TECHNICAL EVALUATION REPORT

AUXILIARY FEEDWATER SYSTEM AUTOMATIC INITIATION AND FLOW INDICATION

FLORIDA POWER CORPORATION

CRYSTAL RIVER UNIT 3

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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. J. E. Kaucher contributed to the technical preparation of this report through a subcontract with WESTEC Services, Inc.

1. INTRODUCTION

1.1 PURPOSE OF REVIEW

The purpose of this review is to provide a technical evaluation of the emergency feedwater (EFW) system design to verify that both safety-grade automatic initiation circuitry and flow indication are provided at Crystal River Unit 3. In addition, the steam generator level indication available at Crystal River Unit 3 is described to assist subsequent NRC staff review.

1.2 GENERIC ISSUE BACKGROUND

A post-accident design review by the Nuclear Regulatory Commission (NRC) after the March 28, 1979 incident at Three Mile Island (TMI) Unit 2 has established that the auxiliary (emergency) feedwater system should be treated as a safety system in a pressurized water reactor (PWR) plant. The designs of safety systems in a nuclear power plant are required to meet general design criteria (GDC) specified in Appendix A of the 10 CFR Part 50 [1].

The relevant design criteria for the auxiliary feedwater (AFW) system design are GDC 13, GDC 20, and GDC 34. GDC 13 sets forth the requirement for instrumentation to monitor variables and systems (over their anticipated ranges of operation) that can affect reactor safety. GDC 20 requires that a protection system be designed to initiate automatically in order to assure that acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences. GDC 34 requires that the safety function of the designed system, that is, the residual heat removal by the EFW system, be accomplished even in the case of a single failure.

On September 13, 1979, the NRC issued a letter [2] to each PWR licensee that defined a set of requirements specified in NUREG-0578 [3]. It required that the EFW system have automatic initiation and single failure-proof design consistent with the requirements of GDC 20 and GDC 34. In addition, auxiliary feedwater flow indication in the control room should be provided to satisfy the requirements set forth in GDC 13.

During the week of September 24, 1979, seminars were held in four regions of the country to discuss the short-term requirements. On October 30, 1979, another letter was issued to each PWR licensee providing additional clarification of the NRC staff short-term requirements without altering their intent [4].

Post-TMI analyses of primary system response to feedwater transients and reliability of installed EFW systems also established that, in the long term, the EFW system should be upgraded in accordance with safety-grade requirements. These long-term requirements were clarified in the letter of September 5, 1980 [5]. This letter incorporated in one document, NUREG-0737 [6], all TMI-related items approved by the commission for implementation at this time. Section II.E.1.2 of NUREG-0737 clarifies the requirements for the EFW system automatic initiation and flow indication.

1.3 PLANT-SPECIFIC BACKGROUND

The Florida Power Corporation (FPC) initially responded to the NRC requirements in a letter dated December 19, 1980 [7]. Supporting information describing the conceptual design of the EFW system in more detail was provided a letter dated August 11, 1981 [8].

This review of the EFW system at the Crystal River Unit 3 plant was begun in December 1981, based on the criteria described in Section 2 of this report.

2. REVIEW CRITERIA

To improve the reliability of the EFW system, the NRC required licensees to upgrade the system, where necessary, to ensure timely automatic initiation when required. The system upgrade was to proceed in two phases. In the short term, as a minimum, control-grade signals and circuits were to be used to automatically initiate the EFW system. This control-grade system was to meet the following requirements of NUREG-0578, Section 2.1.7.a [3]:

"1. The design shall provide for the automatic initiation of the auxiliary feedwater system.

2. The automatic initiation signals and circuits shall be designed so that a single failure will not result in the loss of auxiliary feedwater system function.

3. Testability of the initiating signals and circuits shall be a feature of the design.

4. The initiating signals and circuits shall be powered from the emergency buses.

5. Manual capability to initiate the auxiliary feedwater system from the control room shall be retained and shall be implemented so that a single failure in the manual circuits will not result in the loss of system function.

6. The ac motor-driven pumps and valves in the auxiliary feedwater system shall be included in the automatic actuation (simultaneous and/or sequential) of the loads to the emergency buses.

