TECHNICAL EVALUATION REPORT

AUXILIARY FEEDWATER SYSTEM AUTOMATIC INITIATION AND FLOW INDICATION (F-16, F-17)

ARKANSAS POWER AND LIGHT COMPANY
ARKANSAS NUCLEAR ONE UNIT 2

NRC DOCKET NO. 50-368

NRC TAC NO. 12358

NRC CONTRACT NO. NRC-03-79-118

FRC PROJECT C5257

FRC ASSIGNMENT 9

FRC TASK 307

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May 28, 1982

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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. 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 system* design at Arkansas Nuclear One (ANO) Unit 2 to verify that both safety-grade automatic initiation circuitry and flow indication are provided. In addition, the steam generator level indication available at ANO Unit 2 is described to assist subsequent Nuclear Regulatory Commission (NRC) staff review.

1.2 GENERIC ISSUE BACKGROUND

An NRC design review after the March 28, 1979 incident at Three Mile Island (TMI) Unit 2 established that the emergency feedwater (EFW) system should be treated as a safety system in pressurized water reactor (PWR) plants. The designs of safety systems in a nuclear power plant are required to meet the general design criteria (GDC) specified in 10CFR50, Appendix A [1].

The relevant criteria for the EFW system design are GDC 13, GDC 20, and GDC 34. GDC 13 sets forth the requirement for instrumentation to monitor, over their anticipated ranges of operation, variables and systems that can affect reactor safety. GDC 20 requires that a protection system be designed to initiate automatically 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, can be accomplished even in the event 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 EFW system have automatic initiation and single-failure-proof

*In this report, the system is referred to as the emergency, rather than auxiliary, feedwater system because that designation is used throughout the ANO-2 documentation.

design consistent with the requirements of GDC 20 and GDC 34. In addition, EFW flow indication must be provided in the control room 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 further clarifying the NRC staff's 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 a 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 that 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

In a letter to Arkansas Power and Light Company (AP&L) dated November 6, 1979 [7], the NRC defined both generic and plant-specific requirements for the ANO Unit 2 EFW system. Following an in-house review of the Reference 7 requirements, AP&L responded in a letter dated January 31, 1980 [8]. On September 17, 1980, AP&L proposed a change in ANO Unit 2 Technical Specifications related to post-outage flow tests of the steam-driven EFW pump [9].

The present review of the EFW system at ANO Unit 2 was begun on July 15, 1981, based upon the criteria described in Section 2 of this report.

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.

2. REVIEW CRITERIA

To improve EFW system reliability, 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 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/

*In the ANO Unit 2 plant, this system is called the emergency feedwater system.

inoperable status features, and conform to control system interaction criteria, as stipulated in IEEE Std 279-1971 [10].

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 [3]:

"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" [11].

The NRC staff has determined that, in the long term, a minimal overall flowrate indication system for Combustion Engineering plants must include either one EFW flowrate indicator with one wide-range steam generator level indicator for each steam generator, or two flowrate indicators. The flowrate indication system should be environmentally qualified, powered from a highly reliable, battery-backed non-Class 1E power source, periodically testable, part of the plant's quality assurance program, and capable of display on demand. (See also IEEE Std 279-1971 [10].)

The operator relies on both steam generator level instrumentation and EFW 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" [12].

3. TECHNICAL EVALUATION

3.1 GENERAL DESCRIPTION OF THE EMERGENCY FEEDWATER SYSTEM

The Arkansas Nuclear One Unit 2 EFW system was designed by Combustion Engineering as an engineered safety feature (ESF) system. The two pumps in the EFW system are:

1. one steam turbine-driven multistage centrifugal pump (500 gpm at 1220 psia). Steam for this turbine can be supplied by either of the two steam generators in the unit.

2. one electric motor-driven multistage centrifugal pump (500 gpm at 1220 psia). This pump is powered by a Class 1E bus backed by an independent diesel generator system.

