TECHNICAL EVALUATION REPORT

ECCS REPORTS (F-47)

TMI ACTION PLAN REQUIREMENTS

FLORIDA POWER CORPORATION

CRYSTAL RIVER UNIT 3

NRC DOCKET NO. 50-302

FRC PROJECT C5506

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FRC TASK 272

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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, Mr. F. W. Vosbury, 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 Flordia Power Corporation's (FPC) Crystal River Unit 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 also about all ECC systems for which substantial outages might occur within the limits of the present technical specification. 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 historical 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 GE-designed NSSSs as TMI Action Item II.K.3.17. In NUREG-0737 [3], "Clarification of TMI Action Plan Requirements," the NRC staff expanded the action item to include all light water reactor plants and 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 March 31, 1981 [4], FPC 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 FPC covered the period from December 29, 1976 to March 16, 1981 for Crystal River Unit 3. On August 13, 1982 [5], FPC submitted a second report in response to a request for additional information concerning diesel generator and surveillance testing outages. The second report covered the same period described in the first report. FPC did not include any recommendations in its reports to improve the availability of ECC system components.

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 [6] 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 [7]. 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 [8], 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 FPC's Crystal River Unit 3 consist of the following four separate systems:

- o core flood tank
- o high pressure injection (HPI)
- o low pressure injection (LPI)
- o borated water storage tank (BWST).

In Reference 4, FPC also included information on diesel generator, closed cycle cooling water system, and sea water system outages. The two water systems support the ECC systems under certain accident conditions but are not considered ECC systems. The results of FPC's review were provided for the period from December 29, 1976 to March 16, 1981 for Crystal River Unit 3.

For each ECC system outage event, FPC provided the outage dates, the duration (when available), and the cause, plus sufficient description to discern the corrective action taken. Maintenance activities were included in the ECC system outage data. However, FPC did not provide any information on surveillance testing outages in References 4 or 5. In Reference 5, referring to the NRC request for additional information on surveillance testing outages, FPC states:

> "While surveillance testing of the ECC and diesel generator systems took place as required during the period of the initial report, the duration of these outages is unrecorded. Therefore, no summary of outages is forwarded as it would be meaningless without specific duration information.
>
> FPC cannot with good engineering judgment, estimate a duration for an equipment outage when such duration is not documented."

Based on the preceding discussion, it is concluded that FPC has submitted a report which partially fulfills the requirements of review Criterion 1, as no information concerning surveillance testing outages was provided.

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 four ECC systems (core flood tank, HPI, LPI, and BWST) and the diesel generators were identified from the outage information in References 4 and 5 and are shown in number of days and as percentage of plant operating time per year in Table 1 for Crystal River Unit 3. Outages that occurred during nonoperational 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 Reports" [14]. The remaining outages were segregated into planned and unplanned outages based on FPC's description of the causes. The outage periods for each category were calculated by summing the individual outage durations.

In the Final Safety Analysis Report [15] (FSAR) for Crystal River Unit 3, the following statement was made in Subsection 6.1.4, Tests and Inspections:

> "Performance of active systems is tested by establishing flow and observing pressures and flows during scheduled shutdowns."

Thus, surveillance testing of the ECC systems that would normally render these systems unavailable for emergency service is ostensibly done when ECCS

Table 1. Planned and Unplanned (Forced) Outage Times for Crystal River Unit 3

Year	Days of Plant Operation	Core Flood Outage in Days Forced	Core Flood Outage in Days Planned	HPI Outage in Days Forced	HPI Outage in Days Planned	LPI Outage in Days Forced	LPI Outage in Days Planned	BWST Outage in Days Forced	BWST Outage in Days Planned	Diesel Generator Outage in Days Forced	Diesel Generator Outage in Days Planned
1976	**										
1977	245.5	0.30 (0.1%)	0.30 (0.1%)	3.31 (1.3%)	0.0	0.83 (0.3%)	0.0	0.0	0.0	0.85 (0.3%)	0.0
1978	151.2	0.0	0.0	0.75 (0.5%)	0.0	0.38 (0.3%)	0.0	0.0	0.0	0.49 (0.3%)	0.0
1979	215.0	0.15 (0.1%)	0.0	0.25 (0.1%)	0.50 (0.2%)	1.00 (0.5%)	0.0	0.0	0.0	1.00 (0.5%)	0.0
1980	197.3	0.0	0.0	0.0	0.0	10.00 (5.1%)	0.0	0.0	0.0	1.25 (0.6%)	1.40 (0.7%)
Total	808.9	0.45 (0.1%)	0.30 (<0.1%)	4.31 (0.5%)	0.50 (0.1%)	12.21 (1.5%)	0.0	0.0	0.0	3.59 (0.4%)	1.40 (0.2%)

*Numbers in parentheses indicate system outage time as a percentage of total plant operating time.
**Commercial operation began March 13, 1977.

operation is not required. For this evaluation it was assumed that surveillance testing does not affect ECCS unavailability and that the observed outage times of various ECC systems at Crystal River Unit 3 are comparable with those of other PWRs.

Based on this comparison, it was concluded that the historical unavailability of the core flood tank, BWST, and the HPI systems has been consistent with the performance of those system throughout the industry. The observed unavailability was less than about one standard deviation above the industrial mean for these ECC components and system, assuming that the underlying unavailability is distributed lognormally. The outage times were also consistent with existing technical specifications. The outages of the diesel generators were not included in this comparison.

