TECHNICAL EVALUATION REPORT

ECCS REPORTS (F-47)

TMI ACTION PLAN REQUIREMENTS

TENNESSEE VALLEY AUTHORITY

BROWNS FERRY NUCLEAR PLANT UNITS 1, 2, AND 3

NRC DOCKET NO. 50-259, 50-260, 50-296

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CONTENTS

FOREWORD

This Technical Evaluation Report was prepared by Franklin Research Center under a contract with the U.S. Nuclear Regulatory Commission (Office of Nuclear Reactor Regulation, Division of Operating Reactors) for technical assistance in support of NRC operating reactor licensing actions. The technical evaluation was conducted in accordance with criteria established by the NRC.

Mr. G. J. Overbeck and Mr. B. W. Ludington contributed to the technical preparation of this report through a subcontract with WESTEC Services, Inc.

1. INTRODUCTION

1.1 PURPOSE OF REVIEW

This technical evaluation report (TER) documents an independent review of the outages of the emergency core cooling (ECC) systems at Tennessee Valley Authority's (TVA) Browns Ferry Nuclear Plant Units 1, 2, and 3. The purpose of this evaluation is to determine if the Licensee has submitted a report that is complete and satisfies the requirements of TMI Action Item II.K.3.17, "Report on Outages of Emergency Core-Cooling Systems Licensee Report and Proposed Technical Specification Changes."

1.2 GENERIC BACKGROUND

Following the Three Mile Island Unit 2 accident, the Bulletins and Orders Task Force reviewed nuclear steam supply system (NSSS) vendors' small break loss-of-coolant accident (LOCA) analyses to ensure that an adequate basis existed for developing guidelines for small break LOCA emergency procedures. During these reviews, a concern developed about the assumption of the worst single failure. Typically, the small break LOCA analysis for boiling water reactors (BWRs) assumed a loss of the high pressure coolant injection (HPCI) system as the worst single failure. However, the technical specifications permitted plant operation for substantial periods with the HPCI system out of service with no limit on the accumulated outage time. There is concern not only about the HPCI system, but about all ECC systems for which substantial outages might occur within the limits of the present technical specifications. Therefore, to ensure that the small break LOCA analyses are consistent with the actual plant response, the Bulletin and Orders Task Force recommended in NUREG-0626 [1], "Generic Evaluation of Feedwater Transients and Small Break Loss-of-Coolant Accidents in GE-Designed Operating Plants and Near-Term Operating License Applications," that licensees of General Electric (GE)-designed NSSSs do the following:

> "Submit a report detailing outage dates and lengths of the outages for all ECC systems. The report should also include the cause of the outage (e.g., controller failure or spurious isolation). The outage data for

ECC components should include all outages for the last five years of operation. The end result should be the quantification of hist rical unreliability due to test and maintenance outages. This will establish if a need exists for cumulative outage requirements in technical specifications."

Later, the recommendation was incorporated into NUREG-0660 [2], "NRC Action Plan Developed as a Result of the TMI-2 Accident," for all light water reactor plants as TMI Action Item II.K.3.17. In NURLG-0737 [3], "Clarification of TMI Action Plan Requirements," the NRC staff added a requirement that licensees propose changes that will improve and control availability of ECC systems and components. In addition, the contents of the reports to be submitted by the licensees were further clarified as follows:

"The report should contain (1) outage dates and duration of outages; (2) cause of the outage; (3) ECC systems or components involved in the outage; and (4) corrective action taken."

1.3 PLANT-SPECIFIC BACKGROUND

On December 23, 1980 [4], TVA submitted a report in response to NUREG-0737, Item II.K.3.17, "Report on Outages of Emergency Core-Cooling Systems Licensee Report and Proposed Technical Specification Changes." The report submitted by TVA covered the period from January 1, 1976 to December 31, 1980 for Browns Ferry Nuclear Plant Units 1 and 2, and from March 1, 1977 to December 31, 1980 for Browns Ferry Nuclear Plant Unit 3. TVA did not provide recommendations to improve and control availability of ECC systems but committed itself to continue work with the Owners Group to improve system reliability and to minimize ECC system outages.