The EFW system consists of two trains, one with the motor-driven pump and the other with the turbine-driven pump. Each pump train has two parallel paths from the pump discharge to allow a given pump to feed one or both steam generators. Each flow path in turn has two series electrically operated, normally closed valves (motor-driven pump legs each have one electrically operated ball valve and one electrohydraulic valve; turbine-driven pump legs each have one electrically operated ball valve and one motor-operated valve).

3.2 AUTOMATIC INITIATION

3.2.1 Evaluation

The EFW system is an integral part of the engineered safety features actuation system (ESFAS) for ANO Unit 2. The EFW system is automatically initiated when it receives signals indicating an unsafe low pressure and/or low level condition in either steam generator. When the EFW system is initiated, both pumps start and the appropriate power-operated discharge valves are opened to feed water to the intact steam generators. A main steam isolation signal (MSIS) will prevent water flow to a damaged steam generator. No single failure can prevent the EFW system from delivering emergency feedwater to the intact steam generators when required. Also, no single failure can prevent manual initiation of the EFW system from the control room or from remote locations.

An emergency feedwater actuation signal (EFAS) is initiated to steam generator 1 either by a low steam generator level coincident with no low pressure trip present on steam generator 1, or by a low steam generator level coincident with a differential pressure between the two steam generators with the higher pressure in steam generator 1 (the EFAS is identical for steam generator 2). All actuation signals are devised from 2 of 4 measurement channels coincidence logic. Each measurement channel is powered by a separate dc power source supplied from a separate 120-volt, vital (Class 1E) ac distribution bus.

The motor-driven EFW pump and associated control valves are powered from Class 1E, diesel generator backed power supplies, while the turbine-driven pump steam admission and control valves are powered from a Class 1E battery backed dc sources.

The normal water source for the EFW system is the 200,000 gallon, Non-Seismic Category 1, condensate storage tank (CST) with the secondary source of water being the Seismic Category 1 serviced water system whose supply is either the emergency cooling pond or the Dardanell Reservoir. The plant Technical Specifications state that 160,000 gallons of the 200,000 gallons available from the CST are dedicated to the EFW system. The EFW system is designed to remove reactor decay heat and provide for cooldown of the reactor coolant system to within the temperature and pressure at which the shutdown cooling system can be placed in operation. The EFW supply system is designed so that supply is automatically shifted from normal to secondary on low EFW pump suction pressure. Safety-grade alarms in the control room are also provided.

The instrumentation and controls of the components and equipment of one redundant group are physically and electrically separate and independent of the instrumentation and controls of the components and equipment in the other redundant group, as specified in IEEE Std 279-1971. The automatic initiation signals and circuits are designed such that their failure will not result in the loss of manual capability. ESF loads are divided into two completely redundant groups, thus satisfying the single failure criterion.

The following EFW indication is provided in the control room:

a. motor pump power on/off

b. pressure in steam line at turbine

c. EFW pump discharge pressure

d. EFW flow rate to each steam generator (four sensors and indicators)

e. position of each of four electrohydraulically operated valves between the pumps and the steam generators

f. position of each of four motor-operated valves between the pumps and the steam generators

g. positions of six motor-operated valves governing the routing of source water to the EFW system from condensate storage, demineralizer effluent, or the service water system

h. liquid level in each steam generator (four sensors per steam generator)

i. pressure at each steam generator (four sensors per steam generator)

j. CST level.

Concerning bypasses, the Licensee has stated the following:

o <u>Channel Bypasses</u>

Any one of the four EFW instrumentation channels may be tested, calibrated, or repaired without detrimental effects on the system. Individual trip channels may be bypassed to effect a two-out-of-three logic on remaining channels. The single failure criterion is met during this condition. Indication of bypass is given by light and audible alarm.

o <u>Operating Bypasses</u>

1. During startup and shutdown modes of operation, the initiation channel modules are removed and jumpered to allow operating the EFW system out of the normal operating band. Operation of the EFW system with the modules removed and jumpered is controlled by procedure. No control room annunciation is provided for removal of these modules.

