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TECHNICAL EVALUATION REPORT OF THE OVERPRESSURE MITIGATING SYSTEM FOR ST. LUCIE, UNIT 1

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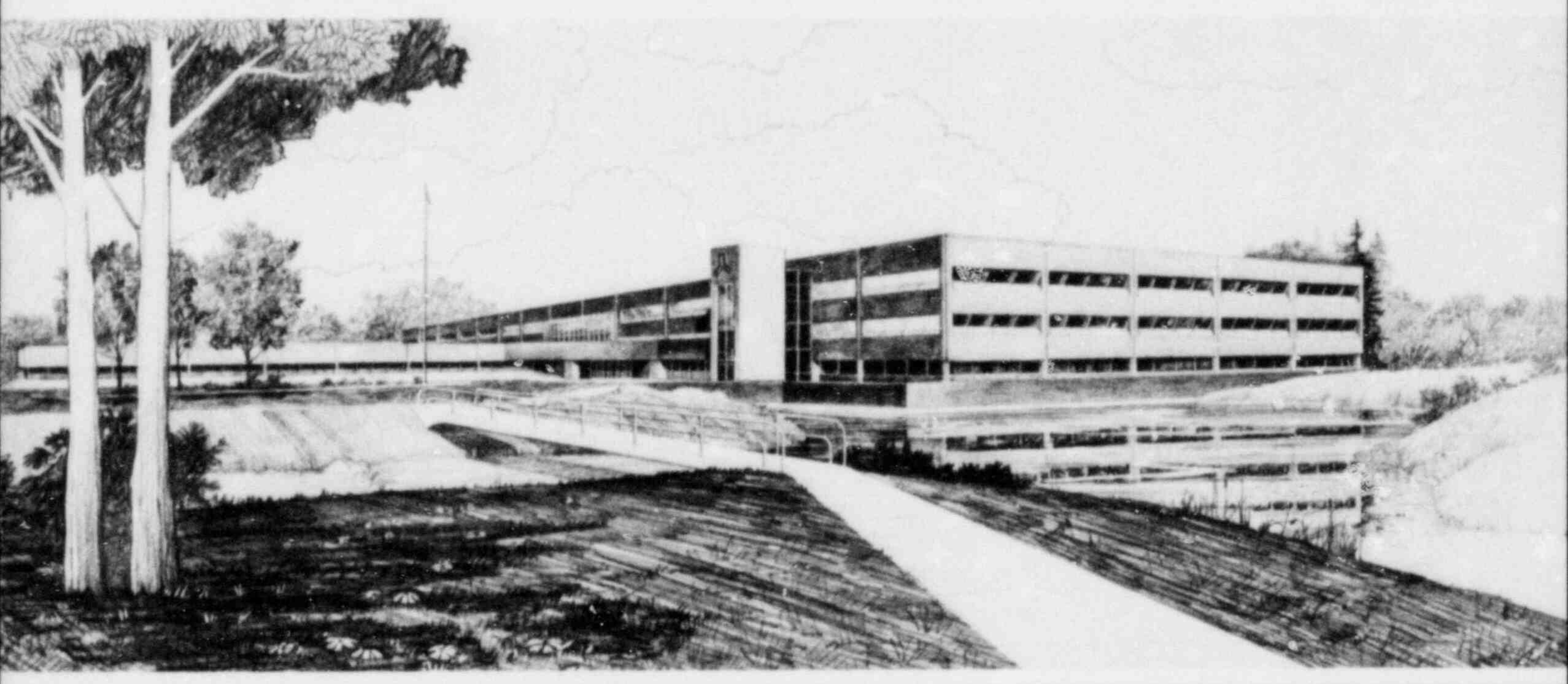

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INTERIM REPORT

TECHNICAL EVALUATION REPORT OF THE OVERPRESSURE MITIGATING SYSTEM FOR ST. LUCIE, UNIT 1

October 1982

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ABSTRACT

This report documents the technical evaluation of the low temperature overpressure protection system of St. Lucie, Unit 1. The criteria used to evaluate the acceptability of the system are those criteria contained in NUREG-0224 as appended by the Branch Technical Position (RSB 5-2).

FOREWORD

This report is supplied as part of the "Steam Generator Transients and Operating Reactors Evaluation for Reactor Systems Branch" being conducted for the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Division of Systems Integration, by EG&G Idaho, Inc., Reliability and Statistics Branch.

