TECHNICAL EVALUATION REPORT

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

CONNECTICUT YANKEE ATOMIC POWER COMPANY
HADDAM NECK PLANT

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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.

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1. INTRODUCTION

1.1 PURPOSE OF REVIEW

The purpose of this review is to provide a technical evaluation of the auxiliary feedwater (AFW) system design at the Haddam Neck Nuclear Plant to verify that both safety-grade automatic initiation circuitry and flow indication are provided. In addition, the steam generator level indication available at this unit is to be described to assist a subsequent Nuclear Regulatory Commission (NRC) staff review. Haddam Neck Nuclear Plant is owned and operated by Connecticut Yankee Atomic Power Company (CYAPCO).

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 AFW system should be treated as a safety system in any pressurized water reactor (PRW) plant. The designs of all safety systems in a nuclear power plant are required to meet 10CFR50, Appendix A general design criteria (GDC) [1].

The relevant criteria for the AFW system design are GDCs 13, 20, and 34. GDC 13 requires that instrumentation be provided to monitor, over anticipated ranges of operation, variables and systems that can affect reactor safety. GDC 20 requires that a protection system be designed to initiate automatically the operation of appropriate systems to assure that acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences. GDC 34 requires that the designed system be able to accomplish its safety function (residual heat removal in the case of the AFW system) in the event of a single failure following initiation.

On September 13, 1979, the NRC issued a letter [2] to all PWR licensees which defined a set of short-term requirements as specified in NUREG-0578 [3]. It required that each AFW system have automatic initiation and single-failure-proof design consistent with the requirements of GDCs 20 and 34, and that AFW flow indication be provided in the control room to satisfy the requirements of 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 clarified the NRC staff's short-term requirements without altering their intent [4].

Post-TMI analyses of primary system response to feedwater transients and the reliability of installed AFW systems also established that, in the long term, AFW systems should be upgraded to meet safety-grade requirements. These long-term requirements were clarified in a letter of September 5, 1979 [5] which incorporated in one document, NUREG-0737 [6], all TMI-related items approved by the Commission for implementation at that time. Sections II.E.1 and II.E.1.1 of NUREG-0737 describe the requirements for AFW system automatic initiation and flow indication.

1.3 PLANT-SPECIFIC BACKGROUND

In a letter dated October 11, 1979, the NRC defined NUREG-0737 AFW system requirements for the Haddam Neck plant [7].

In a letter dated September 15, 1980 [8], CYAPCO reported the status of all efforts expended to that date toward compliance with TMI Lessons-Learned Short-Term Requirements [4, 5].

On April 16, 1981 [9], CYAPCO proposed technical specifications changes.

On July 1, 1981 [10], the NRC called attention to the need for power diversity in the AFW system pump drives.

In a letter dated August 27, 1981 [11] CYAPCO discussed plant modifications necessary to meet the intentions of NUREG-0737 Item II.E.1.1.

On September 9, 1981 [12], CYAPCO responded to NRC staff concerns about valve surveillance.

An NRC letter to CYAPCO on November 20, 1981 [13] formally accepted the AFW system technical specification changes.

2. REVIEW CRITERIA

To improve AFW system reliability, the NRC required licensees to upgrade these systems to ensure timely automatic initiation when required. The system upgrade was to proceed in two phases, short-term and long-term. The short-term requirement were:

"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 meeting 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 the control system interaction criteria 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 indica-

tion 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 [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 [15]."

The NRC staff has determined that, in the long term, the overall flow-rate indication system for Westinghouse plants should include either one AFW flow-rate indicator with one wide-range steam generator level indicator for each steam generator, or two flow-rate indicators. The flow-rate 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.

The operator relies on both steam generator level instrumentation and AFW flow indication to monitor 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 DESIGN OF AUXILIARY FEEDWATER SYSTEM

The auxiliary feedwater (AFW) system at the Haddam Neck plant 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 two steam turbine-driven pumps (450 gpm at 1000 psia each) capable of supplying feedwater to any or all of the four steam generators. The pumps are interconnected on the discharge side by a crossover line, in which the Licensee has committed to installing a normally open, air-operated valve which can be operated from the control room.