2. The motor-driven EFW pump has a pull-to-lock position on the pump control switch, which will override an automatic initiation signal. Placing the pump control switch in the pull-to-lock position is automatically annunciated.

Periodic testing of the ANO Unit 2 EFW system is consistent with the guidelines contained in NUREG-0212 [13] for the ESFAS. The number of measurements, frequency of channel test, and surveillance programs exceed the required values.

All aspects of the EFW system and its circuitry are tested in a manner compatible with the requirements of References 14 and 15. Functional testing of signal, logic, and control circuits is performed every 31 days. When in progress, these tests do not impair the protective function of the system. During routine operation, sensor calibrations are checked by cross-comparison of redundant channels. During extended shutdown, end-to-end calibrations are performed against known standards.

The environmental qualification of all EFW system auto-initiation components is being reviewed separately by the NRC and is outside the scope of this review.

3.2.2 Conclusion

Based on the investigations performed in this evaluation, it is concluded that the initiation signals, logic, and associated circuitry of the EFW system at ANO Unit 2 comply with the safety-grade requirements of Section 2.1.7.a of NUREG-0578 and the subsequent clarification issued by the NRC with the following exception:

- The removal of initiation channel modules to provide an operating bypass is not annunciated in the control room as required by IEEE Std 279-1971.

3.3 FLOW INDICATION

3.3.1 Evaluation

The capability of ascertain the performance of the EFW system at the ANO Unit 2 plant is provided by flow elements (2FE 0710-1, 0717-1, 0713-2, and

0718-2) to the steam generators. One flow element is located in each of the two legs per pump; thus, it is possible to determine not only total flow to each steam generator, but also the flow provided by each pump to a given steam generator. In addition, four wide-range, safety-grade steam generator level indicators are provided in the control room for each steam generator, as well as EFW valve position indication and EFW pump status lights.

The Licensee has stated in Reference 8 that the ANO Unit 2 flow indication system is designed as safety-grade and each channel is powered from an emergency bus; consistent with satisfying the emergency power diversity requirements set forth in Auxiliary Systems Branch Technical Position 10-1.

On-line calibration can be accomplished, on a channel-to-channel comparison basis, whenever the system is running for non-emergency purposes. A true calibration test of a flow meter element requires its removal from the line, which is possible only during plant shutdown. Technical Specifications require a minumum of one active channel as part of the "Remote Shutdown Monitoring Instrumentation." The "Remote Shutdown Instrumentation, Surveillance Requirements" require 31-day channel checks and 18-month calibration. The "Accident Monitoring Instrumentation" Technical Specifications require two channels, with one active, for each steam generators [13].

The qualification of EFW system components, including EFW flow, is being reviewed separately by the NRC and is not within the scope of this review.

3.3.2 Conclusion

Based on the above evaluation, it is concluded that the EFW flow measurement and indication system complies with the long-term safety-grade requirements of Section 2.1.7.b of NUREG-0578 and the subsequent clarification issued by the NRC.

3.4 DESCRIPTION OF STEAM GENERATOR LEVEL INDICATION

Four safety-related level transmitters are connected to eight separate pressure taps on each steam generator. The transmitters are electrically connected to two different dc battery divisions in pairs. Table 1 lists the transmitter numbers, color codes, and battery division connections for the eight safety-grade transmitters. All transmitters are Rosemount Model 1153, and all displays are vertical indicators.

Table 1

Safety-Grade Steam Generator Level Sensors

Steam Generator	Transmitter No.	Color Code	dc Battery Division	Range
A	2LT1031-1	Red	1	0-100%
A	2LT1031-2	Green	2	0-100%
A	2LT1031-3	Yellow	1	0-100%
A	2LT1031-4	Blue	2	0-100%
B	2LT1033-1	Red	1	0-100%
B	2LT1033-2	Green	2	0-100%
B	2LT1033-3	Yellow	1	0-100%
B	2LT1033-4	Blue	2	0-100%

These safety-grade transmitters are part of both the trip circuits for the reactor and the EFW system auto-initiation circuitry.