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NRC FIN No. A6436--Steam Generator Transients and Operating Reactors Evaluation for Reactor Systems Branch

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TECHNICAL EVALUATION REPORT OF
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1. INTRODUCTION

Several instances of reactor vessel overpressurization have occurred in pressurized water reactors in which the technical specifications implementing Appendix G to 10 CFR Part 50 have been exceeded. The majority of cases have occurred during cold shutdown while the primary system was in a water-solid condition. By letter to the Florida Power and Light Company (FPL), owner and operator of St. Lucie, Unit 1, dated August 13, 1976 (Reference 1), the U.S. Nuclear Regulatory Commission (NRC) requested an evaluation of St. Lucie, Unit 1 to determine susceptibility to overpressurization events and an analysis of these possible events, and required FPL to propose interim and permanent modifications to the systems and procedures to reduce the likelihood and consequences of such events.

By letters dated September 3, 1976, and October 18, 1976 (References 2 and 3), FPL submitted to the NRC the interim measures that they had taken to minimize the probabilty of a low temperature-overpressure transient at St. Lucie, Unit 1. FPL participated as a member of a utility task group with other utilities that operate facilities where the Nuclear Steam System Supplier (NSSS) is Combustion Engineering (CE). A generic analysis for CE plants along with possible mitigating systems was provided by a letter dated December 3, 1976 (Reference 5). In an August 23, 1977, letter (Reference 15), FLP proposed an interim overpressure mitigating system (OMS) using the existing pressurizer power operated relief valves (PORV's) with a variable low pressure setpoint. They later proposed that their interim system be considered as the final OMS (Reference 16), and in a letter dated April 13, 1978 (Reference 18), the system was described, an analysis was provided, and technical specifications were proposed for the OMS. FPL submitted additional information regarding the low-temperature overpressure problem including responses to staff concerns and questions, and information about operator awareness and training (References 8, 9, 10, and 12).

This is a report of the evaluation of the compliance of the licensee's Overpressure Protection System with the design criteria established by the NRC.

2. DESIGN CRITERIA

The NRC formally addressed reactor vessel overpressurization in August 1976, and requested that the utilities provide a solution to the problem. The design criteria were subsequently identified through meetings and correspondence with utility representatives. NUREG-0224, "Reactor Vessel Pressure Transient Protection for Pressurized Water Reactors" with appended Branch Technical Position (RSB 5-2) formalizes the staff requirements for the overpressure mitigating system. This NUREG also includes a thorough discussion of the background of this problem and technical discussions pertaining to vessel stresses and other aspects of vessel overpressurization.

3. SYSTEM DESCRIPTION AND EVALUATION

The St. Lucie, Unit 1 OMS consists of two separate trains, each containing a power-operated relief valve (PORV), an isolation valve and associated circuitry. When in the low pressure mode the system provides a variable low pressure setpoint for both PORV trains. When the system is enabled, it will terminate all analyzed pressure transients below the Appendix G limit by automatically opening the PORVs. A three-position PORV mode selector switch is used to enable and disable the low setpoint of each relief valve. An enabling alarm which monitors system temperature and pressure is provided to alert the control room operator to enable the overpressure mitigating system when either RCS temperature falls to 275°F or RCS pressure decreases to 400 psig. This alarm will not clear unless the PORV mode selector switch is in the low setpoint position and the MOVs upstream of the PORVs indicate "open". If the reactor coolant pressure comes within 25 psi of the variable low pressure setpoint, an alarm will alert the operator of pending PORV actuation. Should the reactor coolant pressure reach the variable low pressure setpoint, an alarm will inform the operator that the PORVs have received a signal to open. When both RCS pressure and temperature exceed specified setpoints, an alarm alerts the operator to return the PORVs to their normal setpoint. The variable low pressure setpoint for the OMS is derived from the reactor coolant system (RCS) wide range temperature using redundant transmitters. Below an RCS temperature of 160°F the PORV setpoint is a constant 465 psia. Above 160°F the PORV setpoint follows the MPT cooldown curve, with 75 psi between the PORV setpoint and the cooldown curve. At a reactor coolant temperature of 275°F, a high temperature interlock removes the OMS from service. This interlock provides assurance that the OMS will not be inadvertently actuated at power. This RCS temperature is the highest temperature anticipated for OMS operation. (The isothermal pressure limit at 275°F is approximately 1800 psia, which is well above the shutoff head of the HPSI pumps.)

