relate to the effectiveness of inspection efforts. Some of these are reviewed in the following paragraphs.

Review of Inspection Program

- Within the broad scope of the inspection program, test, calibration and maintenance operations are reviewed periodically for each of the systems identified in WASH-1400 as having high importance to risk.
- Too many test and maintenance activities are performed at a plant for the inspector to review each. From a risk standpoint the inspector needs only to review an adequate sample to assure that a systematic deterioration in the management control of the plant operations does not exist.
- Guidelines for the frequency of inspection of various plant activities are based almost entirely on judgement rather than a quantitative or statistical basis.
- No relative weighting of inspection effort is given among systems identified for review according to the potential risk importance or number of periodic surveillance requirements of the system.

- Some improvement in the efficiency of the inspection program can probably be made through a systematic allocation of inspection effort developed on a semi-quantitative basis without reducing the coverage of risk-related activites.

The Sensitivity of Reactor Risk to Non-Compliance

- The results of WASH-1400 indicate that human error in testing and maintenance can be an important contributor to risk. A poorly managed plant with a resulting higher rate of human errors could be expected to pose a higher risk than an average plant. Since the inspection and enforcement effort focuses on assuring the effectiveness of plant management control, the inspection effort can have a direct influence on risk magnitude.
- Acts of non-compliance by the owner/operator can be viewed as a subset of a broader class of human errors which we have called performance deviations.
- Citations issued for the violation of technical specification requirements would be expected to be indicative of increased risk. However, because a large fraction of non-compliance citations have little direct relationship with risk, the total number of citations may not be a good performance indicator for a plant.
- Licensee Event Reports are an important source of data on plant performance. The review of abnormalities in plant operation is an effective means for the inspector to uncover problems in both equipment performance and management performance.
- Expanded analysis of Licensee Event Reports and Citations could be effective in identifying faulty equipment, faulty procedures or as a performance measure for plant management control.

- The occurrence of performance deviations (human errors) cannot be eliminated. From the limited number of LER's and citations reviewed, there was no indication of a frequency of human errors higher than would be expected.
- The occurrence of performance deviations can usually be attributed to inadequate procedures or failure to follow procedures. By identifying the causes of procedural inadequacies, NRC should be able to effect changes that could reduce or control the rate of these errors.

Adequacy of Test and Maintenance Procedures

- The ANSI standard (N 18.7-1976) for the writing of procedures appears to stress the key elements of good procedures.
- Significant variations existed in the format and quality of the small sample of procedures reviewed in this effort.
- Procedural steps to return equipment to service following tests are an essential aspect of good procedures. These steps are handled in a variety of ways, apparently with different degrees of effectiveness.
- Although the technical adequacy and completeness of testing procedures are believed to have an important impact on risk, the Technical Specifications prescribe the manner of testing. The inspection program can, therefore, influence the technical adequacy of procedures only to the degree to which the procedures satisfy the Technical Specifications.

The purpose of the Operations Phase of the Light Water Reactor Inspection Program "is to obtain sufficient information through direct observations, personnel interviews, and review of facility records and procedures to ascertain whether the licensee's management control program is effective and whether the facility is being operated safely and in conformance with Regulatory requirements"[(2)]. Each of the activities (direct observation, personnel interviews, review of facility records, and review of procedures) appears to be essential. In addition, data analysis could be a beneficial additional acitivity within the inspection program. In order to improve efficiency, it is essential to know how effective each of these activities is. Unfortunately, the inspection program lacks both measures of performance for the owner/operator and measures of effectiveness of the inspection program itself. Without these types of measures, it is difficult to reduce inspection effort or redirect inspection effort with assurance that the effectiveness of the program is not being decreased. In order to develop these measures, considerable additional understanding must be developed of the relationship between the inspection program and reactor risk.

Recommendations

Based upon the conclusions that have been drawn from this effort, the following recommendations are made. At this time, it is premature to suggest changes in the current inspection program. Each of the recommendations would involve investigations which as their end product would evaluate the potential advantages of changes in the program.

- A review should be undertaken of the allocation of inspection effort. In addition to protecting the safety of the public, the inspection program has other functions such as the prevention of the diversion of nuclear materials. Each of the activities in the existing program should be reviewed and the intended function identified. Inspection activities that are associated with the control of public risk should then be evaluated in terms of their effectiveness and their relationship to risk. Although it will be difficult to quantify the relationship between inspection activities and risk, the exercise of making semi-quantitative or qualitative judgements of these activities will help to clarify the role of the inspection program in the control of risk. Included in this study would be an analysis of the guidelines used to specify the frequency of inspection activities.

- Licensee Event Reports and non-compliance citations should be reviewed for an operating period of a number of years. The events should be categorized by cause similar to the breakdown presented in Table 5. The data should be analyzed to identify underlying causal factors for system faults and to evaluate the potential use of evaluated data as performance measures.
- Test and maintenance procedures should be reviewed from a cross section of reactors. The quality of these procedures should be evaluated in terms of consistency with the ANSI guide. Deficiencies in procedures should be identified and the root causes of poor procedures determined where possible. For the reactors whose procedures are being studied, reported occurrences should be reviewed and the causes of the occurrences traced back to procedural inadequacies or other types of breakdown of plant management control.

References

1. "Reactor Safety Study, An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants", WASH-1400, October, 1975.