2. REVIEW CRITERIA

The Licensee's response to NUREG-0737, Item II.K.3.17, was evaluated against criteria provided by the NRC in a letter dated July 21, 1981 [5] outlining Tentative Work Assignment F. Provided as review criteria in Reference 5, the NRC stated that the Licensee's response should contain the following information:

1. A report detailing outage dates, causes of outages, and lengths of outages for all ECC systems for the last 5 years of operation. This report was to include the ECC systems or components involved and corrective actions taken. Test and maintenance outages were to be included.

2. A quantification of the historical unavailability of the ECC systems and components due to test and maintenance outages.

3. Proposed changes to improve the availability of ECC systems, if necessary.

The type of information required to satisfy the review criteria was clarified by the NRC on August 12, 1981 [6]. Auxiliary systems such as component cooling water and plant service water systems were not to be considered in determining the unavailability of ECC systems. Only the outages of the diesel generators were to be included along with the primary ECC system outages. Finally, the "last five years of operation" was to be loosely interpreted as a continuous 5-year period of recent operation.

On July 26, 1982 [7], the NRC further clarified that the purpose of the review was to identify those licensees that have experienced higher ECC system outages than other licensees with similar NSSSs. The need for improved reliability of diesel generators is under review by the NRC. A Diesel Generator Interim Reliability Program has been proposed to effect improved performance at operating plants. As a consequence, a comparison of diesel generator outage information within this review is not required.

3. TECHNICAL EVALUATION

3.1 REVIEW OF COMPLETENESS OF THE LICENSEE'S REPORT

The ECC systems at TVA's Browns Ferry Nuclear Plant Units 1, 2, and 3 consist of the following four separate systems:

- o high pressure coolant injection (HPCI) system
- o automatic depressurization system (ADS)
- o core spray (CS) system
- o residual heat removal (RHR) system as low pressure coolant injection (LPCI).

In Reference 4, TVA also included the residual heat removal service water (RHRSW) and the reactor coolant isolation cooling (RCIC) systems. The RHRSW system is an essential support system for the RHR system, while the RCIC system is a non-safety-related high pressure system available for high pressure injection. Neither of these systems is considered a primary ECC system for this review.

For each ECC system outage, TVA provided the date, the duration, a brief description, and the cause, with sufficient details to indicate the corrective action taken. For the diesel generators, TVA explicitly stated when the outage was caused by maintenance and surveillance testing activities. Verification that maintenance and surveillance testing activities were included for other ECC systems was obtained by the NRC on January 6, 1982 [8].

TVA's review encompassed the period from January 1, 1976 to December 31, 1980 for Browns Ferry Units 1 and 2, and from March 1, 1977 to December 31, 1980 for Browns Ferry Unit 3. The period for Unit 3 represents the plant operating time since fuel loading.

Based on the preceding discussion and NRC verification of the inclusion of outages caused by maintenance and surveillance testing activities, it has been established that the TVA report fulfills the requirements of review criterion 1 without exception.

3.2 COMPARISON OF ECC SYSTEM OUTAGES WITH THOSE OF OTHER PLANTS

The outages of ECC systems can be categorized as (1) unplanned outages due to equipment failure or (2) planned outages due to surveillance testing or preventive maintenance. Unplanned outages are reportable as Licensee Event Reports (LERs) under the technical specifications. Planned outages for periodic maintenance and testing are not reportable as LERs. The technical specifications identify the type and quantity of ECC equipment required as well as the maximum allowable outage times. If an outage exceeds the maximum allowable time, then the plant operating mode is altered to a lower status consistent with the available ECC system components still operational. The purpose of the technical specification maximum allowable outage times is to prevent extended plant operation without sufficient ECC system protection. The maximum allowable outage time, specified per event, tends to limit the unavailability of an ECC system. However, there is no cumulative outage time limitation to prevent repeated planned and unplanned outages from accumulating extensive ECC system downtime.

Unavailability, as defined in general terms in WASH-1400 [9], is the probability of a system being in a failed state when required. However, for this review, a detailed unavailability analysis was not required. Instead, a preliminary estimate of the unavailability of an ECC system was made by calculating the ratio of the ECC system downtime to the number of days that the plant was in operation during the last 5 years. To simplify the tabulation of operating time, only the period when the plant was in operational Mode 1 was considered. This simplifying assumption is reasonable given that the period of time that a plant is starting up, shutting down, and cooling down is small compared to the time it is operating at power. In addition, an ECC system was considered down whenever an ECC system component was unavailable due to any cause.