3.1 Power Operated Relief Valves

The St. Lucie pressurizer PORVs are pilot-operated self-actuating valves. The pilot mechanism is comprised of a solenoid operated pilot valve that vents the pressure from one side of an operating piston allowing system pressure to actuate the relief valve. The orifice area of each PORV is 1.354 square inches and the opening times are approximately 3 milliseconds. The valve discharge rate is a function of the RCS pressure and the variable backpressure. A single PORV has sufficient capacity to mitigate all of the postulated overpressure events except for an inadvertent SI actuation and a RCP start with a 150°F ΔT between the RCS and a steam generator. For these events administrative controls have been instituted to restrict conditions so that a single PORV can mitigate the overpressure event.

3.2 Electrical Controls

The electrical, instrumentation, and control system aspects of the St. Lucie, Unit 1 Low Temperature Overpressure Mitigating System have been reviewed and reported in a separate technical evaluation (Reference 20).

3.3 Testability

The staff position requires that a test be performed to assure operability of the system electronics prior to each shutdown and that a test for valve operability, as a minimum, be conducted as specified in the ASME Code Section XI. FPL performs channel calibration and full stroke testing of the solenoid-operated pilot valve once per 18 months. They have proposed procedures to verify operability prior to each shutdown which would meet the staff position for the system electronics and the pilot-operated valve. However, the proposed testing frequency for the self-actuated valve does not meet the current staff inservice testing (IST) acceptance criteria. FPL has not yet proposed adequate OMS testing requirements in their technical specifications.

3.4 Single Failure Criteria

The specified single failure criteria for the overpressure mitigating system is that it should be designed to protect the vessel given a single failure in addition to the failure that initiated the pressure transient. The St. Lucie, Unit 1 OMS meets this criteria for all cases reviewed except for the case where the initiating event is a loss of power from one DC control bus. This loss of power would result in isolation of the letdown line and one PORV failing to open upon request. Because the other PORV is powered from the other DC control bus, it will remain functional. However, when a single failure is postulated in the remaining PORV, no low-temperature overpressure protection is afforded the plant.

FPL performed a probablity study to show that the above scenario has a low probability of occurrence. This study was not analyzed because its validity has no bearing on the problem of the St. Lucie, Unit 1 OMS not meeting the specified single failure criteria. This criteria is stated in NUREG 0224 (Reference 21) and is supported by IEEE-279 Section 4.7.3 and by GDC-24. It is, therefore, concluded that the St. Lucie, Unit 1 OMS does not meet the single failure criteria.

3.5 Seismic Design

The specified seismic criteria is that the Overpressure Protection System should be designed to function during an Operating Basis Earthquake (OBE). FPL stated that the seismic design of the equipment installed prior to the OMS modification would be maintained. The PORVs were designed and manufactured in accordance with ASME Boiler and Pressure Vessel Code Section III and are Class I valves. Additional electronic equipment was installed so as not to compromise the seismic qualification of existing safety systems.

Our evaluation has shown that the St. Lucie, Unit 1 OMS is designed so it will not compromise the integrity of the RCS or existing safety systems during an OBE. However, the FPL submittals have not indicated that the PORVs have been tested to demonstrate that they will operate under seismic loadings or that the remainder of the system will perform its function during an OBE. Therefore, based on the FPL submittals, it is concluded that the St. Lucie, Unit 1 OMS does not meet the specified seismic criteria in NUREG-0224.

3.6 Analysis Results

The analyses are divided into two general categories of pressure transients: mass input from sources such as charging pumps, safety injection pumps, and accumulator tanks; and energy input, which causes thermal expansion, from sources such as steam generators and decay heat. FPL conducted the analyses by first determining the worst case overpressurization events for both of these general categories, and then evaluating the effectiveness of the OMS in terminating these worst case events. All analyses were performed assuming water-solid RCS conditions. This assumption is conservative since it eliminates any time delay in transient response due to a vapor space in the pressurizer. Also, all letdown flow paths which could mitigate a particular overpressurization event were considered isolated.

3.6.1 Mass Input Cases

The analysis submitted for St. Lucie, Unit 1 by FPL considered the following overpressurization mass input events:

1. Inadvertent Safety Injection (SI) actuation

2. Inadvertent start of a single High Pressure Safety Injection (HPSI) pump

3. Inadvertent mismatch of charging and letdown flow.

The Low Pressure Safety Injection (LPSI) pumps and the SI accumulator tanks were not considered as contributing mass inputs since the LPSI pump's shut-off head (180 psi) and the SI accumulator tank design pressure (250 psig) are below the 10 CFR Part 50, Appendix G curve limits.