2. Inspection and Enforcement Manual, U.S. Nuclear Regulatory Commission, Office of Inspection and Enforcement.

3. Nuclear Safety, Nuclear Safety Information Center, Oak Ridge National Laboratory.

4. "Reporting Procedures Manual for the Nuclear Plant Reliability Data System", Southwest Research Institute, April 1974.

5. ANSI N18.7-1976/ANS-3.2, "Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants", approved by the American National Standards Institute, February, 1976.

APPENDIX A

SELECTED RISK-RELATED NON-COMPLIANCES

TABLE A-1. SELECTED RISK-RELATED NON-COMPLIANCES

05000155 7609 FCEP 2
CONTRARY TO TECHNICAL SPECIFICATION 4.1.2.(B), THE PRIMARY CORE SPRAY SYSTEM DID NOT MEET OPERABILITY REQUIREMENTS DURING POWER OPERATIONS FROM JUNE 1975 TO FEBRUARY 1976 DUE TO UNACCEPTABILITY OF WELD NO. 8 WITH CODE (B 31.1.0) FOLLOWING MODIFICATION OFTHE CORE SPRAY SYSTEM IN MAY 1975.

05000237 7614 FCUS 2
CONTRARY TO PARAGRAPH 4.5.A.3 OF THE DRESDEN 2 TECHNICAL SPECIFICATIONS, LPCI PUMPS AND MOTOR OPERATED VALVES WERE NOT TESTED FO OPERABILITY BETWEEN APRIL 11 AND JUNE 1, 1976.

05000237 7706 FDHHJ2
CONTRARY TO TECHNICAL SPECIFICATION SECTION 4.2, CALIBRATION OF THE UNDERVOLTAGE EMERGENCY BUS RELAYS WERE NOT ACCOMPLISHED DURING THE REFUELING OUTAGES OCCURRING IN 1976 ON UNIT 2 AND 3. THE LICENSEE'S OPERATION ANALYSIS DEPARTMENT LAST CALIBRATED THESE RELAYS EARLY IN 1975.

05000237 7715 FDHH 2
CONTRARY TO TECHNICAL SPECIFICATIONS, SECTION 1.0.C.C.A AND B, SURVEILLANCE INTERVALS FOR FIVE-SPECIFIC SURVEILLANCES CONDUCTED ON UNITS 2 AND 3 WERE EXCEEDED IN FEBRUARY 1977. (REF: LERS 237/77-06 AND 249/77-06) TECHNICAL SPECIFICATION 1.0.C.C REQUIRES: (A) A MAXIMUM ALLOWABLE EXTENSION NOT TO EXCEED 25% OF THE SURVEILLANCE INTERVAL AND (B) A TOTAL MAXIMUM COMBINED INTERVAL TIME FOR ANY THREE-CONSECUTIVE INTERVALS NOT TO EXCEED 3.25 TIMES THE SPECIFIED SURVEILLANCE INTERVAL.

05000247 7622 FCEGI2
CONTRARY TO TECHNICAL SPECIFICATION 3.3.A.1.I, THE CIRCUIT BREAKERS FOR THE ACCUMULATOR ISOLATION VAVLES WERE NOT LOCKED IN THE DEENERGIZED POSITION.

05000247 7624 FJFP 2
CONTRARY TO TECHNICAL SPECIFICATION 6.8.1, INSTRUMENT AIR SYSTEM VALVES IA-11 AND IA-11-1 WERE OPEN BUT WERE NOT LOCKED IN THAT POSITION AS REQUIRED BY COL-39.

05000249 7630 FCGS 2
CONTRARY TO TECHNICAL SPECIFICATIONS 3.7.2, THE UNIT 3 LPCI PUMP ROOM FLOOD DOOR WAS FOUND OPEN AND UNATTENDED, DURING A PLANT CLEANLINESS TOUR. UNIT 3 WAS IN OPERATION AT THE TIME OF THE EVENT.

05000249 7706 FDHHJ2
CONTRARY TO TECHNICAL SPECIFICATION SECTION 4.2, CALIBRATION OF THE UNDERVOLTAGE EMERGENCY BUS RELAYS WERE NOT ACCOMPLISHED DURING THE REFUELING OUTAGES OCCURRING IN 1976 ON UNITS 2 AND 3. THE LICENSEE'S OPERATION ANALYSIS DEPARTMENT LAST CALIBRATED THESE RELAYS EARLY IN 1975.

05000249 7715 FDHH 2
CONTRARY TO TECHNICAL SPECIFICATIONS, SECTION 1.0.C.C.A AND B, SURVEILLANCE INTERVALS FOR FIVE-SPECIFIC SURVEILLANCES CONDUCTED ON UNITS 2 AND 3 WERE EXCEEDED IN FEBRUARY 1977. (REF: LERS 237/77-06 AND 249/77-06) TECHNICAL SPECIFICATION 1.0.C.C REQUIRES: (A) A MAXIMUM ALLOWABLE EXTENSION NOT TO EXCEED 25% OF THE SURVEILLANCE INTERVAL AND (B) A TOTAL MAXIMUM COMBINED INTERVAL TIME FOR ANY THREE-CONSECUTIVE INTERVALS NOT TO EXCEED 3.25 TIMES THE SPECIFIED SURVEILLANCE INTERVAL.

