TECHNICAL EVALUATION REPORT

AUXILIARY FEEDWATER SYSTEM AUTOMATIC INITIATION AND FLOW INDICATION

INDIANA & MICHIGAN ELECTRIC COMPANY
DONALD C. COOK UNITS 1 AND 2

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293

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CONTENTS

1. INTRODUCTION

1.1 PURPOSE OF REVIEW

The purpose of this review is to provide a technical evaluation of the emergency feedwater system design to verify that both safety-grade automatic initiation circuitry and flow indication are provided at D. C. Cook Units 1 and 2. In addition, the steam generator level indication available at D. C. Cook is described to assist subsequent NRC staff review.

1.2 GENERIC ISSUE BACKGROUND

A post-accident design review by the Nuclear Regulatory Commision (NRC) after the March 28, 1979 incident at Three Mile Island (TMI) Unit 2 has established that the auxiliary feedwater (AFW) 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 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 AFW 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 short-term requirements specified in NUREG-0578 [3]. It required that the AFW 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 shall 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 impact of 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 AFW systems also established that, in the long term, the AFW 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 AFW system automatic initiation and flow indication.

1.3 PLANT-SPECIFIC BACKGROUND

The Indiana & Michigan Electric Company responded to NRC requirements through letters [7-12], with supporting documents and logic diagrams, describing the AFW systems at the Donald C. Cook Units 1 and 2.

The Franklin Research Center (FRC) staff started a review of the AFW systems at the Donald C. Cook Units on September 19, 1980, based on the criteria described in Section 2 of this report. In a conference call among staff of the Licensee, FRC, and NRC on September 30, 1980, FRC requested more information, and the Licensee documented the additional information in a letter to the NRC dated December 10, 1980 [13].

2. REVIEW CRITERIA

To improve the reliability of the AFW 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 AFW 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 AFW 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 [14].

The capability to ascertain the AFW 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 AFW 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 System Branch Technical Position 10-1 of the Standard Review Plan, Section 10.4.9 [Ref. 15 in this report]."

The NRC staff has determined that, in the long term, the overall flowrate indication system for Westinghouse plants should include at least one auxiliary feedwater flowrate indicator for each steam generator. The safety-grade flowrate indication system must satisfy the single failure criterion, be environmentally qualified, have as a design feature the capability to test the indicating channels, and conform to the 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 AFW 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" [16].

3. TECHNICAL EVALUATION

3.1 GENERAL DESCRIPTION OF AFW SYSTEM

The Donald C. Cook Units 1 and 2 are Westinghouse-designed "four loop" nuclear generating plants. The AFW systems for the two units are essentially identical and are, by design, part of the engineered safety features (ESF). The Licensee has proposed modifications of the AFW system to meet long-term safety requirements. FRC's review is based on those proposed modifications.

For each unit, the AFW system consists of a steam-turbine-driven pump and two motor-driven pumps. The steam-turbine-driven pump supplies auxiliary feedwater flow to each of the four steam generators of its associated unit. The two motor-driven auxiliary feedwater pumps supply two steam generators each (i.e., the east motor-driven pump supplies steam generators Nos. 2 and 3, and the west motor-driven pump supplies steam generators Nos. 1 and 4.

FMO-211, -221, -231, and -241 (Unit 1 or Unit 2) are the steam generator supply valves from the turbine-driven auxiliary feedwater pump (TDAFP). These motor-operated valves are normally open, but each may be closed by the control room operator in the event of a feedwater or steam line break. They also may be throttled to regulate steam generator level. In the event of a steam line break and rapid depressurization of a steam generator, or upon detection of a high flow at the TDAFP, these valves are automatically driven to an intermediate position to prevent pump runout. On loss of power, the valves fail as is.

FMO-212, -222, -232, and -242 (Unit 1 or Unit 2) are the steam generator supply valves from the motor-driven auxiliary feedwater pumps (MDAFP). These motor-operated valves are normally closed and are opened and/or throttled as described above. The valves open automatically as a result of any of the signals which require MDAFP start-up for that unit. On loss of power, the valves fail as is. A single failure (a safety bus blackout) will cause the failure of a MDAFP and prevent the associated motor-operated valves from opening. However, the remaining MDAFP and TDAFP are capable of supplying water to their respective steam generators, thus satisfying the single failure criterion.

Steam is supplied to the TDAFPs from the Nos. 2 and 3 steam generators of the associated unit. The steam is taken upstream of the main steam isolation valves. The TDAFP steam supply isolation valves (MCM-221 and -231) are normally open, allowing steam pressure to be available up to the trip-and-throttle (T&T) valve at each turbine. The motor-operated steam isolation valves (MCM-221 and -231) can be opened or closed from the control room; on loss of power, they fail as is. The T&T valve opens automatically when the TDAFP receives a start-up signal.

Each auxiliary feedwater pump has an emergency leakoff line and a test line. The emergency leakoff line ensures a minimum flow through the pump to prevent pump overheating and possible damage. The test valves are normally closed. They are diaphragm type valves, spring actuated to fail closed on loss of air pressure. Should the test valves be left in the open position, an automatic start-up of the auxiliary feed pumps will automatically close them.