Each steam generator is also equipped with two non-safety-grade transmitters that are powered from non-safety ac power sources. Table 2 lists these non-safety-grade transmitters, all of which are Rosemount Model 1153.

Table 2

Non-Safety-Grade Steam Generator Level Transmitters

Steam Generator	Transmitter No.	Type of Readout	Range
A	2LT1033	Indicator	0-100%
A	2LT1034	Recorder	0-100%
B	2LT1133	Indicator	0-100%
B	2LT1134	Recorder	0-100%

Commonality exists with respect to pressure taps for both types of transmitters. For example, 2LT1034 and 2LT1031-4 share the same taps and lines but are not powered from the same source.

Safety-related transmitters are check-calibrated every 31 days. Cross comparisons are made each day. Calibration is performed during refueling outages every 12 to 18 months.

Each safety-grade level transmitter output is indicated in the control room.

In addition to the safety-grade indicators, each steam generator level is shown on an "indicator/controller" with a continuous history provided on a recorder.

4. CONCLUSIONS

Based on the investigations performed in this evaluation, it is concluded that the initiation signals, logic, and associated circuitry of the emergency feedwater (EFW) system at ANO Unit 2 comply with the safety-grade requirements of Section 2.1.7.a of NUREG-0578 and the subsequent clarification issued by the NRC with the following exception:

- The removal of initiation channel modules to provide an operating bypass is not annunciated in the control rrom as required by IEEE Std 279-1971.

It is concluded that the EFW flow measurement and indication system complies with the long-term, safety-grade requirements of Section 2.1.7.b of NUREG-0578 and the subsequent clarification issued by the NRC.

5. REFERENCES

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Enclosure 2

UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SUPPLEMENTAL
SAFETY EVALUATION
ARKANSAS UNIT 2 - BYPASS OF
STEAM GENERATOR LOW LEVEL
EMERGENCY FEEDWATER AUTOMATIC
INITIATION SIGNALS

INTRODUCTION AND SUMMARY

The Arkansas Unit 2 (ANO-2) plant protection system uses steam generator (SG) water level signals for reactor trip on low SG level, automatic initiation of Emergency Feedwater (EFW) on low SG level, and reactor trip on high SG level. These protection signals are bypassed when entering mode 5 (cold shutdown) to prevent starting the EFW pumps and tripping the reactor (the ANO-2 design requires cocked rods to be maintained for additional shutdown margin in modes 5 and 6).

The methods currently used to implement these bypasses and to remove them prior to plant startup are not acceptable to the staff for reasons discussed below.

EVALUATION

The ANO-2 SG level protective signals are bypassed when entering mode 5 by lifting the SG level transmitter input leads (total of eight; there are four level transmitters for each of the two SGs) and inserting resistors across the transmitter input terminals to the protection system. This causes the SG level trip bistables, level indicators and recorders, and the plant computer to see a constant level (approximately 70%) regardless of the actual level in the SGs. Thus, all SG level trips/initiations normally caused by the plant protection system circuitry are inhibited. During 1982 there were nine entries into mode 5 at ANO-2. There is no automatic continuous indication of this bypass in the control room when in effect, and administrative controls (procedures) are relied upon to remove the bypass and thus, restore the SG level channels to their normal operating configuration prior to plant startup.

This type of bypass is an operating bypass (defined as the inhibition of the capability to accomplish a safety function that could otherwise occur in response to a particular set of generating conditions) used to permit mode changes (i.e., the prevention of reactor trip and EFWS initiation during the cold shutdown mode). The staff's position is that reliance upon administrative controls to remove an operating bypass is not a sufficient means for restoring protective functions. Section 4.12 (Operating Bypasses) of IEEE Standard 279-1971 (Criteria for Protection Systems for Nuclear Power Generating Stations) requires that operating bypasses be removed automatically whenever permissive conditions (entry into mode 5) are not met. The ANO-2 design should be modified to include provisions to automatically remove the SG level bypasses described above. The devices used to achieve automatic removal of the bypasses should be classified as part of the protective system and be designed in accordance with the applicable criteria.