05000250 7701 FCKPL2
CONTRARY TO THE REQUIREMENTS OF 10 CFR 50.36(C)(2), REACTOR SHUTDOWN WAS NOT INITIATED ON TP 3 ON SEPTEMBER 9, 1976, WHEN THE REQUIREMENTS OF TECHNICAL SPECIFICATION 3.7.2 WERE NOT MET AT 0530 P.M. WHEN THE 'A' EMERGENCY DIESEL 4160 VOLT CIRCUIT BREAKER WAS OUT OF SERVICE FOR MAINTENANCE THUS RENDERING TP 3 WITHOUT DIESEL CAPABILITY FOR APPROXIMATELY 25 MINUTES.

05000254 7615 FPFGL2
CONTRARY TO TECHNICAL SPECIFICATION 6.2.A, CALIBRATION OF THE UNIT 1 EMERGENCY BUS UNDERVOLTAGE RELAYS WAS PERFORMED ON JANUARY 14, 1976 WITHOUT USE OF PROCEDURE THAT HAD BEEN REVIEWED AND APPROVED AS SPECIFIED.

05000255 7617 FDAP 2
CONTRARY TO TECHNICAL SPECIFICATION TABLE 4.1.1, MONTHLY TESTS INCLUDING THE 25% ALLOWANCE OF SPECIFICATION 4.0.2.A, WERE NOT PERFORMED ON THE POWER RANGE SAFETY CHANNELS AND REACTOR PROTECTIVE SYSTEM FROM ABOUT APRIL 2, 1976 TO MAY 11, 1976.

05000255 7621 FDDG 2
CONTRARY TO THE REQUIREMENTS OF TECHNICAL SPECIFICATION 4.6.1, TESTING OF THE SAFETY INJECTION SYSTEM CONDUCTED AT REACTOR REFUELING DID NOT VERIFY THAT ALL COMPONENTS RECEIVED THE SAFETY INJECTION SIGNAL IN THE PROPER SEQUENCE AND TIMING AS REQUIRED BY TECHNICAL SPECIFICATION 4.6.1.B.

05000255 7622 FCEX 2
CONTRARY TO TECHNICAL SPECIFICATIONS 3.3.2.F, A VALVE (CV 3038), WHICH IS ASSOCIATED WITH THE SAFETY INJECTION SYSTEM, WAS INOPERABLE FOR A PERIOD GREATER THAN 24 HOURS DURING THE PERIOD OF OCTOBER 5-23, 1976, AND REACTOR OPERATIONS CONTINUED.

05000259 7620 FJEFK2
CONTRARY TO T.S. 6.3.A, PROCEDURES WERE NOT ADHERED TO IN THAT THE CORE SPRAY DIFFERENTIAL PRESSURE INSTRUMENTATION FOR SYSTEM II WAS VALVED OUT OF SERVICE DURING OPERATION AND NO CORRECTIVE ACTION WAS TAKEN IN RESPONSE TO THE LIGHTED ANNUNCIATOR PANEL OR THE DATA SHEET WHICH SHOWED AN ABNORMAL READING.

05000261 7606 FJHH 2
CONTRARY TO TECHNICAL SPECIFICATION 6.8 PROCEDURES FOR CONTROL OF MAINTENANCE ACTIVITIES DEFINED IN SECTION 7 OF THE CONTINUING QUALITY ASSURANCE PROGRAM, SECTION 4.2 OF THE PLANT ADMINISTRATIVE PROCEDURES AND IN THE PLANT MAINTENANCE INSTRUCTION 7 WERE NOT ADHERED TO FOR CERTAIN MAINTENANCE ACTIVITIES PERFORMED DURING THE SECOND HALF OF 1975, IN THAT DETAILED WORK INSTRUCTIONS WERE NOT PROVIDED; POST-MAINTENANCE TESTING REQUIREMENTS AND ACCEPTANCE CRITERIA WERE NOT SPECIFIED; RESULTS OF VARIOUS INSPECTIONS WERE NOT RECORDED; JUSTIFICATION AND/OR AUTHORITY FOR DEVIATING FROM ACCEPTANCE CRITERIA CONTAINED IN MAINTENANCE PROCEDURES WAS NOT SPECIFIED; AND QA REVIEW OF CERTAIN MAINTENANCE ACTIVITIES APPEARS TO BE INADEQUATE.

05000269 7606 FJGHL2
CONTRARY TO TECHNICAL SPECIFICATION 6.4.1 MAINTENANCE ACTIVITIES ON SAFETY-RELATED ELECTRICAL EQUIPMENT AT KEOWEE AND OCONEE WERE NOT PROPERLY CONTROLLED AS STATED IN SECTION 2.7.1 OF THE LICENSEE'S ADMINISTRATIVE POLICY MANUAL.

05000270 7606 FJGHL2
CONTRARY TO TECHNICAL SPECIFICATION 6.4.1 MAINTENANCE ACTIVITIES ON SAFETY-RELATED ELECTRICAL EQUIPMENT AT KEOWEE AND OCONEE WERE NOT PROPERLY CONTROLLED AS STATED IN SECTION 2.7.1 OF THE LICENSEE'S ADMINISTRATIVE POLICY MANUAL.

05000271 7626 FPFP 3
CONTRARY TO TECH. SPEC. 6.5.A AND SURVEILLANCE PROCEDURE OP-2114, VALVE SLC-41 WAS CLOSED BUT NOT LOCKED CLOSED.