Historical unavailability of the remaining ECC system, LPI, did not compare favorably with the performance of similar systems throughout the industry. The average unavailability for this system, shown in Table 1, is well above the industrial mean plus one standard deviation. Due to the higher unavailability of the LPI system, the outage times were reviewed in detail using the FPC submittal [4] and licensee event report (LER) information obtained for the Nuclear Safety Information Center (NSIC) of Oak Ridge National Laboratory [16]. The purpose of this investigation was to ascertain the major contribution(s) to the high unavailability. This investigation revealed that most of the LPI system unavailability is attributable to failures of the decay heat pump discharge throttle valves (one in each of the two trains). The outages of these two valves contributed approximately 10 days out of a total of 12 days of LPI unavailability during the reporting period (82.8%).

In Reference 15, FPC states the "the decay heat pumps are provided with automatic flow control circuitry and throttle valves which maintain flow between 2800 gpm (with a 2750 gpm low flow alarm) and 3100 gpm (with a 3150 gpm high flow alarm) to preclude pump runout during any plant upset conditions." In addition to the automatic flow control mode, the valves have a manual mode to allow the operator to determine the flow rate. A listing of the outages of

the two throttle valves, DHV-110 and DHV-111, is provided in Table 2. In an effort to identify failure mode trends, this listing includes all available failure information and is not limited to only those failures occurring during Mode 1 operation.

From the data provided in Table 2, it can be concluded that valves DHV-110 and -111 have had continual flow control problems caused by the automatic control scheme. Review of outage information provided in References 4 and 5 and related LERs indicates that FPC had not identified a successful reoccurrence control measure as of late 1980. LER 80-036 described an event which occurred on August 27, 1980 and concludes that the cause was water in the sensing line. FPC indicated that the sensing line will be blown down after surveillance testing for 3 months to determine the extent of a condensation problem. FPC also indicated that an engineering evaluation of the control methodology for DHV-110 and -111 was in progress. On December 7, 1982 [17], it was confirmed that the engineering study is still in progress (over 2 years old) and that FPC is still experiencing automatic flow control problems with DHV-110 and -111. The NRC Resident Inspector indicated that FPC has not been able to identify a successful reoccurrence control measure.

The automatic flow control problem has not affected the ability of the operator to take manual control; however, the system was designed to start automatically without operator action and to initiate on low reactor coolant system pressure or high reactor building pressure. In the system design, operator action was not anticipated until 25 minutes after a LOCA when the operator was expected to open suction valves from the reactor building emergency sump to permit recirculation of the spilled reactor coolant and injection water from the reactor building sump. Failure within the automatic control scheme would require operator action following a LOCA. During the initial licensing review of the facility, operator action to manually control decay heat removal system flow was not considered in the system design bases.

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

In References 4 and 5, FPC did not include any recommendations to improve the availability of ECC systems and components. However, it is recommended

Table 2. Decay Heat Pump Discharge Throttle Valve Failures

Valve	Date	Power Level	Duration (hr)	Reference	Description
DHV-110	9/3/80	NA	48	4	failed valve operator
DHV-111	8/27/80	80%	12 estimate	4, 16	failed to control flow; water in sensing line
DHV-110	8/27/80	80%	12	4	failed to control flow; air in sensing line
DHV-110	8/6/80	0%	8	4	failed to control flow; air in sensing line
DHV-110	7/13/80	0%	80	4	failed to control flow; no cause-related information provided
DHV-111	7/13/80	0%	72.5	4	valve cycling; cause not determined
DHV-110	2/6/80	100%	168	4, 16	failed to control flow; Ref. 4: caused by loose wires; Ref. 16: cause unknown
DHV-110	3/17/79	0%	NA	4	valve inoperable; no cause-related information provided
DHV-110	3/11/79	0%	NA	4	failed to control flow; cause not determined
DHV-110	10/4/78	100%	9	4, 16	failed to control flow; flow controller valved out
DHV-111	6/21/78	0%	NA	4, 16	failed to open; cause not determined
DHV-110	12/7/77	100%	0.8	4, 16	failed to control flow; controller out of calibration
DHV-110	8/3/77	NA	12 estimate	4	failed to control flow; fuses blown

that the cause of each DHV-110 or DHV-111 outage be examined in detail and a determination made as to whether modifications to the current control scheme can be accomplished to improve the reliability of the throttle valves. Since previous attempts have not corrected the automatic flow control problem, it is further recommended that an evaluation be made of the viability of using passive flow control devices such as cavitating venturis as an alternative to active automatic flow control valves.

4. CONCLUSIONS

Flordia Power Corporation (FPC) has submitted reports for Crystal River Unit 3 which contain (1) outage dates and duration of outages, (2) causes of the outages, (3) ECC systems or components involved in the outages, and (4) corrective actions taken. The reports did not include information on surveillance testing; however, the FSAR states that surveillance testing is performed during plant shutdown. Therefore, it is concluded that FPC has fulfilled the requirements of NUREG-0737, Item II.K.3.17.

In addition, the historical unavailability of the core flood tank, high pressure injection, and borated water storage tank systems has been consistent with the performance of those systems throughout the industry. The observed unavailability was less than about one standard deviation above the industrial mean for the above ECCS systems. The observed unavailability of the low pressure injection system (LPI) did not compare favorably with those of similar systems throughout the industry. It is recommended that LPI outages subsequent to the reporting period be examined with particular attention given to outages of valves DHV-110 and -111. If subsequent data identifies continued automatic flow control problems, then a determination should be made as to whether modifications to the current control scheme can be accomplished to improve the availability of the throttle valves. It is further recommended that an evaluation be made of the viability of using passive flow control devices such as cavitating venturis as an alternative to active automatic flow control valves.

5. REFERENCES

1. NUREG-0626
   "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. NUREG-0660
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