The analyzed inadvertent SI events included actuation of two HPSI pumps with all three charging pumps, actuation of a single HPSI pump with three charging pumps, and actuation of only the three charging pumps when all HPSI pumps are disabled.

The analyses results indicated that inadvertent Safety Injection (SI) actuation, the case with two HPSI and three charging pumps running, is the most severe mass input event. This event was evaluated further assuming one PORV and two PORVs available in the low setpoint mode. With one PORV available, the RCS would reach an equilibrium pressure of 800 psia which corresponds to an Appendix G curve temperature of 195°F. With two PORVs available, the equilibrium pressure would be 470 psia which corresponds to a temperature of 95°F on the MPT curve. Once a PORV opens, it will remain open as long as the equilibrium pressure is above the valve blowdown closure setting. If the equilibrium pressure becomes less than the blowdown setpoint, the peak RCS pressure will equal the valve set pressure and valve cycling will occur. For equilibrium pressures above the closure setpoint, the valve or valves will remain open until operator action secures the input flow.

These analyses results indicate that the PORVs do not have sufficient capacity to mitigate the most severe mass input event for all RCS temperatures below the minimum pressurization temperature. FPL has, therefore, instituted operating instructions and proposed administrative controls that provide a reasonable degree of assurance that the Appendix G curve limits will not be exceeded during an inadvertent SI actuation. As stated above, a single PORV will mitigate the resultant overpressure transient for all RCS temperatures above 195°F. Proposed St. Lucie, Unit 1 technical specifications state that prior to decreasing RCS temperature below 215°F a maximum of one HPSI pump is to be operable. With one HPSI pump and three charging pumps in operation, one PORV will mitigate an inadvertent SI transient at 550 psia which corresponds to 155°F on the MPT curve. The proposed technical specifications state that prior to decreasing the RCS temperature below 165°F, all HPSI pumps must be disabled with their associated header stop valves closed. A single PORV has sufficient capacity to relieve the volume of coolant supplied by three charging pumps or a single HPSI pump by itself. Therefore, an inadvertent SI actuation that results in either of the above situations, would be mitigated with a single PORV cycling at its setpoint until operator action is taken to stop the mass addition. For all temperatures below 165°F the PORV setpoint is 465 psia which corresponds to a minimum allowable isothermal temperature of 95°F.

It is concluded that the St. Lucie, Unit 1 OMS with proposed administrative controls will satisfactorily mitigate all analyzed mass addition events. However, the OMS will not mitigate the scenario described in Section 3.4 Single Failure Criteria; therefore, the system does not completely meet the requirements of NUREG-0224 for all mass addition events.

3.6.2 Energy Input Cases

The St. Lucie, Unit 1 analysis considered the following energy input overpressurization events:

1. Decay heat addition due to shutdown cooling system isolation

2. Inadvertent pressurizer heater input

3. Energy input from the steam generator secondary to the primary coolant subsequent to operation of a reactor coolant pump (RCP) when the steam generators are at a higher temperature than the reactor vessel inventory.

Energy addition analyses determined the RCS pressure response as a function of time. After each time increment the RCS pressure was determined as a function of the average liquid system enthalpy and average liquid specific volume. The system enthalpy changes according to the heat addition rate. For analyses which assume no liquid relief capability, the specific volume of the system is considered a constant since pressure boundaries are assumed fixed and system mass remains constant. Other conservative assumptions include isolated letdown and no sensible heat absorption by the RCS component metal mass.

From the analysis it was determined that the Reactor Coolant Pump (RCP) start transient is the most severe of the energy addition events analyzed. The other two energy addition events result in a rate of pressure increase that is relatively slow in comparison to the rate of pressure increase indicated for the RCP start transient. These two events are bounded by the three charging pump mass addition event and can be adequately mitigated by a single PORV.

A RCP operating when the steam generators are at a higher temperature than the reactor vessel will cause a rapid pressure increase in a water-solid RCS. The energy addition rate is not constant and so a computer model that represents the RCS by five nodes was employed to simulate the resulting water-solid RCS pressure response. Assuming an instantaneous RCP start, no heat absorption or metal expansion at the primary pressure boundaries, full pressurizer heater input, and one-percent decay heat a conservative upper bound RCS pressure was computed as a function of time.

