SAFETY EVALUATION REPORT
TROJAN NUCLEAR PLANT
IMPLEMENTATIONS OF RECOMMENDATIONS FOR
AUXILIARY FEEDWATER SYSTEMS

I. Introduction and Background

The Three Mile Island Unit 2 (TMI-2) accident and subsequent investigations and studies highlighted the importance of the Auxiliary Feedwater System (AFWS) in the mitigation of transients and accidents. As part of our assessment of the TMI-2 accident and related implications for operating plants, we evaluated the AFW systems for all operating and near-term operating license plants having nuclear steam supply systems (NSSS) designed by Westinghouse (NUREG-0611), or Combustion Engineering (NUREG-0635). Our evaluations of these system designs are contained in the NUREGs along with our recommendations for each plant and the concerns which led to each recommendation. The objectives of the evaluation were to: (1) identify necessary changes in AFW system design or related procedures in order to assure the safe operation of these plants, and (2) to identify other system characteristics of the AFW systems which, on a long term basis, may require system modifications. To accomplish these objectives, we:

(1) Reviewed plant specific AFW system designs in light of current regulatory requirements (SRP) and,

(2) Assessed the relative reliability of the various AFW systems under various loss of feedwater transients (one of which was the initiating event of TMI-2) and other postulated failure conditions by determining the potential for AFW system failure due to common causes, single point vulnerabilities, and human error.

We concluded that the implementation of the recommendations identified during this review will considerably improve the reliability of the AFW systems for each operating plant.

The following generic recommendations did not apply to this plant: GS-1, GS-3, GS-8 and GL-1. The basis for these recommendations can be found in Appendix III of NUREG-0611, and the system description which determined the specific reason for not applying these recommendations to this plant can be found in Appendix X of NUREG-0611.

II. Implementation of Our Recommendations

A. Short Term Recommendations

1. Recommendation GS-2 - "The licensee should lock open single valves or multiple valves in series in the AFW system pump suction piping and lock open other single valves or multiple valves in series that could interrupt all AFW flow. Monthly inspections should be performed to verify that these valves are locked and in the open position. These inspections should be proposed for incorporation into the surveillance requirements of the plant Technical Specifications. See Recommendation GL-2 for the longer-term resolution of this concern."

In response, the licensee indicated in a letter dated December 31, 1979, that the valves in the supply piping between the condensate storage tank and the suction of the two existing AFW pumps are maintained in a locked open condition. The licensee stated that the Plant Operating Test (POT) which provides for a monthly verification of the position of these valves was

revised to assure that these valves are included. In addition, the monthly surveillance test of the AFW pumps which is required by the plant Technical Specifications assures that the suction supply is available. These measures are required only on an interim basis pending resolution and implementation of Recommendation GL-2. For these reasons, we conclude that current plant Technical Specifications and revised procedures adequately cover our concern in this area, and are, therefore, acceptable pending verification of the Plant Operating Test procedure by the Office of Inspection and Enforcement.

2. Recommendation GS-4 - "Emergency procedures for transferring to alternate sources of AFW supply should be available to the plant operators. These procedures should include criteria to inform the operator when, and in what order, the transfer to alternate water sources should take place. The following cases should be covered by the procedures:

   - The case in which the primary water supply is not initially available. The procedures for this case should include any operator actions required to protect the AFW system pumps against self-damage before water flow is initiated; and,

   - The case in which the primary water supply is being depleted. The procedure for this case should provide for transfer to the alternate water sources prior to draining of the primary water supply."

In response, the licensee indicated in a letter dated December 31, 1979, that the case where auxiliary feedwater primary supply, the condensate storage tank, is not available is currently covered in existing plant pr. .edures. The procedure for transferring auxiliary feedwater pump supply from the condensate storage tank to the service water s contained in Trojan Emergency Instruction EI-5, Emergency Backup Core Heat Removal. We conclude that the licensee's response is acceptable.

3. Recommendation GS-5 -"The as-built plant should be capable of providing the required AFW flow for at least two hours from one AFW pump train, independent of any alternating current power source. If manual AFW system initiation or flow control is required following a complete loss of alternating current power, emergency procedures should be established for manually initiating and controlling the system under these conditions. Since the water for cooling of the lube oil for the turbine-driven pump bearings may be dependent on alternating current power, design or procedural changes shall be made to eliminate this dependency as soon as practicable. Until this is done, the emergency procedures should provide for an individual to be stationed at the turbine-driven pump in the event of the loss of all alternating current power to monitor pump bearing and/or lube oil temperatures. If necessary, this operator would operate the turbine-driven pump in a manual on-off mode

until alternating current power is restored. Adequate lighting powered by direct current power sources and communications at local stations should also be provided if manual initiation and control of the AFW system is needed. (See Recommendation GL-3 for the longer-term resolution of this concern.)"