05000272 7708 FCEG22
CONTRARY TO TECHNICAL SPECIFICATION TABLE 3.3-1, ITEM 7 ON 12/30/76 AND 1/26/77 LESS THAN THREE VITAL BUS, UNDERVOLTAGE CHANNELS WERE OPERABLE DURING THE PERFORMANCE PROCEDURE M3T.

05000277 7719 FJGGC2
CONTRARY TO TS 6.8.2 A COMPLETED MODIFICATION TO A SAFETY RELATED MOTOR OPERATED VALVE CIRCUITRY WAS FUNCTIONALLY VERIFIED WITHOUT AN APPROVED PROCEDURE.

05000280 7607 FJEG 2
CONTRARY TO THE REQUIREMENTS OF TECHNICAL SPECIFICATION 6.4.A, AN OPERATING PROCEDURE HAD NOT BEEN PREPARED TO ALIGN THE STARTING AIR SYSTEMS FOR THE EMERGENCY DIESEL GENERATORS. CONSEQUENTLY, ON JUNE 3, 1976, THE TWO REDUNDANT AIR SUPPLIES FOR THE NO. 1 DIESEL AIR START SYSTEMS WERE FOUND TO BE VALVED TOGETHER AND NOT OPERATING AS INDEPENDENT SYSTEMS AS SPECIFIED IN SECTION 8.5 OF THE FSAR.

05000282 7619 FCGA 2
CONTRARY TO TECHNICAL SPECIFICATION 3.6.4.5, UNIT 1 TRAIN "A" VACUUM BREAKER WAS INOPERABLE FROM AUGUST 31, 1976 TO SEPTEMBER 10, 1976.

05000287 7606 FJGHL2
CONTRARY TO TECHNICAL SPECIFICATION 6.4.1 MAINTENANCE ACTIVITIES ON SAFETY-RELATED ELECTRICAL EQUIPMENT AT KEOWEE AND OCONEE WERE NOT PROPERLY CONTROLLED AS STATED IN SECTION 2.7.1 OF THE LICENSEE'S ADMINISTRATIVE POLICY MANUAL.

05000287 7609 FCHHO2
CONTRARY TO TECHNICAL SPECIFICATION 4.6.7.C, THE ANNUAL ONE HOUR DISCHARGE TEST WAS NOT CONDUCTED ON THE 125 VDC INSTRUMENTATION AND CONTROL BATTERIESSINCE JULY 19, 1974.

05000295 7626 FJFNJ2
CONTRARY TO TECHNICAL SPECIFICATION 6.2.A, VALVE 1I-0153 WAS NOT CLOSED AS REQUIRED PER APPENDIX SOI-43A-1 OF PROCEDURE SOI-7.

05000295 7632 FCAG 2
CONTRARY TO SECTION 3.0 AND TABLE 3.4-1 OF THE TECHNICAL SPECIFICATIONS, UNIT 1 WAS OPERATED WITH LESS THAN THE MINIMUM REQUIRED NUMBER OF CHANNELS FOR PHASE B CONTAINMENT ISOLATION PRIOR TO SEPTEMBER 23, 1976, BECAUSE OF SHORTED DIODE ACROSS RELAY CT 4X2/TR2.

05000302 7706 FCHIO2
CONTRARY TO TECHNICAL SPECIFICATION 3.8.1.1.1 ACTION STATEMENT, SUMP PUMPS IN THE TUNNEL CONTAINING THE DC CONTROL FEEDS TO THE 230 KV SWITCHGEAR WERE NOT TESTED WITHIN ONE HOUR ON JANUARY 31, 1977, AS REQUIRED.

05000302 7709 FCPK-2
TECHNICAL SPECIFICATION 3.7.1.2.B, REQUIRES THE TURBINE DRIVEN EMERGENCY FEEDWATER PUMP TO BE POWERED FROM AN OPERABLE STEAM SUPPLY SYSTEM WHENEVER THE FACILITY IS IN MODE 1, 2 OR 3. CONTRARY TO THE ABOVE, AT VARIOUS TIMES DURING OPERATION OF THE FACILITY IN MODES 1, 2 AND 3, DURING THE MONTH OF MARCH AND APRIL, 1977 THE TURBINE DRIVEN EMERGENCY FEEDWATER PUMP WAS LINED UP TO BE POWERED FROM THE AUXILIARY STEAM HEADER RATHER THAN THE MAIN STEAM HEADER.

05000304 7707 FCGA 2
CONTRARY TO SECTION 3.0 AND TABLE 3.4-1 OF THE TECHNICAL SPECIFICATIONS, UNIT 2 WAS OPERATED WITH LESS THAN THE MINIMUM REQUIRED NUMBER OF CHANNELS FOR THE HI-HI CONTAINMENT PRESSURE CONTAINMENT SPRAY INITIATION PRIOR TO DECEMBER 18, 1976, DUE TO THE BISTABLE SWITCHES BEING LEFT IN THE WRONG POSITION.

05000306 7609 FJEG 2
CONTRARY TO TECHNICAL SPECIFICATION 3.2.C AND 3.2.C.7, UNIT 2 VALVE 8808C WAS NOT OPEN AND ITS BREAKER LOCKED OPEN WHEN THE PLANT WAS HEATED UP ABOVE 200 DEGREES F ON JUNE 24, 1976, DURING REACTOR STARTUP NO. 38.