7. The automatic initiating signals and circuits shall be designed so that their failure will not result in the loss of manual capability to initiate the EFW system from the control room."

In the long term, these signals and circuits were to be upgraded in accordance with safety-grade requirements. Specifically, in addition to the above requirements, the automatic initiation signals and circuits must have independent channels, use environmentally qualified components, have system bypassed/inoperable status features, and conform to control system interaction criteria, as stipulated in IEEE Std 279-1971 [9].

The capability to ascertain the EFW system performance from the control room must also be provided. In the short term, steam generator level indication and flow measurement were to be used to assist the operator in maintaining the required steam generator level during EFW system operation. This system was to meet the following requirements from NUREG-0578, Section 2.1.7.b:

"1. Safety-grade indication of auxiliary feedwater flow to each steam generator shall be provided in the control room.

2. The auxiliary feedwater flow instrument channels shall be powered from the emergency buses consistent with satisfying the emergency power diversity requirements of the auxiliary feedwater system set forth in Auxiliary Systems Branch Technical Position 10-1 of the Standard Review Plan, Section 10.4.9 [10]."

The NRC staff has determined that, in the long term, the overall flowrate indication system for Babcock & Wilcox plants should include at least two AFW flowrate indicators per steam generator. The flowrate indication system should have independent channels, use environmentally qualified components, conform to single failure requirements, have the capability for periodic testing, and conform to control system interaction criteria as stipulated in IEEE Std 279-1971.

The operator relies on steam generator level instrumentation, in addition to auxiliary feedwater flow indication, to determine EFW system performance. The requirements for this steam generator level instrumentation are specified in Regulatory Guide 1.97, Revision 2, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident" [11].

3. TECHNICAL EVALUATION

3.1 GENERAL DESCRIPTION OF EMERGENCY FEEDWATER SYSTEM

The emergency feedwater (EFW) system at Crystal River Unit 3 supplies water to the secondary side of the steam generator for reactor decay heat removal when normal feedwater sources are unavailable due to loss of offsite power or other malfunctions. The system consists of one steam turbine-driven pump (740 gpm at 1300 psig) and one motor-driven pump (740 gpm at 1300 psig). Each pump is capable of feeding one or both steam generators. The pumps are interconnected on the discharge side by two crossover lines, one from each pump train.

3.2 AUTOMATIC INITIATION

3.2.1 Evaluation

Emergency feedwater flow to the steam generators will be automatically initiated when preset levels of any of the following parameters are exceeded.

A. Motor-Driven Pump

1. loss of both main feed pumps
2. low level in either steam generator
3. loss of all four reactor coolant pumps
4. flux to main feedwater flow ratio present
5. low pressure in either steam generator if main feedwater is isolated on this parameter

B. Turbine-Driven Pump

1. loss of both main feed pumps
2. low level in either steam generator
3. loss of all four reactor coolant pumps
4. flux to main feedwater flow ratio present
5. low pressure in either steam generator if main feedwater is isolated on this parameter.

Normal valve lineup is such that one air-operated flow control valve in each train must open in order to supply EFW to the respective steam generator or one of the pumps can supply water to both steam generators via a normally closed, air-operated valve in the respective crossover line and the normally closed, air-operated steam generator EFW control valve. Both pumps will be capable of manual start from either the control room or the equipment cabinet. The operation of either pump provides the capacity to remove decay heat from the steam generators at a rate sufficient to prevent overpressurization of the reactor coolant system and to maintain steam generator levels. Consequently, the EFW system will be capable of automatically initiating appropriate protective action with precision and reliability whenever a condition monitored by the system reaches a preset level.

The EFW system at Crystal River Unit 3, as stated in Reference 8, is designed as a safety-grade system, and the automatic initiation signals and circuits comply with the single-failure criterion of IEEE Std 279-1971. A review of initiation logic revealed no credible single malfunction that would prevent proper protective action at the system level when required. The diverse signals and redundant channels that provide automatic initiation are physically separated, electrically independent, and powered from emergency buses.