A third, motor-driven pump/valve system is available to move water from normal AFW sources to the steam generators. This motor-driven pump was originally installed to provide a source of water for filling and hydrostatically testing the steam generators and was temporarily connected into the system via spool pieces. The Licensee has committed to permanently installing the spool pieces and resupporting adjacent piping to meet seismic requirements [11]; however, this pump will not be part of the automatic initiation scheme and cannot be started from the control room.

3.2 AUTOMATIC INITIATION

3.2.1 Evaluation

Auxiliary feedwater flow to the steam generators is automatically initiated when preset levels of either of the following parameters is exceeded:

Turbine-Driven Pumps

1. Low steam generator level in any 2 of 4 steam generators (train A or B)
2. Loss of both main feedwater pumps.

All initiating signals and circuits are supplied from redundant, Class 1E, vital power supplies, as is the control power for all AFW valves. The initiation circuits are fed by two separate 125-volt dc batteries, with backup

supply from 120-volt vital instrumentation inverters. Power for the two channels of steam generator level instrumentation is supplied by 120-volt ac inverters B and C. The four AFW supply valves to the four steam generators are powered by 120-volt ac panelboards A through D, and the two steam admission valves to the turbine-driven AFW pumps by 120-volt ac panelboards A and C. In addition, all ac-operated valves are automatically loaded onto the diesel generators.

The normal valve configuration for the AFW system is all AFW pump suction valves open, discharge flow control valves closed, and the steam admission valves to the turbine-driven pumps closed. All of these valves are air operated, solenoid type valves which fail open.

The operation of any one AFW pump will provide the necessary capacity for removing decay heat to prevent overpressurization of the reactor coolant system and to maintain steam generator levels. Both turbine-driven AFW pumps start upon automatic system actuation. Automatic isolation of a leaking steam generator is not a design feature of the system, and the operator is relied upon to isolate the leaking steam generator and to ensure AFW is supplied only to the intact steam generators.

The primary source of water is the demineralized water storage tank (DWST) (minimum capacity 50,000 gallons by technical specifications), which is always lined up to the pump's suction header via locked open manual valves. The secondary source of water is the primary water storage tank (PWST) (minimum capacity of 80,000 gallons by technical specifications), which must be transferred to the DWST for use in the AFW system. The 50,000 gallons of water in the DWST is sufficient for 2 hours of decay heat removal, at which point the makeup water requirement to the steam generators is 150 gpm which can be transferred to the DWST from the PWST at the rate of 200 gpm. A back-up supply of 100,000 gallons of water is available from the recycle water storage tank. Redundant level indicators and low level alarms for the DWST are provided in the control room.

A review of initiation logic and wiring diagrams revealed no credible single malfunction that would prevent automatic or manual protective action at

the system level when required. In addition, the Licensee has stated that the design of the AFW system initiation logic meets IEEE Std 279-1971 in that no single component failure will prevent the initiation of the automatic start signal, and the initiating signals and circuits are powered by safety-grade power supplies.

Manual operation of the AFW system is provided in the control room and at the local station. Each control circuit is independent so that a single failure in one train will not affect the redundant train. In addition, the automatic initiating circuits are designed to be electrically independent of the control room manual start circuit so that the failure of the automatic initiating signals does not affect the control room manual capability of AFW pumps.

Seismic requirements for the auxiliary feedwater system were not considered in the single failure analysis because the NRC will address this issue separately. A determination of whether components are qualified for accident and post-accident environments was not conducted. The environmental qualification of safety-related systems, including AFW system circuits and components, is being determined separately by the NRC and is not within the scope of this review. Review of the initiation circuit diagrams revealed no credible single malfunction that would prevent proper system action when required.

The electrical isolation and physical separation of elements of the proposed AFW actuation system design comply with the requirements of NUREG-0578 [3] and IEEE Std 279-1971 [14].

The proposed new instrumentation channels for initiation of AFW will be used only for protective functions. Therefore, there will be no interaction of control and protective functions. The Licensee has stated that if, at a later date, there arises a need to provide control functions from these protective channels, isolation devices will be used and in accordance with the requirements of Section 4.7 of IEEE Std 279-1971.

Concerning bypasses, the Licensee has stated the following:

Channel Bypasses

- Channels can be bypassed without spurious initiation when required for testing during power operation. The 2/4 logic matrix which permits this also permits retention of the ability to meet the single-failure criterion [19].