05000306 7612 FCFM 2
CONTRARY TO TECHNICAL SPECIFICATION 4.4.A AND PARAGRAPH IV.A OF APPENDIX J TO 10 CFR 50, UNIT 2 CONTAINMENT ISOLATION VALVE CV-31554 WAS NOT LEAK TESTED FOLLOWING REPLACEMENT OF THE VALVE SEAT ON JANUARY 4, 1975.

05000309 7705 FPFHO2
CONTRARY TO TECHNICAL SPECIFICATION 5.5.4.6, ON 6/19/75 A PRESSURIZER SAFETY RELIEF VALVE WAS REMOVED AND INSTALLED WITHOUT THE USE OF A DETAILED APPROVED PROCEDURE.

05000312 7604 FDDPI2
A LEAKAGE RATE TEST WAS NOT CONDUCTED FOR THE DECAY HEAT REMOVAL SYSTEM FOLLOWING THE REPAIR OF A PUMP SEAL PRIOR TO THE RESUMPTION OF REACTOR OPERATIONS.

TABLE A-1. SELECTED RISK-RELATED NON-COMPLIANCES (Continued)

05000315 7611 FCHG 2
IMPROPER CALIBRATION OF ALL FOUR PRESSURIZER PRESSURE TRANSMITTERS CAUSED THE LIMITING CONDITIONS FOR OPERATION OF TECHNICAL SPECIFICATIONS 3.3.1.1 AND 3.3.2.1 TO BE EXCEEDED WITH RESPECT TO LOW PRESSURIZER PRESSURE TRIPS AND OPERATING OF THE REACTOR AT PRESSURES LOWER THAN SPECIFIED IN TECHNICAL SPECIFICATION 3.2.5.

05000315 7618 FJHG 2
CONTRARY TO TECHNICAL SPECIFICATION 6.8.1, MAINTENANCE PROCEDURES FOR THE INSTALLATION OF SAFETY RELATED CABLE FOR MODIFICATION RFC-DC-12-897 WERE NOT IMPLEMENTED.

05000315 7709 FCFA 2
CONTRARY TO TECHNICAL SPECIFICATION 4.6.3.1.1., A CONTAINMENT ISOLATION VALVE (CCR-303) ISOLATION TIME WAS NOT VERIFIED PRIOR TO RETURNING THE VALVE TO SERVICE ON APRIL 24, 1977.

05000317 7606 FJFP 3
TS 6.8.1 REQUIRES "SFT WRIT PROC INCLUDING APPLI CHECKOFF LISTS & INST SHALL BE PRE,APPROVED,.& ADHERED TO FOR OPER OF ALL SYS AND COMP INVOLV NUC SAFETY. OI032,AUX FEEDWATER REV 2 DTD 1/16/76, STEP II.A.3 REQ "VALVE LINEUP MADE AS PER ATTACH VALVE LINEUP SHT POSITION VALVE AHR-131 IS REQ TO BE "LOCKED OPEN" ON THE VALVE LINEUP SHT. CONT TO ABV,WRITT & APPRVD PROC WERE NOT ADHRD TO IN THAT VALVE AHR-131 WAS NOT LOCKED OPEN. THE VALVE WAS HOWEVER IN THE OPEN POS, ONLY THE REQ "LOCK" WAS MISS. PRIOR TO COMPOF THE INSP, THE REQ LOCK WAS INST BY LIC AND VERIF BY THE INSP.

05000317 7708 FCFS 2
CONTRARY TO TECHNICAL SPECIFICATION 3.04, THE PLANT WAS TAKEN INTO OPERATIONAL MODE 3 WITHOUT PERFORMING THE INSPECTION REQUIRED BY T.S. 4.5.2.C.

05000317 7708 FJFP 2
CONTRARY TO TECHNICAL SPECIFICATION 6.8.1 PROCEDURES WERE NOT IMPLEMENTED IN THE AREAS OF SMOKING IN RADIOLOGICAL CONTROL AREAS AND LOCKING VALVES.

05000318 7639 FJFS22
CONTRARY TO TECHNICAL SPECIFICATION 6.8.1, 33 PERCENT OF THE VALVES REQUIRED BY OP-6 TO BE LOCKED IN POSITION WERE NOT LOCKED.

05000321 7607 FCESO2
CONTRARY TO THE REQUIREMENTS OF TECHNICAL SPECIFICATION 3.5.A AND 3.5.B, THE LICENSEE FAILED TO PERFORM OPERABILITY TESTING AFTER PERFORMING MAINTENANCE ON A CORE SPRAY PUMP ON MARCH 1, 1975 AND FEBRUARY 5, 1976, AND ON VARIOUS RESIDUAL HEAT REMOVAL PUMPS DURING THE PERIOD MARCH 3-10, 1975.

05000321 7608 FCHEK2
CONTRARY TO TECHNICAL SPECIFICATION 6.8.1, ADMINISTRATIVE PROCEDURE HNP-1-832 HAD NOT BEEN FULLY IMPLEMENTED IN THAT APPROXIMATELY 8% OF THE INSTRUMENTS LISTED IN THE COMPUTER PRINTOUT, DATED 6/1/76, WERE OVERDUE FOR CALIBRATION.