3.2 AUTOMATIC INITIATION

3.2.1 EVALUATION

The automatic initiation signals and circuitry for the AFW systems at D. C. Cook Units 1 and 2 comply with the general functional requirements of IEEE Std 279-1971 [14]. The following signals are used for auxiliary feedwater automatic initiation:

A. Turbine-Driven Auxiliary Feedwater Pump

1. low-low steam generator water level in any two of the four steam generators (possible loss of feedwater or steam line break)

2. undervoltage of reactor coolant pumps (RCP) bus (anticipation of loss of offsite power)

B. Motor-Driven Auxiliary Feedwater Pumps

1. low-low steam generator water level in any one of the four steam generators

2. undervoltage of RCP bus (two out of four logic)

3. any safety injection actuation signal derived from:

a. low pressurizer pressure

b. high differential pressure between steam lines

c. high steam flow in two steam lines, coincident with either low-low Tavg or low steam line pressure (Unit 1 only)

d. low steam line pressure (Unit 2 only)

e. high containment pressure

4. blackout safeguards sequence

5. loss of main feedwater pumps.

The TDAFP can also be started manually from the local hot shutdown panel or remotely from the control room; the MDAFP can also be started manually.

The automatic initiation signals and circuits for the AFW systems at the D. C. Cook plant comply with the single-failure criterion of IEEE Std 279-1971. The initiating signals and associated circuitry that actuate the AFW system are the same as those used to initiate the reactor trip and the ESFs. They are powered from the essential buses. A two-train concept is used for redundancy, and the Licensee has stated that the channels which provide the AFW system automatic initiation signals are independent and physically separated. In addition, no single failure within the manual or automatic initiation systems will prevent initiation of auxiliary feedwater by manual or automatic means. In case of safety bus blackout, the motor-driven pumps start in sequence onto the diesel generators with the remainder of the blackout load. For safety injection coincident with safety bus blackout, the motor starts in sequence with the remainder of the safety injection loads.

The AFW system and components are tested in accordance with technical specification requirements. During each work shift, the sensors used in automatic initiation circuits, the steam generator water level indicators, and the 4-kV bus loss of voltage and undervoltage detectors are checked for operation by cross-checking between channels. The channel functional tests for logic trip circuits and trip set points are performed once a month. The auxiliary feedwater pumps are tested monthly by manual initiation from the control room. The operability of the auxiliary feedwater pumps and power-operated valves are

checked, at least once every 18 months during shutdown, by verifying that the pumps and associated valves operate automatically upon receipt of each auxiliary feedwater actuation test signal (including blackout signal) that simulates emergency operation of the system.

The Licensee has stated that the automatic initiation signals for the AFW system that are generated by the ESF actuation system are designed as a minimum in accordance with IEEE Stds 279-1971 and 323-1974 [17]. Adequate environmental qualification of the circuits and components is reviewed separately by NRC staff and is beyond the scope of the present FRC task.

There are no bypasses at the system level during periodic testing of the AFW system automatic initiation circuits for the D. C. Cook plant. The status of process analog channels and trip circuits during surveillance testing is indicated on the ESF bypass panel in the control room. No interaction between the AFW system safety and control functions was found.

The operating bypasses associated with the automatic initiation logic are:

A. Turbine-Driven Auxiliary Feedwater Pump

There are no bypasses in the TDAFP logic which prevent automatic initiation.

B. Motor-Driven Auxiliary Feedwater Pump

There are two bypasses in the MDAFP automatic initiation logic.

1. The P-11 interlock in the reactor protection system (RPS) logic is used to allow the manual block of the safety injection actuation signal generated by low pressurizer pressure. This interlock is reset automatically when pressurizer pressure goes above 1915 psig for Unit 1 and 2010 psig for Unit 2.

2. The P-12 interlock in the RPS logic is used to allow the manual block of the safety injection actuation signal generated by (a) high steam flow in two steam lines coincident with low steam line pressure in Unit 1 and (b) low steam line pressure in Unit 2. This interlock (both units) is reset automatically when primary system temperature is above the low-low Tavg set point of 541°F.

The remaining signals that generate a safety injection actuation (which automatically starts the MDAFPs) and the automatic MDAFP start-up signals listed earlier do not have operating bypasses.

3.2.2 CONCLUSION

Based on the evaluation documented in Section 3.2.1, it is found that the initiation signals, logic, and associated circuitry of the AFW systems at D. C. Cook Units 1 and 2 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.