In response to this recommendation, the licensee indicated in a letter dated December 31, 1979, that the turbine-driven AFW pump would be utilized to provide decay heat removal in the event of a loss of all AC power. However, this pump currently relies on an AC power dependent water source for bearing and jacket cooling. The licensee is implementing emergency procedures to provide the following:

a) Make every effort to restore AC power within 20 minutes.

b) Provide a material "kit" for use by the operators which provides the necessary hardware to hook up temporary cooling water to the turbine driven AFW pump bearing lube oil cooler.

c) Provide a procedure that instructs the operator to hook up the temporary cooling system if AC power is not restored within 20 minutes, manually valve in the steam supply to the AFW pump turbine and align the condensate storage tank and AFW pump to feed the steam generators. The procedure will include a statement directing the operator to take portable lighting and portable communication devices with him to the AFW pump operation station.

If the above measures are required, an individual will be stationed at the turbine-driven pump to monitor pump bearing and/or lube oil temperatures.

Based on our review, we conclude that the licensee's response is not acceptable. We require the following additional information from the licensee:

a) What is the basis for taking no action for the first 20 minutes following station blackout? Indicate the time required for installing the temporary "kit" and establishing AFW flow.

b) Provide a diagram of the temporary cooling system.

c) Where is the temporary cooling "kit" to be located and what administrative controls will be included to assure its availability?

d) Verify that all necessary personnel have been trained in the procedure for installing the temporary cooling system.

We will report resolution of this item in a supplement to this SER.

4. Recommendation GS-6 - "The licensee should confirm flow path availability of an AFW system flow train that has been out of service to perform periodic testing or maintenance as follows:

   - Procedures should be implemented to require an operator to determine that the AFW system valves are properly aligned and a second operator to independently verify that the valves are properly aligned.

- The licensee should propose Technical Specifications to assure that prior to plant startup following an extended cold shutdown, a flow test would be performed to verify the normal flow path from the primary AFW system water source to the steam generators. The flow test should be conducted with AFW system valves in their normal alignment."

In response, the licensee indicated in a letter dated December 31, 1980, that: 1) In lieu of revising operating procedures to include second operator verification of AFW system valve positions after performing periodic testing or maintenance, the licensee has committed to the identification system connected to all main AFW flow path valves to monitor the position of the valves such that a condition where any single valve is out of position will be annunciated in the control room. We conclude that this response adequately complies with our concern for independent verification of proper AFW system valve alignment and is acceptable. 2) At least one of the two safety-grade AFW pumps is required presently to initiate plant startup from cold shutdown conditions. Therefore, an AFW flow path from the condensate storage tank to the steam generators is automatically verified. Once the new non-safety electric motor-driven startup AFW pump is installed, the AFW pump Periodic Operating Test will be revised to include a step to verify the ability of each safety-grade AFW pump to feed all four steam generators following an extended plant outage. This change is required inorder to meet the current requirements of Technical Specification 3.7.1.2 which requires that an AFW flow path be maintained in Modes 1, 2 and 3. The above test will verify the flow path. We conclude that this response is acceptable.

5. Recommendation GS-7 - "The licensee should verify that the automatic start AFW system signals and associated circuitry are safety-grade. If this cannot be verified, the AFW system automatic initiation system should be modified in the short-term to meet the functional requirements listed below. For the longer term, the automatic initiation signals and circuits should be upgraded to meet safety-grade requirements as indicated in Recommendation GL-5.

   - The design should provide for the automatic intiation of the auxiliary feedwater system flow.

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

   - Testability of the initiation signals and circuits shall be a feature of the design.

   - The initiation signals and circuits should be powered from the emergency buses.

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

   - The alternating current motor-driven pumps and valves in the auxiliary feedwater system should be included in the automatic actuation (simultaneous and/or sequential) of the loads on the emergency buses.

- The automatic initiation 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 response, the licensee in a letter dated December 31, 1979, stated that the Trojan AFW pump auto start signals and associated circuits are safety grade.

We conclude that this response satisfies the "control grade" requirements specified in the NUREG-0578 position and clarifications and is, therefore, acceptable. Refer to GL-5 for long term "safety grade" implementation of this item.