With both PORVs functioning properly, the maximum allowable ΔT between the RCS and the steam generator is approximately 150°F. However, to conform with the single failure criteria, only one PORV is considered in the analysis. With only one PORV, a ΔT of 50°F between the RCS and the steam generators was used. The proposed technical specifications state that a reactor coolant pump shall not be started if the ΔT is more than 45°F unless the pressurizer liquid level is less than 40%. With this large of a steam bubble, a RCP start transient would be mitigated before it reached the low pressure PORV setpoint.

The analysis was performed using an initial RCS pressure of 300 psia, a 50°F ΔT, and RCS temperature of 150°F. The PORV opens at the set pressure of 465 psia and limits the peak RCS pressure to 490 psia which corresponds to a minimum RCS temperature of 105°F based on the isothermal (heatup) pressure-temperature limits. If the same transient is initiated at an RCS temperature of 200°F, the PORV is assumed to operate at the programmed set pressure of 640 psia. The peak RCS pressure attained is 650 psia which is well below the isothermal (heatup) pressure-temperature limit of 850 psia at 200°F.

The analysis results indicate that when using a 50°F ΔT limitation the OMS, with only one PORV functioning, provides assurance that the Appendix G curve limits will not be exceeded. However, the analysis failed to address the effects that the variable setpoint feature of the OMS will have upon the PORV setpoints during this transient. As the flow is initiated through the idle RCS loops, the temperatures will begin to rise. The wide range temperature detectors used in the OMS will sense the higher loop temperatures and will respond, causing the variable setpoint generating circuits to increase the pressure setpoint at which the PORVs will operate. Thus, the PORV setpoints will be based upon the temperature of the coolant in the loops while the vessel temperature would be much lower. FPL has been notified of this concern and is presently evaluating this situation.

The St. Lucie, Unit 1 OMS is considered satisfactory in mitigating all energy addition transients evaluated except for the concern relating to the variable setpoints expressed above. We will consider the system acceptable in this area upon receiving a re-evaluation from FPL that satisfactorily addresses this concern.

3.7 Codes and Models

FPL did not use NRC approved computer codes in their analysis of the St. Lucie, Unit 1 OMS. The mass addition events were modeled using desk calculator computations. The RCP start transient was modeled using a code developed specifically for that purpose.

The computer model represents the RCS as a five nodal system. The nodes are:

1. Operating RCP loop steam generator

2. Non-operating RCP loop steam generator

3. Reactor vessel annulus region

4. Reactor core

5. Reactor vessel upper plenum.

The representation of steam generator heat transfer by single nodes is said to be conservative for heat transfer from the steam generator secondary side to the primary coolant. The overall heat transfer coefficients for each steam generator are flow dependent, based upon initial steam generator properties. FPL states that this results in conservatively high coefficients which are then assumed constant throughout the transients. Considered in the model are the loop flow splits resulting from a single RCP operation.

Other assumptions used in the model to enhance the simplicity and conservatism are:

1. An instantaneous RCP start to full speed

2. No heat absorption or metal expansion at the primary pressure boundaries

3. The RCS is water-solid

4. Full pressurizer heater input

5. One-percent decay heat input.

This model is not an NRC approved code; however, it is the same model that was used for the Millstone, Calvert Cliffs, and Fort Calhoun submittals.

4. ADMINISTRATIVE CONTROLS

To supplement the hardware modifications and to limit the magnitude of postulated pressure transients to within the bounds of the analysis provided by the licensee, procedural and administrative controls should be provided by the licensee. Those specific conditions required for the plant to be operated within the bounds of the analysis and requirements for enabling and testing the OMS should be spelled out in the plant Technical Specifications.

4.1 Procedures

A number of provisions for the prevention of pressure transients are incorporated in the plant operating procedures. Some examples of these provisions are given below:

1. Normal heatup and cooldown procedures act to minimize the time the plant is in a water solid condition

2. It is standard practice not to cool the plant down in excess of the amount required by the maintenance to be performed

3. During plant heatup, a steam bubble is drawn in the pressurizer before the Shutdown Cooling System is removed from service

4. During plant cooldown, the Shutdown Cooling System is placed in service prior to collapse of the pressurizer steam bubble

5. Initial pump runs for venting purposes have an air cushion in the steam generators. Subsequent pump starts are done after a bubble is drawn in the pressurizer

6. Procedures have been revised to eliminate unnecessary reactor coolant system venting operations

7. Procedures have been revised to eliminate initiation of charging pump flow without adequate letdown capability during solid plant operations

8. The procedure for fill and vent of the RCS has been modified so that the second backup charging pump control switch is placed in the "off" position to preclude auto start of the pump

9. The procedure for testing the HPSI pumps during shutdown was changed to require closing the motor-operated pump discharge valves.