It should be noted that the ratio calculated in this manner is not a true measure of the ECC system unavailability, since outage events are included that appear to compromise system performance when, in fact, partial or full function of the system would be expected. Full function of an ECC system would be expected if the design capability of the system exceeded the capacity required for the system to fulfill its safety function. For example, if an ECC system consisting of two loops with multiple pumps in each loop is designed so that only one pump in each loop is required to satisfy core cooling requirements, then an outage of a single pump would not prevent the system from performing its safety function. In addition, the actual ECC system unavailability is a function of planned and unplanned outages of essential support systems as well as of planned and unplanned outages of primary ECC system components. In accordance with the clarification discussed in Section 2, only the effects of outages associated with primary ECC system components and emergency diesel generators are considered in this review. The inclusion of all outage events assumed to be true ECC system outages tends to overestimate the unavailability, while the exclusion of support system outages tends to underestimate the unavailability, of ECC systems and components. Only a detailed analysis of each ECC system for each plant could improve the confidence in the calculated result. Such an analysis is beyond the intended scope of this report.

The planned and unplanned (forced) outage times for the ECC systems (HPCI, CS, and RHR), the emergency diesel generators, and (for informational purposes) the RCIC system were identified from the outage information in Reference 4 and are shown in number of days and as percentage of plant operating time per year in Tables 1, 2, and 3 for Browns Ferry Units 1, 2, and 3, respectively. Outages that occurred during non-operational periods were eliminated as were those caused by failures or test and maintenance of support systems. Data on plant operating conditions were obtained from the annual reports, "Nuclear Power Plant Operating Experience" [10-13], and from monthly reports, "Licensed Operating Reactors Status Summary Report" [14]. The remaining outages were segregated into planned and unplanned outages on the basis of TVA's description of the cause. The outage periods for each category were calculated by summing the individual outage durations. Excluded from the tables is the ADS, which TVA stated in Reference 4 had experienced no outages.

Observed outage times of various ECC systems at Browns Ferry Units 1, 2, and 3 were compared with those of other BWRs. Based on this comparison, it

Table 1. Planned and Unplanned (Forced) Outage Times for Browns Ferry Unit 1

Year	Days of Plant Operation	HPCI Outage in Days		Core Spray Outage in Days		RHR (LPCI) Outage in Days		RCIC Outage in Days		Diesel Generator Outage in Days	
		Forced	Planned	Forced	Planned	Forced	Planned	Forced	Planned	Forced	Planned
1976	106.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06 (<0.1%)*	0.0
1977	243.46	3.20 (1.1%)	0.0	0.0	0.0	2.07 (0.8%)	0.0	1.92 (0.1%)	0.0	0.0	0.0
1978	293.46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.02 (3.1%)	0.0
1979	331.08	12.03 (3.6%)	0.0	0.0	0.0	0.0	0.0	0.35 (0.1%)	0.0	0.0	6.20 (1.9%)
1980	241.67	4.59 (1.7%)	0.75 (0.3%)	0.70 (0.3%)	0.37 (0.1%)	10.23 (4.2%)	0.0	0.70 (0.3%)	0.0	0.0	7.99 (2.9%)
Total	1215.88	19.82 (1.6%)	0.75 (<0.1%)	0.70 (0.1%)	0.37 (<0.1%)	12.30 (1.0%)	0.0	2.97 (0.2%)	0.0	9.08 (0.7%)	14.19 (1.5%)

*Numbers in parentheses indicate system outage time as a percentage of total plant operating time.

Table 2. Planned and Unplanned (Forced) Outage Times for Browns Ferry Unit 2

Year	Days of Plant Operation	HPCI Outage in Days Forced	HPCI Outage in Days Planned	Core Spray Outage in Days Forced	Core Spray Outage in Days Planned	RHR (LPCI) Outage in Days Forced	RHR (LPCI) Outage in Days Planned	RCIC Outage in Days Forced	RCIC Outage in Days Planned	Diesel Generator Outage in Days Forced	Diesel Generator Outage in Days Planned
1976	203.83	0.46 (0.2%)*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.79 (0.4%)	0.0
1977	290.29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	251.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.02 (3.6%)	0.0
1979	317.54	6.06 (1.9%)	0.0	0.0	0.0	0.0	0.0	7.94 (2.5%)	0.0	0.0	5.62 (1.8%)
1980	261.58	1.03 (0.4%)	0.54 (0.2%)	0.0	1.25 (0.5%)	27.92 (10.7%)	0.0	0.0	0.0	0.0	3.45 (1.3%)
Total	1324.67	7.55 (0.6%)	0.54 (<0.1%)	0.0 0.0	1.25 (0.1%)	27.92 (2.1%)	0.0	7.94 (0.6%)	0.0	9.82 (0.7%)	9.07 (0.7%)

*Numbers in parentheses indicate system outage time as a percentage of total plant operating time.