3.3 FLOW INDICATION

3.3.1 EVALUATION

Flow indication is used to ascertain the performance of the AFW systems at the D. C. Cook plant. The AFW system flow indication consists of individual sensors, current loop circuitry, and individual meters for each of the four auxiliary feedwater lines, one to each steam generator. The major equipment used in the indication system is individual differential pressure transmitters, individual dc power supplies, and individual dc ammeters. The auxiliary feedwater flow indicators (FFI-210, FFI-220, FFI-230, and FFI-240) are fed from the balance-of-plant (BOP) inverter in each unit (non-class 1E), which is an uninterruptible power source fed by the CD battery of Unit 1 and the AB battery of Unit 2 (safety-related station batteries). One instrument channel per steam generator is provided. The flow indication instruments are located on Panel SG in the main control room and on the appropriate hot shutdown panel for each unit. Also, each pump has a discharge pressure indicator (FPI-244, FPI-253, FPI-254) in the control room. The pressure indicators are powered by the same source as the flow indicators. Operability of this power source (BOP inverter) is required by the Technical Specifications.

The present transmitters, located outside containment, are control grade. The Licensee has stated that the existing transmitters will be qualified or replaced with ones qualified to the outside containment requirements of IEEE Std 323-1974 by January 1, 1981.

The AFW system flow indication by itself does not satisfy the single failure criterion; however, each flow channel is backed by steam generator level indicators. Testing of the AFW system flow indication is provided in accordance with the D. C. Cook plant Technical Specifications. Under surveillance requirements, the auxiliary feedwater pumps are started at least once every 31 days using the pump recirculation lines, and the flow is checked. The AFW system flow indication channels are calibrated during refueling outages.

The flow channels have no control functions and are used for indication only. The indication error is not greater than ±5.5%.

3.3.2 CONCLUSION

Based on the review detailed in the previous section, it is concluded that the flow channels of the AFW systems at D. C. Cook Units 1 and 2 comply with the long-term safety-grade requirements of Section 2.1.7.b of NUREG-0578 and the subsequent clarification issued by the NRC, with the exception of the flow transmitters, which are control grade.

3.4 STEAM GENERATOR LEVEL INDICATION DESCRIPTION

The D. C. Cook steam generator level instrumentation is described here to document the in-place hardware for subsequent NRC evaluation. The instrumentation consists of three safety-grade narrow-range level channels and one non-safety-grade wide-range level channel per steam generator. The narrow-range level channels are designed as part of the ESF and meet the single failure criterion. The three narrow-range level indicators are used in the RPS in a 2 out of 3 coincidence logic. The testing of narrow-range channels is performed under Technical Specification surveillance requirements on a shift (channel check), monthly (functional test), and refueling outage (calibration) basis.

The Licensee stated that the wide-range channel is not used in any protection system and therefore is not designed to meet safety-grade criteria.

All steam generator level measurement systems are supplied from the vital instrument buses, which are Class 1E uninterruptible power sources. There are four independent vital instrument buses: Channels 1, 2, 3, and 4.

The level instrumentation for the steam generators is tabulated below:

A. Steam Generator No. 1

BLP-110, Channel 4 Indicator
BLP-111, Channel 2 Indicator-Recorder
BLP-112, Channel 3 Indicator
BLI-110,* Channel 4 Indicator-Recorder

B. Steam Generator No. 2

BLP-120, Channel 4 Indicator
BLP-121, Channel 1 Indicator-Recorder
BLP-122, Channel 3 Indicator
BLI-120,* Channel 4 Indicator-Recorder

C. Steam Generator No. 3

BLP-130, Channel 4 Indicator
BLP-131, Channel 1 Indicator-Recorder
BLP-132, Channel 3 Indicator
BLI-130,* Channel 4 Indicator-Recorder

D. Steam Generator No. 4

BLP-140, Channel 4 Indicator
BLP-141, Channel 2 Indicator
BLP-142, Channel 3 Indicator-Recorder
BLI-140,* Channel 4 Indicator-Recorder

Note: Asterisk indicates wide-range level indicator.

All indicator and recorder elements have D'Arsonval movements, which obtain their energy from the transducer system and require no further energy to drive the indicating devices. The chart motors of the recorders, which are not required for recorder pen indication, are fed from non-safety-grade BOP control buses.

All narrow-range channels have a range of 144 inches and begin to indicate at 431 inches of water.

4. CONCLUSIONS

The FRC review of the D. C. Cook Units 1 and 2 AFW system automatic initiation circuits and flow instrumentation concludes that these systems comply with the long-term safety-grade requirements with the exception of the flow transmitters, which are presently control grade.

5. REFERENCES

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2. NRC generic letter to all PWR Licensees regarding short-term requirements resulting from Three Mile Island Accident, September 13, 1979.

3. NUREG-0578, "TMI-2 Lessons Learned Task Force Status Report and Short-Term Recommendations," USNRC, July 1979.

4. NRC generic letter to all PWR Licensees clarifying lessons learned short-term requirements, October 30, 1979.

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6. NUREG-0737, "Clarification of TMI Action Plan Requirements," USNRC, November 1980.

7. American Electric Power Company letter from J. E. Dolan to H. R. Denton (NRC), August 9, 1979.

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15. NUREG-75/087, Standard Review Plan Section 10.4.9, Rev. 1, USNRC, no date.

16. Regulatory Guide 1.97 (Task RS 917-4), "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident," Rev. 2, USNRC, December 1980.

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