05000321 7608 FCHEK2
CONTRARY TO APPLICABLE PORTIONS OF SECTION 4.2 OF THE TECHNICAL SPECIFICATIONS, CALIBRATION FREQUENCY EXCEEDED THE GRACE PERIOD FOR THREE ITEMS: RHM CHANNELS A AND B, CORE SPRAY SPARGER NOZZLE DIFFERENTIAL PRESSURE INSTRUMENTS, AND SRM CHANNELS.

05000321 7612 FJFP 2
CONTRARY TO TECHNICAL SPECIFICATION 6.8.1 WHICH REQUIRES WRITTEN PROCEDURES BE ESTABLISHED AN IMPLEMENTED, THREE EXAMPLES OF FAILURE TO FOLLOW APPROVED PROCEDURES WERE IDENTIFIED ON SEPTEMBER 16, 1976. (1) MOVIS P41-F317A AND B WERE NOT LOCKED OPEN AS SPECIFIED BY PROCEDURE. (2) DRYWELL TO TORUS DIFFERENTIAL PRESSURE WAS NOT MAINTAINED, ON 9/3/76, AS REQUIRED BY STANDING ORDERS. (3) VALVE T48-F011 WAS NOT CLOSED AND TAGGED AS SPECIFIED ON AN OUTSTANDING CLEARANCE AND TAGGING SHEET.

05000321 7613 FJGG02
CONTRARY TO THE REQUIREMENTS OF TECHNICAL SPECIFICATION 6.8.1 AND 6.8.2, THE LICENSEE FAILED TO ESTABLISH, AND APPROVE PRIOR TO IMPLEMENTATION, PROCEDURES WHICH MEET THE REQUIREMENTS AND RECOMMENDATIONS OF SECTIONS 5.1 AND 5.3 OF ANSI N18.7-1972 IN THAT MAINTENANCE PROCEDURES DID NOT INCLUDE OR REFERENCE STEPS FOR REMOVING EQUIPMENT FROM OR RETURNING IT TO SERVICE AND FOR PERFORMING OPERABILITY TESTING SUBSEQUENT TO MAINTENANCE. SPECIFIC EXAMPLES OF MAINTENANCE ACTIVITIES PERFORMED WITHOUT THE REQUIRED PROCEDURES INCLUDE: (1) THE RCIC SHAFT DRIVEN OIL PUMP WAS REMOVED FROM AND RETURNED TO SERVICE ON OCTOBER 12, 1976; (2) THE RPS MOTOR-GENERATOR SET 1A WAS REMOVED FROM AND RETURNED TO SERVICE ON OCTOBER 10, 1976.

05000321 7701 FOHP 2
CONTRARY TO TECHNICAL SPECIFICATION 4.2, TABLE 4.2-2, THE DIESEL GENERATOR INITIATE LOGIC FUNCTIONAL TEST WAS NOT PERFORMED WITHIN THE REQUIRED 15 MONTH INTERVAL. THE LAST DOCUMENTED TEST WAS PERFORMED ON JULY 26, 1974.

05000321 7705 FJHA02
CONTRARY TO TECHNICAL SPECIFICATION 6.8.1, AN APPROVED PROCEDURE FOR THE CONTROL OF LIFTED WIRES AND JUMPERS WAS NOT FOLLOWED DURING MAINTENANCE ON MARCH 11, 1977.

05000321 7706 FOHGL2
CONTRARY TO TECHNICAL SPECIFICATION 4.9.A.6.E, THE SWING BUSES SUPPLYING POWER TO THE LOW PRESSURE COOLANT INJECTION VALVES WERE NOT TESTED EVERY TWO MONTHS TO ASSURE THAT THE TRANSFER CIRCUITS OPERATE AS DESIGNED. AS OF MAY 18, 1977, THE SURVEILLANCE TESTS HAD NOT BEEN PERFORMED.

05000324 7624 FJGC2
CONTRARY TO TECHNICAL SPECIFICATION 6.8 AS IMPLEMENTED BY OPERATIONAL GUIDELINE NO. 7, PREPARATION OF OPERATING WORK PERMITS (OWP), OPERATING WORK PERMITS WHICH INCLUDED THE STEPS NECESSARY TO PREPARE SAFETY-RELATED EQUIPMENT FOR MAINTENANCE, AND THE TESTING NECESSARY TO ASSURE PROPER OPERATION PRIOR TO RETURNING THE EQUIPMENT TO SERVICE WERE NOT PREPARED FOR THE FOLLOWING: (A) REPLACE THE REACTOR CORE ISOLATION COOLING DISCHARGE CHECK VALVE ON FEBRUARY 2, 1976; (B) EXTENSIVE MAINTENANCE ON CORE SPRAY VALVE PCV-F026A ON MAY 9, 1976.