There is no indication of bypass provided in the control room when the SG level protective signals are bypassed. Temporary modification tags are hung inside the protection system cabinets where the resistors are installed. In addition, safety grade SG level indication from the bypassed channels will read a constant value different from the actual level as indicated by non-safety indications which are unaffected by the bypass. The staff's position is that this is not positive indication that plant protection system inputs have been bypassed, and that continuous indication (automatically activated) should be provided at the main control board when this bypass is in effect. Section 4.13 of IEEE Std. 279 (Indication of Bypasses) requires that when the protective action of some part of the protection system has been bypassed or deliberately rendered inoperative for any purpose, this fact shall be continuously indicated in the control room. If conditions a, b, and c of Section C.3 of Regulatory Guide 1.47 (Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems) are met, then an automatic indication of bypass of EFWS automatic start capability should be provided in the control room to supplement existing administrative procedures. This is particularly important since steam generator low level is the only automatic initiation signal (steam generator pressure is used as a permissive) for the ANO-2 EFWS. The staff realizes that the EFWS is not required to be operable in modes 5 or 6. However, given the potential high frequency of use of this bypass, the importance of the SG level signals in accomplishing safety functions at ANO-2, and the potential for not restoring these signals (past experience has shown that procedures are not always a reliable method for restoring protection systems to their operational status), automatic indication of bypass should be provided.

The staff is concerned about the false level indications provided in the control room by the eight steam generator narrow range level channels when the bypass is in effect. Section 4.20 (Information Read-Out) of IEEE Std. 279-1971 states that "The protection system shall be designed to provide the operator with accurate, complete, and timely information pertinent to its own status and to generating station safety. The design shall minimize the development of conditions which would cause meters, annunciators, recorders, alarms, etc., to give anomalous indications confusing to the operator." The staff realizes that incorrect operator actions based on false SG level indications during modes 5 and 6 that could possibly affect the health and safety of the public are unlikely. However, the potential for not removing the SG level bypasses in the present design, and thus, to initiate plant startup using false SG level indications is unacceptable. The fact that the false indications are at midscale is of particular concern since this may give the plant operators a false sense of security regarding SG level conditions. Control room personnel typically rely on the eight safety grade indications as opposed to non-safety grade indications which would indicate actual level. The ANO-2 design should be modified to prevent false SG level indications in the control room at all times.

In addition, the method used to effect the bypass (i.e., lifting leads and modifying existing protection system circuitry) is not acceptable. We have received LERs in the past where lifted leads have been connected to the wrong terminals following maintenance. This has resulted in the failure of plant protection systems to automatically initiate in response to plant protection signals and has gone undetected during periodic testing. The use of keylock switches to effect such a bypass, with corresponding control room indication, is more preferable to the staff. The licensee should propose an alternate means of accomplishing this bypass that does not involve lifting leads or other modifications to protection system circuitry.

CONCLUSION

Based on our review, the staff has concluded that the methods used to implement and remove the SG level bypasses at ANO-2 are not acceptable for reasons described in the above evaluation. The licensee should be requested to commit to:

1. provide means to automatically remove these bypasses when the associated protective functions are required to be operable,

2. provide continuous indication (automatically activated) at the main control board when these bypasses are in effect,

3. modify the existing design to prevent false SG level indications in the control room when the SG level bypasses are in effect, and

4. modify the existing design such that temporary circuit changes are not required to effect these bypasses.

In addition, the plant startup procedures should be revised to verify that these bypasses have automatically cleared at the appropriate time. These modifications are consistent with the criteria of IEEE Std. 279-1971 which is used as the basis for acceptance of protection system designs by the staff.