B. Additional Short Term Recommendations

1. Recommendation - "The licensee should provide redundant level indications and low level alarms in the control room for the AFW system primary water supply to allow the operator to anticipate the need to make up water or transfer to an alternate water supply and prevent a low pump suction pressure condition from occurring. The low level alarm setpoint should allow at least 20 minutes for operator action, assuming that the largest capacity AFW pump is operating."

In response to this recommendation, the licensee stated in letters dated December 31, 1979, and July 1, 1980, that a new redundant condensate storage tank level indicator with a low-low level alarm set to provide more than 30 minutes for operator action to realign AFW pump suction will be provided by the startup of the plant following the next refueling outage. The new level instrumentation will be powered from a separate battery backed instrument bus to that for the existing level alarm. We conclude that the licensee's response is acceptable.

2. Recommendation (This recommendation has been revised from the original recommendation in NUREG-0611) - "The licensee should perform a 48-hour endurance test on all AFW system pumps, if such a test or continuous period of operation has not been accomplished to date. Following the 48-hour pump run, the pumps should be shut down and cooled down and then restarted and run for one hour. Test acceptance criteria should include demonstrating that the pumps remain within design limits with respect to bearing/bearing oil temperatures and vibration and that pump room ambient conditions (temperature, humidity) do not exceed environmental qualification limits for safety-related equipment in the room.

The licensee should provide a summary of the conditions and results of the tests. The summary should include the following: 1) A brief description of the test method (including flow schematic diagram)

and how the test was instrumented (i.e., where and how bearing temperatures were measured). 2) A discussion of how the test conditions (pump flow, head, speed and steam temperature) compare to design operating conditions. 3) Plots of bearing/bearing oil temperature vs. time for each bearing of each AFW pump/driver demonstrating that temperature design limits were not exceeded. 4) A plot of pump room ambient temperature and humidity vs. time demonstrating that the pump room ambient conditions do not exceed environmental qualification limits for safety-related equipment in the room. 5) A statement confirming that the pump vibration did not exceed allowable limits during tests."

The licensee provided the results of the endurance tests for both the turbine-driven and diesel-driven AFW pumps in a letter dated July 25, 1980. The results included: (1) a description of the test method and how the tests were instrumented, (2) a description of how the test conditions compared to design operating conditions, (3) plots of bearing or bearing oil temperatures vs. time for each bearing demonstrating that limits were not exceeded, (4) plots of pump room ambient temperature and humidity vs. time, and (5) a statement confirming that the pump vibration did not exceed allowable limits during the tests.

We have reviewed the test method and test results and conclude that no design limits were exceeded during the 48 hour tests. We, therefore, conclude that the licensee has met this recommendation, and the AFW pumps are acceptable for long term operation.

3. Recommendation - "The licensee should implement the following requirements as specified by Item 2.1.7.b on page A-32 of NUREG-0578:

> "Safety-grade indication of auxiliary feedwater flow to each steam generator shall be provided in the control room.
>
> The auxiliary feedwater flow instrument channels shall be powered from the emergency buses consistent with satisfying the emergency power diversity requirements for the auxiliary feedwater system set forth in Auxiliary Systems Branch Technical Position 10-1 of the Standard Review Plan, Section 10.4.9."

The licensee indicated in a letter dated December 31, 1979, that control room indication of AFW flow to each steam generator is already provided. We conclude that this response satisfies the "control grade" requirements specified in the NUREG-0578 position and clarifications and is, therefore, acceptable.

The "safety-grade" requirements for this recommendation are still under review. Our evaluation of this matter will be contained in a supplement to this SER.

4. Recommendation - "Licensees with plants which require local manual realignment of valves to conduct periodic tests on one AFW system train and which have only one remaining AFW train available for operation, should propose Technical Specifications to provide that a dedicated individual who is in communication with the control room be stationed at the manual valves. Upon instruction from the control room, this operator would re-align the valves in the AFW system train from the test mode to its operational alignment."

   In response to this recommendation, the licensee stated in a letter dated December 31, 1979, that manual realignment of local valves is not required when conducting periodic operating tests. We, therefore, conclude that this recommendation does not apply to Trojan.

C. Long Term Recommendations

1. Recommendation GL-2 - "Licensees with plants in which all (primary and alternate) water supplies to the AFW systems pass through valves in a single flow path should install redundant parallel flow paths (piping and valves).