Operating Bypasses

- The Licensee has stated that the system contains no operating bypasses. However, because there is no provision in the design of the AFW system for automatic flow control, the operator must take the system out of automatic and control flow manually. If during the time the system is in the non-automatic mode the initiation signal clears and AFW flow is stopped, a return of the initiating signal will not automatically reinitiate AFW flow.

Indication of Bypasses

- Bypasses are annunciated on a panel in the main control room. Annunciator panel segments show lighted areas for:

  AFWS Auto-Start (Trip)
  AFWS Auto-Start Bypassed (Trains A/B)
  AFWS Auto-Start Channel Block (Trains A/B).

  Bypass indications comply with the requirements of IEEE 279 [19].

Amendment 44 to the facility operating license for the Haddam Neck plant outlines the following testing requirements for the AFW system:

1. The auxiliary feedwater system shall be demonstrated OPERABLE at least once per 31 days by:

   a. Verifying that each steam turbine driven pump develops a discharge pressure of greater than or equal to 800 psig at a steam supply pressure of 300 psig.

   b. Functionally testing the automatic auxiliary feedwater initation steam generator level instrumentation channels and their logic.

   c. Verifying each non-automatic valve in the flow path that is not locked, sealed, or otherwise secured in position, is in its correct position.

2. The DWST shall be demonstrated OPERABLE at least once per 12 hours by verifying the contained water volume is within its limits.

3. At refueling intervals, the auxiliary feedwater system shall be demonstrated OPERABLE by:

   a. Verifying the capability of each pump to attain rated flow of 450 gpm at 1050 psig.

   b. Verifying that each automatic valve in the flow path actuates to its correct position upon receipt of each auxiliary feedwater actuation test signal.

   c. Verifying that each auxiliary feedwater pump starts as designed automatically upon receipt of each auxiliary feedwater actuation test signal.

3.2.2 Conclusion

It is concluded that the initiation signals, logic, and associated circuitry of the Haddam Neck AFW system 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 exception:

- The system bypass, which is provided to allow manual control of the AFW system, is used as an operating bypass in certain plant conditions such as start-up. This design is acceptable; however, no annunication is provided to remind the operator to return the AFW system to the automatic mode of operation upon completion of manual system operation.

3.3 FLOW INDICATION

3.3.1 Evaluation

Each of the AFW pump headers to each steam generator is equipped with a flow transmitter with output indicated in the control room and locally at the AFW control valve location. In addition, wide-range steam generator level indication is provided. Both flow and level are continuously displayed in the control room.

Each AFW flow indication channel is powered from a diesel-generator-backed non-class 1E power source.

The entire AFW system is to be demonstrated operable every 31 days. The flow-indicating system is included in this test. A formal calibration will be performed during each refueling shutdown (every 18 months).

The Licensee has stated that the AFW flow indication system is part of the plant quality assurance program.

The environmental qualification of flow measurement and indication equipment is being reviewed separately by the NRC and is outside the scope of this review.

3.3.2 Conclusi

It is con uded that the sensors, transmitters, indicators, and recorders of the Haddam Neck AFW flow measurement system comply with the 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

Each steam generator has three level indicators, all safety-related and powered accordingly. Two wide-range indicator circuits are part of the AFW auto-initiation system. One narrow-range indicator circuit on each steam generator is part of the safe shutdown instrumentation.

The wide-range sensors are Foxboro Model N-E-13-DM-HI-C-F nuclear electronic force balance differential pressure transmitters. Signals from these transmitters are conditioned by Foxboro SPEC 200 electronic control equipment.

One wide-range transmitter per steam generator is connected to each of two SPEC 200 systems divisions, A and B. Each SPEC 200 division is powered by 120 Vac from a battery-fed inverter: battery 1-A for division A, and battery 1-B for division B.

4. CONCLUSIONS

It is concluded that the initiation signals, logic, and associated circuitry of the Haddam Neck auxiliary feedwater system 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 exception:

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It is concluded that the sensors, transmitters, indicators, and recorders of the Haddam Neck AFW flow measurment system comply with the requirements of Section 2.1.7.b of NUREG-0578 and the subsequent clarification issued by the NRC.

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