The two EFW trains are powered from diverse power sources. EFW pump EFP-2 is turbine-driven and EFW pump EFP-1 is motor-driven (4160 kV ac, bus 3A) with backup power from diesel generator 3A. To ensure EFW flow in the event of a loss of all ac power, the turbine-driven pump train derives its power from the steam generators for the pump and from battery-backed dc bus 8B for its steam supply valves. The motor-driven pump is part of the automatic sequencing of loads on the diesel generator.

All of the valves associated with each pump train are normally open with the exception of the four flow control valves (two in each train, in parallel). These valves are air operated with control power from battery-backed, dc, buses 3A and 3B. The control air for these valves is supplied from qualified, redundant, control-grade air supply systems, with redundant valves in the same train being connected to a different air supply system. The EFW control valves (EFW-55, EFW-56, EFW-57, and EFW-58) fail full open on loss of control air, and fail half open on loss of control power. Thus, in order to lose EFW flow in either train, both air supplies must fail and both control valves must fail out of their fail-safe position.

The capability to manually initiate EFW flow is provided, and these manual initiation circuits meet single failure criteria. Both the motor-driven and turbine-driven pumps can be started from either the control room or local equipment cabinets. A single failure in the manual circuits will not result in the loss of system automatic function, and a failure of the automatic initiation signals and circuits will not result in the loss of manual capability.

The automatic initiation signals and circuitry used at Crystal River Unit 3 comply with the IEEE Std 279-1971 requirements concerning control and protection system interaction, including the use of isolation amplifiers to transmit protection signal intelligence to other than protection functions.

The quality of components used in the EFW system is assured by safety-grade, seismic, and Class 1E requirements imposed upon the design, fabrication, and quality assurance of engineered safety features systems. The determination of adequate environmental qualification of all safety-related systems, including the EFW system, is being accomplished separately and is beyond the scope of this review.

The primary source of water for the EFW system is the Seismic Category 1 condensate storage tank. Water is supplied from this tank via an 8-inch line, with a locked-open manual valve (CDV-103), to separate 6-inch lines containing normally open motor-operated valves EFV-3 and EFV-4. A reserve of 150,000 gallons is maintained within the tank and is verified by redundant, safety-grade level indication in the control room. This volume is sufficient to remove decay heat for approximately 15 hours or to remove decay heat plus cooldown to allow use of the decay heat removal system in about 11 hours. Safety-grade low-level alarms are also provided to alert the operators. The secondary water source is the main condenser hotwell. Water from the hotwell is supplied via separate 8-inch lines with normally closed, dc-powered valves EFV-1 and EFV-2. The tertiary water supply is the fire service system.

Automatic isolation of EFW flow to a leaking steam generator is provided. A steamline or feedwater line break that depressurizes a steam generator will cause the isolation of the main steamlines and main feedwater lines on the depressurized steam generator. If isolation of the steam generator main feed and main steam lines does not then isolate the break, EFW will be isolated from the leaking steam generator so that EFW flow will be provided only to the intact steam generator. The Licensee has stated that no single active failure will prevent EFW from being supplied to the intact steam generator or allow EFW to be supplied to the leaking steam generator.

Initiation and control of the EFW system are accomplished by the emergency feed initiation and control system (EFIC). The EFIC channels are powered from inverters. The EFIC is designed to provide the following:

- o initiate EFW
- o control EFW
- o provide level rate control
- o isolate the main steam and main feed lines of a depressurized steam generator
- o control the atmospheric dump valve.

Manual initiation of the system is accomplished by depressing two manual trip switches. The use of two switches permits testing of the trip switches and also reduces the possibility of accidental manual initiation. A manual reset switch is provided which functions not only for system reset, but also as a system bypass. Operation of this manual reset (bypass) push button:

- o will have no effect on the trip logic so long as a trip condition does not exist

- o will remove the trip from the trip bus only so long as the switch is depressed in the case of a one half trip (either bus, but not both tripped). This allows for testing the manual function.

- o will remove the trip from both buses so long as a full trip exists. This is accomplished by means of manual latching logic. If the initiating signal clears, the trip logic will revert to the automatic trip mode in preparation for tripping if a parameter returns to the trip region.