   Licensees with plants in which the primary AFW system water supply passes through valves in a single flow path, but the alternate AFW system water supplies connect to the AFW system pump suction piping downstream of the above valve(s), should install redundant valves parallel to the above valve(s) or provide automatic opening of the valve(s) from the alternate water supply upon low pump suction pressure.

The licensee should propose Technical Specifications to incorporate appropriate periodic inspections to verify the valve positions."

In response to this recommendation, in letters dated December 31, 1979, and July 1, 1980, in lieu of the long term requirements presented above for assuring AFW pump protection in the event of an inadvertently closed valve on the primary AFW supply from the condensate storage tank, the licensee stated that prior to startup from the next refueling outage, low suction pressure alarms and safety-grade automatic trip of the auxiliary feedwater pumps on low suction pressure will be installed. Operator action can then be taken locally to manually open the normal supply valve or remotely to open the alternate supply (service water system) valves as necessary. In addition, control room position indication for the single locked open primary AFW supply line suction valve will also be installed. The licensee further notes that the new electric motor-driven AFW pump will be provided with a separate flow path from the condensate storage tank to the pump suction. We conclude that the licensee's response is acceptable.

2. Recommendation GL-3 -"At least one AFW system pump and its associated flow path and essential instrumentation should automatically initiate AFW system flow and be capable of being operated independently of any AC power source for at least two hours. Conversion of DC power to AC power is acceptable."

In response to this recommendation, the licensee indicated in letters dated December 31, 1979, and July 1, 1980, that the turbine-driven auxiliary feedwater pump and its associated systems will be modified to automatically initiate AFW flow and operate for at least two hours independent of AC power sources. The modifications are proceeding in two parts. First, the cooling water system for the turbine-driven pump will be modified to provide a closed cycle self-cooling water system which circulates auxiliary feedwater from the pump discharge through the lube oil bearing coolers and back to the pump suction. This system will replace the current bearing cooling arrangement supplied from the service water booster pumps. Second, the present motor-operated steam admission valves will be replaced with solenoid-operated pneumatic control valves. These valves will fail open on loss of the normal AC power dependent air supply. A passive seismic Category I backup air supply accumulator will be included to provide remote steam admission control valve operability on loss of AC power. The valves will fail as-is on loss of the backup air supply. With the above modifications, we conclude that auxiliary feedwater can be automatically supplied to the steam generators by the turbine-driven AFW pump train in a loss of all AC power condition. Based on our review, we find the licensee's response acceptable.

3. Recommendation GL-4 - "Licensees having plants with unprotected normal AFW system water supplies should evaluate the design of their AFW systems to determine if automatic protection of the pumps is

necessary following a seismic event or a tornado. The time available before pump damage, the alarms and indications available to the control room operator, and the time necessary for assessing the problem and taking action should be considered in determining whether operator action can be relied on to prevent pump damage. Consideration should be given to providing pump protection by means such as automatic switchover of the pump suctions to the alternate safety-grade source of water, automatic pump trips on low suction pressure, or upgrading the normal source of water to meet seismic Category I and tornado protection requirements."

The concern raised in this recommendation is similar to that of Recommendation GL-2, namely, providing automatic protection for the AFW pumps in the event of loss of normal suction supply for whatever reason. We consider the measures provided by the licensee and discussed in this SER under Recommendation GL-2 to be acceptable, and these same features to also satisfy the requirements of this item.

4. Recommendation GL-5 - "The licensee should upgrade the AFW system automatic initiation signals and circuits to meet safety-grade requirements."

In response to this recommendation, the licensee stated in a letter dated December 31, 1979, that with the exception of the main feedwater trip signals, the present AFW system automatic initiation

signals are safety grade. We will review the licensee's design in detail and our evaluation will be contained in a supplement to this SER.

5. Recommendation -"A motor-driven pump is currently being installed or is planned to be installed by the licensee. Present plans are for a non-safety grade motor-driven pump system. Based on past experience of the problems associated with the speed control (overspeed trips) of both the diesel and turbine-driven pumps and other Licensee Event Reports on the Trojan AFW system, the licensee should further review the proposed installation to determine if the motor-driven pump should be safety grade and automatically actuated by the AFW automatic start logic."