4.2 Technical Specifications

FPL has submitted a proposed technical specification change that relates to the St. Lucie, Unit 1 OMS. Some examples of the controls identified in this submittal are listed below. Some of these items have been identified in previous sections of this report.

1. If the steam generator temperature exceeds the primary temperature by more than 45°F, reactor coolant pump(s) shall not be started unless the pressurizer liquid level is less than 40%.

2. When Reactor Coolant System cold leg temperature is below 275°F, two power operated relief valves (PORV's) shall be operable, with their setpoints selected to the low temperature mode of operation.

The PORVs shall be verified operable by:

a. Verifying the isolation valves open when the PORV's are reset to the low temperature mode of operation

b. Performance of a channel functional test of the Reactor Coolant System overpressurization protection system circuitry up to and including the relief valve solenoids once per refueling outage

c. Performance of a channel calibration of the pressurizer pressure sensing channels once per 18 month.

3. Prior to decreasing the reactor coolant system temperature below 215°F a maximum of only one high pressure safety injection pump is to be operable with its associated header stop valves open.

4. Prior to decreasing the Reactor Coolant System temperature below 165°F all high pressure safety injection pumps will be disabled and their associated header stop valves closed. The high pressure safety injection pumps shall be verified inoperable and the associated header stop valves closed prior to decreasing below the above specified RCS temperature and once per month when the RCS is at refueling temperatures.

The following is the action statement for Item 2 above:

1. With less than two PORV's OPERABLE and while at Hot Standby during a planned cooldown, both PORV's will be returned to OPERABLE status prior to entering the applicable MODE unless:

   a. The repairs cannot be accomplished within 24 hours or the repairs cannot be performed under hot conditions, or

   b. Another action statement requires cooldown, or

c. Plant and personnel safety requires cooldown to Cold Shutdown.

With less than two PORV's OPERABLE, the plant will proceed to Cold Shutdown with extreme caution.

2. With less than two PORV's OPERABLE while in COLD SHUTDOWN, both PORV's will be returned to OPERABLE status prior to startup.

This is an extremely weak action statement; it allows part or all of the St. Lucie, Unit 1 OMS to remain out of service indefinitely during low temperature conditions with only a caution to the operators. It is felt that more specific action is warranted if one PORV becomes inoperable and specific action should be identified for the case of both PORVs being inoperable along with definite time intervals for completion of the actions.

The proposed technical specifications also state:

"PORV's are not required at Reactor Coolant System temperatures below 165°F when all HPSI pumps and respective injection or header isolation valves are disabled and if a pressurizer bubble is formed with a pressurizer liquid level less than or equal to 40%."

The FPL analysis does not include what is considered to be adequate justification for rendering the OMS inoperable in this situation. The restrictions give reasonable assurance that the HPSI pumps will not be available; however, the other mass addition mechanisms are not directly affected. The analysis does not demonstrate that the pressurizer steam bubble would provide the required 10 minutes between when the operator is made aware of the transient by an alarm and when he must take action to prevent exceeding the pressure setpoint during a mass addition event.

It is concluded that the proposed St. Lucie, Unit 1 technical specifications will be acceptable when they are modified so as to satisfactorily address the concerns expressed above and in Section 3.1 of this report.

5. CONCLUSIONS

The adminstrative controls and plant modifications proposed by Florida Power and Light Company provide protection for St. Lucie, Unit 1 from pressure transients at low temperatures by reducing the probability of initiation of a transient and by limiting the pressure of such a transient to below the limits set by 10 CFR 50 Appendix G. We find that the St. Lucie, Unit 1 Overpressure Mitigating System meets GDC 15 and 31 and that FPL has implemented the guidelines of NUREG-0224 except as noted in Sections 3.3, 3.4, 3.5, 3.6.1, 3.6.2, and 4.2 of this report. Pending resolution of these items, the St. Lucie, Unit 1 Overpressure Mitigating System is judged as an adequate solution to the problem of low temperature overpressure transients.

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