Table 3. Planned and Unplanned (Forced) Outage Times for Browns Ferry Unit 3

Year	Days of Plant Operation	HPCI Outage in Days		Core Spray Outage in Days		RHR (LPCI) Outage in Days		RCIC Outage in Days		Diesel Generator Outage in Days	
		Forced	Planned	Forced	Planned	Forced	Planned	Forced	Planned	Forced	Planned
1977*	268.33	2.03 (0.8%)**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.72 (0.6%)	0.0
1978	259.63	0.49 (0.2%)	0.0	0.0	0.0	3.81 (1.5%)	0.0	2.03 (0.8%)	0.0	0.50 (0.2%)	0.0
1979	238.83	0.0	0.0	0.0	0.0	0.0	0.0	1.92 (0.8%)	0.0	0.0	0.0
1980	294.33	0.0	0.0	0.78 (0.3%)	0.51 (0.2%)	1.68 (0.6%)	0.0	1.78 (0.6%)	0.0	6.58 (2.2%)	16.66 (5.7%)
Total	1061.12	2.52 (0.2%)	0.0	0.78 (0.1%)	0.51 (<0.1%)	5.49 (0.5%)	0.0	5.73 (0.5%)	0.0	8.80 (0.8%)	16.66 (1.6%)

*Plant began commercial operation March 1, 1977.

**Numbers in parentheses indicate system outage time as a percentage of total plant operating time.

was concluded that the historical unavailability of the HPCI, CS, and RHR systems has been consistent with the performance of those systems throughout the industry, and also consistent with existing technical specifications. The RHR system at Unit 2, however, had an observed unavailability significantly higher than that observed in other plants and has exceeded the industrial mean by greater than about one standard deviation assuming that the underlying unavailability is distributed lognormally. The outages of the diesel generators and the RCIC system were not included in this comparison.

Closer inspection of the RHR system outage data for all three units revealed that the higher component downtime resulted from a design deficiency in the RHR heat exchangers. The cause of these outages was attributed to a leaking inner head gasket on the RHR heat exchanger due to the loosening of flange nuts by thermal cycling and vibration. On a number of occasions, repairs were attempted, including the use of additional locking nuts and higher torque values; however, the problem continued until locking tabs were installed on the flange nuts. Verification that this modification was made on all RHR heat exchangers in all Browns Ferry units was obtained on January 15, 1982 [15].

3.3 REVIEW OF PROPOSED CHANGES TO IMPROVE THE AVAILABILITY OF ECC EQUIPMENT

In Reference 4, TVA did not provide recommendations to improve and control availability of ECC systems or equipment, but committed itself to continue work with the Owners Group to improve system reliability and minimize ECC system outages.

4. CONCLUSIONS

The Tennessee Valley Authority (TVA) has submitted a report for Browns Ferry Units 1, 2, and 3 which contains (1) outage dates and durations of outages, (2) causes of the outages, (3) ECC systems or components involved in the outages, and (4) corrective actions taken. It is concluded that TVA has fulfilled the requirements of NUREG-0737, Item II.K.3.17. In addition, the historical unavailability of the ECC system has been consistent with the performance of those systems throughout the industry, and also consistent with existing technical specifications. The RHR system at Unit 2, however, had an observed unavailability significantly higher than that observed in other plants, and exceeded the industrial mean by greater than about one standard deviation. Further investigation, as noted in Section 3.2, revealed that the higher RHR component outage was attributed to an RHR heat exchanger design deficiency which has been corrected.

5. REFERENCES

1. "Generic Evaluation of Feedwater Transients and Small Break Loss-of-Coolant Accidents in GE-Designed Operating Plants and Near-Term Operating License Applications"
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2. "NRC Action Plan Developed as a Result of the TMI-2 Accident"
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3. "Clarification of TMI Action Plan Requirements"
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5. J. N. Donohew, Jr. (NRC)
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6. NRC
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