05000325 7704 FJFPI2
CONTRARY TO TECHNICAL SPECIFICATIONS 6.8.1, THE HIGH PRESSURE COOLANT INJECTION (HPCI) AND REACTOR CORE ISOLATION COOLING (RCIC) CONDENSATE STORAGE TANK SUCTION VALVE (1-CC-V127) WAS NOT LOCKED OPEN ON FEB 17, 1977, AS REQUIRED BY SYSTEM VALVE LINEUP SHEET, OP-31-2-V AND PLANT DRAWING 9527-D-2040. (DETAILS I, PARAGRAPH 4.8.5)

05000325 7704 FPEPL2
CONTRARY TO TECHNICAL SPECIFICATIONS 6.8 AND PLANT OPERATING MANUAL, VOLUME 1, ADMINISTRATIVE PROCEDURE SECTION 6.0, MODIFICATIONS WERE MADE TO THE DIESEL GENERATOR CONTROL PANELS WITHOUT A SUBSEQUENT RETEST TO ASSURE THAT THE DIESEL GENERATORS WERE OPERABLE UNTIL APPROXIMATELY TWO WEEKS LATER ON DECEMBER 29, 1976, WHEN RETESTING WAS REQUIRED BY A LIMITING CONDITION FOR OPERATION. (AT THAT TIME TWO OF THE DIESEL GENERATORS WERE DECLARED INOPERABLE)

05000331 7615 FJFP 2
CONTRARY TO T.S., SECT. 6.8.1, THE LICENSEE FAILED TO ADHERE TOPLANT OPERATING PROCEDURES AS FOLLOWS: A) CERTAIN ITEMS OF THEPLANT PRESTARTUP MASTER CHECKLIST WERE NOT COMPLIED WITH DURINGTHE STARTUP AFTER REFUELING IN APRIL 1976. B) CONTRARY TO OPERTING INSTRUCTION 53, THE SODIUM PENTABORATE TANK SPARGING VALVE(L-26-11) WAS FOUND UNLOCKED.

05000331 7621 FPFS02
CONTRARY TO TECHNICAL SPECIFICATIONS 6.8.3, TEST PROCEDURE 83.3 USED TO PRE-OP THE MSIV-LCS WAS INCOMPLETE IN THAT A STEP WAS MISSING BETWEEN STEPS 4 AND 5, AND THE TEST WAS PERFORMED BY DEPARTING FROM THE PROCEDURE WITHOUT THE REQUIRED REVIEWS AND APPROVALS.

TABLE A-1. SELECTED RISK-RELATED NON-COMPLIANCES (Continued)

05000331 7622 FPFP 2
CONTRARY TO DAEC TECHNICAL SPECIFICATIONS, SECTION 6.8.1, A RELAY BLOCK WAS NOT REMOVED FROM THE HPCI CONTROL LOGIC IN ACCORDANCE WITH THE SURVEILLANCE TEST PROCEDURE.

05000335 7707 FPDF 2
CONTRARY TO TECHNICAL SPECIFICATION 4.8.1.1.2.C.6 THREE OF FOUR CONTAINMENT COOLER FAN AUTOMATIC SEQUENCE TIMERS ARE NOT OPERABLE WITHIN PLUS OR MINUS 10 PERCENT OF THE LOAD SEQUENCE TIME. CONTAINMENT COOLER FANS 1A, 1B AND 1D LOADING TIMERS ARE SET AT 3.798, 2.68 AND 3.766 SECONDS RESPECTIVELY CON TRARY TO A SPECIFICATION OF 3 PLUS OR MINUS 0.3 SECONDS.

05000336 7708 FPFS 3
CONTRARY TO TS 6.8.1, ON MARCH 19 AND 20, 1977, S P 2619A WAS IMPROPERLY IMPLEMENTED ON 2 OCCASSION S IN THAT THE CHANNEL CHECKS FOR THERMAL MARGIN L OW PRESSURE AND PRESSURIZER PRESSURE DID NOT MEET THE STATED ACCEPTANCE CRITERIA AND INSTEAD THERE EXCEPTIONS BEING IDENTIFIED AND DOCUMENTED AS RE QUIRED THE COMPLETED PROCEDURES WERE SIGNED OFF A ND APPROVED INDICATING ALL ACCEPTANCE CRITERIA HA S BEEN MET.

APPENDIX B

SELECTED RISK-RELATED ABNORMAL OCCURRENCES

TABLE B-1. SELECTED RISK-RELATED ABNORMAL OCCURRENCES

Date	Occurrence	Cause	Docket
07-29-76	Core spray pump flow rate not tested as required	Change not incorporated into schedule	50-155
09-03-76	Diesel generator not retested after maintenance	Misundertanding of criteria	50-155
12-01-76	Emergency diesel generator start time exceeds limit	Fuel governor marginal	50-155
09-24-76	Required surveillance of vacuum breakers not performed	Not posted on startup check-off sheets	50-220
03-02-77	LPCI valve fails to reopen	Limit switch out of adjust-ment	50-237
11-26-76	HPCI found in closed position with severed valve stem	Unknown	50-237
08-24-76	Gas turbine generator becomes inoperable during plant trip	Improper alignment	50-245
09-15-76	All three safety injection pumps inoperable	Suction valves closed	50-247
06-29-76	Supplemental report on LPCI valve motor trip	Undersized overload heaters	50-249
11-10-76	Drywell spray valve fails to open	Loose terminal	50-249
12-02-76	Diesel generator speed fails to increase from control room station	Governor limit switch out of adjustment	50-249
09-23-76	Diesel generator circuit breaker inoperable	Closing springs not charged	50-250
10-15-76	Diesel generator cooling water surge tank level low	Sample valve not closed completely	50-250
11-15-76	Charging pump connecting rod bearings fail	Insufficient lubrication	50-250

TABLE B-1. SELECTED RISK-RELATED ABNORMAL OCCURRENCES (Continued)