In response to this recommendation, the licensee stated in a letter dated December 31, 1979, that it is felt that upgrading the new motor-driven AFW pump to safety grade or automatic start is not justified. In lieu, the licensee proposes to develop a procedure which will provide for manually switching the motor-driven pump to an emergency AC bus and manually starting this pump in the event normal suction supply from the condensate storage tank to the safety-grade AFW pumps is unavailable or both safety-grade AFW pumps fail to operate. These actions can be accomplished from the control room, and closely parallel the operator actions that would be necessary to verify that the motor-driven pump had auto started. The licensee concludes that

the design for the motor-driven pump as presented including the above procedure will substantially enhance AFW system reliability for the case of loss of main feedwater and loss of offsite power.

We have reviewed the licensee's response and conclude that it is incomplete. Licensee's final conclusions as to the feasibility of supplying emergency power to the new motor-driven pump should be provided, together with details as to how this would be done, in order that we may assess the complexity of the evolution and the amount of time it would take for the necessary manual operations to be performed. The capability of a diesel-generator to start the motor-driven pump should be discussed.

Reliability studies for other AFW systems employing a manually started pump suggest that a significant improvement in reliability is achieved by automatic starting. Licensee should present additional justification for manual (emergency power) alignment and for manual starting from a reliability standpoint, including a discussion of gains in reliability that could result by providing emergency power from one or both diesel-generators.

We will report our resolution of this matter in a supplement to this SER.

6. Recommendation - A pipe break in certain locations of the turbine driven auxiliary feedwater pump discharge piping may affect both AFW trains, since portions of this piping pass through the diesel driven pump room. The motor driven pump to be installed should be located such that a break in the AFW system (not associated with the motor driven pump train) could not affect the motor driven pump. Also the licensee should 1) install the motor pump with appropriate valves in the pump discharge line connections to meet the high energy line break criteria in SRP 10.4.9 and

Branch Technical Position 10-1; namely, the AFWS should maintain the capability to supply the required AFW flow to the steam generator(s) assuming a pipe break anywhere in the AFW pump discharge lines plus a single active failure or 2) describe how the plant can be brought to a safe shutdown condition by use of other available systems following such a postulated event.

In response to this recommendation, the licensee stated in a letter dated December 31, 1979, that based on the Trojan Nuclear Plant Analyses of Pipe System Breaks Outside Containment, PGE-1004, rupture of that portion of the turbine-driven auxiliary feedwater pump discharge piping passing through the diesel-driven pump room is not considered a credible event because of:

a. The quality control associated with the fabrication and installation of this safety-grade piping;

b. The periodic inspection required for the AFW system;

c. The low usage factor associated with the operation of the system;

d. The low operating temperature of the system; and

e. The strict administrative controls associated with system operation.

The licensee further noted that the above mentioned pipe break report is based on the current AFW system design which requires use of the safety grade pumps for plant startup and shutdown. With the addition

of the third non-safety grade motor-driven startup pump, the already low usage factor for the safety-grade pumps will be further reduced. In addition, the licensee stated that the piping in question is a straight run with no terminal ends, branch connections or high combined stress points. For the reasons stated above, the licensee indicated that it was unreasonable to postulate breaks in this section of piping.

In our position letter to the licensee dated May 14, 1980, we stated that the licensee's response was unacceptable and that adequate protection for the diesel-driven AFW pump from postulated rupture of the turbine-driven AFW pump discharge piping located in the diesel-driven pump room should be provided. We further required that the licensee assure that the new motor-driven AFW pump train is separate from the existing AFW pump trains to assure that a break in the AFW system (not associated with the motor-driven pump train) could not affect the motor-driven pump. In lieu of the above, the licensee could describe the means for achieving a safe shutdown condition by use of other available systems following such a postulated event.

In response to our position, the licensee stated in a letter dated July 25, 1980, that in accordance with our position, positive protection will be provided for the diesel-driven AFW pump from postulated rupture of the turbine-driven AFW pump discharge line. The modified

system design will include a guard pipe encasing that portion of the turbine-driven pump discharge line which passes through the diesel-driven pump room. In addition, the new motor-driven AFW pump discharge line will connect to the existing turbine-driven and diesel-driven AFW pump discharge lines with check valves and failed closed gate valves to assure separation and isolation. These modifications will be completed by resumption of power operation for Cycle 4 in 1981.

Based on our review of the licensee's response, we conclude that the proposed modifications are acceptable.

D. Basis for Auxiliary Feedwater System Flow Requirements (Enclosure 2 to NRC Letter Dated October 3, 1979)

We have reviewed the licensee's response on this subject which was provided in a letter dated February 5, 1980, and find it acceptable.