Present design is such that this reset (bypass) is activated from the EFIC room, and no annunciation for the bypass condition is provided.

Channel bypasses exist in the EFIC system at Crystal River Unit 3 to allow testing of the initiation logic, and are known as maintenance bypasses. Only one channel at a time is allowed in test and this is ensured by electric interlock.

An operational bypass exists for the power/main feedwater flow trip signal, in that the plant can be taken to 20% power with no main feedwater flow, after which the trip will be automatically initiated. This bypass is for plant start-up.

Status light indication is provided for the EFIC system (bypass, test, tripped, etc.).

The capability to monitor system operation is provided by direct position indication for all automatically operated and remote manual, power-operated valves as well as the following:

- o high steam generator level (for SGA and SGB)
- o low steam generator level (for SGA and SGB)
- o low source water level
- o low EFW pump discharge pressure (pump P-318 and P-319)
- o steam line valves MSV-55 and MSV-56 closed
- o all motor-operated valves in the EFW system not in proper position.

Future test requirements are proposed to be monthly on the EFIC signals and circuits, with an 18-month calibration interval, although no technical specifications presently exist to cover these testing requirements.

3.2.2 Conclusion

Based on the evaluation in Section 3.2.1, it is concluded that the initiation signals, logic, and associated circuitry of the EFW system at Crystal River Unit 3 comply with the long-term safety-grade requirements of Section 2.1.7.a of NUREG-0578 [3] and the subsequent clarification issued by the NRC with the following exceptions:

- o No indication is provided for the override of the EFW system automatic initiation. Even though deliberate operator action is required to initiate this override from the EFIC room, annunciation of this condition should be provided in the control room
- o No technical specifications exist which cover the testing requirements for the EFW system.

3.3 FLOW INDICATION

3.3.1 Evaluation

The performance of the EFW system at Crystal River Unit 3 can be assessed by the EFW flow indication, steam generator level indication, and system valve position indication. Each of the four EFW flow paths (two for each steam generator) will have flow indication. The flowmeters will receive electrical power from safety-grade power supplies. The power for the inverters is supplied from a diesel-generator-backed ac bus and a battery-backed dc bus.

Each flowmeter system will be independent from the other flowmeters, and channel separation will be maintained as with any Class IE wiring system.

Each flowmeter will have an indicator in the control room. The system will be able to be fed on an individual flowmeter basis.

As stated in Section 3.2.1, future test requirements are proposed to be monthly on the EFIC signals and circuits, with an 18-month calibration interval.

The environmental qualification of safety-related electrical and mechanical equipment including EFW system circuits and components is being reviewed separately by the NRC and is not within the scope of this review.

3.3.2 Conclusion

The flow indication system at Crystal River Unit 3 satisfies the long-term requirements of Section 2.1.7.b of NUREG-0578 that at least two EFW flowrate indicators exist for each steam generator.

3.4 DESCRIPTION OF STEAM GENERATOR LEVEL INDICATION

Steam generator level instrumentation at Crystal River Unit 3 consists of four qualified low-range and four qualified high-range level transmitters (which provide indication, control, and protection) for each steam generator. These transmitters provide inputs to four EFIC channels. Each EFIC channel receives a low-range and high-range input from each steam generator and will have local indication in the EFIC cabinet, as well as redundant indicators on the main operator control console. The EFIC channels are powered from inverters.

4. CONCLUSIONS

Based on the evaluation in Section 3.2.1, it is concluded that the initiation signals, logic, and associated circuitry of the EFW system at Crystal River Unit 3 comply with the long-term safety-grade requirements of Section 2.1.7.a of NUREG-0578 [3] and the subsequent clarification issued by the NRC with the following exceptions:

- No indication is provided for the override of the EFW system automatic initiation. Even though deliberate operator action is required to initiate this override from the EFIC room, annunciation of this condition should be provided in the control room
- No technical specifications exist which cover the testing requirements for the EFW system.

The flow indication system at Crystal River Unit 3 satisfies the long-term requirements of Section 2.1.7.b of NUREG-0578 that at least two EFW flowrate indicators exist for each steam generator.

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