	Date	Occurrence	Cause	Docket
Ia	07-29-76	Containment spray valve inoperable	Motor hold-down bolts loose	50-254
Ib	08-20-76	Operability test on containment cooling loop performed on wrong unit	Supervisor error	50-254
Ia	08-19-76	Component cooling water pump bearing fails	Improper alignment or bearing slippage	50-255
Ia	12-21-76	Two DBA sequencers fail to operate	Insufficient clutch disc gap	50-255
Ia	10-22-76	Core spray sparger vessel DP switch found valved out	Personnel error	50-259
Ia	11-24-76	Diesel generator has erratic speed behavior	Dirty oil in governor	50-259
Ia	08-31-76	Auxiliary feedwater pump valve fails to open	Valve binding to seat	50-261
Ia	10-07-76	Containment fan cooler unit dampers fail to function	Improper alignment and dirt	50-261
Ia	11-09-76	Diesel generator fails to start on No. 2 starting system	Rust particles in air relay	50-263
Ia	08-20-76	Four drywell pressure switches inoperable	Blocked sensing line	50-265
Ia	09-24-76	ECCS drywell high pressure switch found valved out	Personnel error	50-265
Ia	08-05-76	RPS channel fails to trip on high pressure	Instrument root valve closed	50-270
II	08-23-76	LPI Train A taken out of service without testing Train B	Failure to follow tech specs	50-270
IV	10-08-76	230 KV switchyard red bus and startup transformer isolated	Error in implementation of modification	50-270
Ia	09-16-76	LPCI pump flows limited by valving	Incomplete communication for change	50-277
Ia	10-05-76	Permissive set point for core spray and LPCI improper	Inadequate communication	50-277
Ia	09-16-76	LPCI pump flows limited by valving	Incomplete communication for change	50-278

TABLE B-1. SELECTED RISK-RELATED ABNORMAL OCCURRENCES (Continued)

Date	Occurrence	Cause	Docket
10-05-76	Permissive set point for core spray and LPCI improper	Inadequate communication	50-278
08-04-76	Jumper not removed from pressure switches	Jumper log not reviewed	50-280
09-17-76	Normally closed isolation valve found open	Inadequate administrative control	50-281
10-07-76	Containment vacuum breaker train inoperable	Switch left valved out	50-282
09-15-76	Primary air start motor fails to disengage after DG start	Improper setting or pickup unit	50-285
09-13-76	Core flood tanks not sampled following makeup	Inadequate sampling program	50-287
11-15-76	HPI stop-check valves found to be closed	Operator error	50-287
07-22-76	Containment spray valve fails to open fully	Torque switch dropped out too soon	50-295
10-15-76	Containment fan cooler dampers fail to shift modes	Poor orientation of counterweight arm	50-295
10-15-76	Unplanned dilution occurs	Valve left open	50-295
08-18-76	Core spray valve fails to operate	Tripper pin dislodged	50-298
09-09-76	Safety relief valve adjusted incorrectly	Personnel error	50-298
10-06-76	ECCS differential pressure switch found inoperable	Equalizing valve left open	50-298
10-22-76	Standby liquid control injection found inoperable	Wiring error	50-298
12-09-76	Containment isolation valve fails to close	Operator related	50-298

TABLE B-1. SELECTED RISK-RELATED ABNORMAL OCCURRENCES (Continued)

Date	Occurrence	Cause	Docket
01-14-77	Containment pressure hi-hi status light fails to energize	Bistables in test position	50-304
12-21-76	Boron injection tank outlet valve fails to operate	Packing gland misaligned	50-304
09-20-76	Diesel generator trips	Disconnected pipe	50-306
10-14-76	Diesel generator fails to start	Dirty oil in governor	50-312
01-14-77	Containment spray pump suction valve found closed	Personnel error	50-315
09-17-76	Diesel generator fails to start	Isolation valve to switches closed	50-315
11-17-76	Containment sump valve fails to close	Stem bushing threads stripped	50-317
12-04-76	Service water outlet valves for diesel generator closed	Operator error	50-317
01-31-77	ADS permissive switch found valved out	No reason determined	50-321
08-18-76	Diesel generator trips due to loss of excitation	Out-of-phase syncronization	50-321
09-23-76	Diesel generator trips due to tripping of reverse PWER relay	Voltage regulator improperly set	50-321
12-C8-76	Diesel generator fails	Control air check valve rusted closed	50-324
08-19-76	Core spray sparger DP instrument alarm card found pulled	Operator error	50-331
09-16-76	Pressure switch root valve found closed	Valve not on prestartup checklist	50-331
11-19-76	LPCI valve fails to open	Motor burned up from excess torque	50-333
08-23-76	Auxiliary feed pump inlet steam valve fails to open	Valve shaft sheared	50-336

TABLE B-1. SELECTED RISK-RELATED ABNORMAL OCCURRENCES (Continued)

Date	Occurrence	Cause	Docket
09-03-76	Safety injection tank level found below limit	Operator error	50-336
11-12-76	Safety injection supply valve fails to open	Torque switch set improperly	50-344
11-12-76	Reactor protection system interlock set incorrectly	Pressure bistables incorrectly adjusted	50-344
11-12-76	Supplemental information on RWST valve failures	Bypass switch set incorrectly	50-344
11-12-76	Centrifugal charging pump suction valves fail to open	Failed coil/torque switch too low	50-344
12-03-76	HPCS pump fails to start automatically	Wire pulled loose during modification	50-409

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