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March 2, 1990

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit No. 1; Docket No. 50-317
Clarification of the Low Temperature Overpressure Protection System Description

REFERENCE: (a) Letter from Mr. G. C. Creel (BG&E) to Document Control Desk (NRC), dated February 7, 1990, Description of Calvert Cliffs Low Temperature Overpressure Protection System

Gentlemen:

Reference (a) provided a description of the Low Temperature Overpressure Protection (LTOP) setpoints. It primarily addressed the differences between the original LTOP system configuration and the system that has been put in place to support Unit 1 operation henceforth. To facilitate the Nuclear Regulatory Commission's (NRC's) review of the present system, a more complete, summary level system description is attached. Unit 1 startup is contingent upon NRC's review and approval of the Unit LTOP system; therefore, your prompt attention to this matter is appreciated.

Should you have any further questions, we will be pleased to discuss them with you.

Very truly yours,

GCC/PSF/bjd

Attachment

A001 Cert NO
1/1 P 170958265

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LTOP SYSTEM DESCRIPTION
CALVERT CLIFFS NUCLEAR POWER PLANT
UNIT 1

MARCH 2, 1990

1.0 INTRODUCTION

On July 21, 1977, a plant specific report on Reactor Coolant System (RCS) overpressure protection (LTOP) at low temperatures (Reference 8.1) was submitted to the NRC. That report detailed the administrative controls and hardware modifications which were necessary to protect Calvert Cliffs from a low temperature over pressurization event for 10 effective full power years (EFPY). This document describes additional measures required to continue adequate 10 CFR Appendix G protection for 12 EFPY. It addresses the same issues as the 1977 report and therefore could be considered an extension of the original submittal. The focus of this description is not on the technical detail of supporting analyses, although some information is provided. Rather, a general overview of LTOP protective measures at CCNPP is presented.
Since no major modifications to systems affecting LTOP have been made, the important overpressurization events are the same as those postulated in the 1977 report; i.e., letdown isolation, safety injection (SI) pump start, charging pump start, reactor coolant pump (RCP) start, and full pressurizer heater actuation. The re-analysis of these events is similar to the analysis discussed in the 1977 report.

2.0 GENERAL APPROACH TO OVERPRESSURIZATION PROTECTION

BG&E's approach to LTOP is based primarily on the fact that the potential for overpressurization of the RCS can be minimized by a combination of administrative procedures and operator action. However, because operator action cannot always be assumed, and because possible equipment malfunctions must be considered, BG&E has put in place additional controls to ensure adequate protection exists for all postulated events. Analyses have been performed which demonstrate that a combination of administrative controls and hardware modifications provide this protection. In general, this protection includes the following:

- Procedural precautions and controls;
- Disabling of non-essential components whenever LTOP is required (below MPT enable temperature and RCS not vented);
- Maintenance of a non-solid system whenever practical; and,
- Use of the low relief setpoint in the PORV control logic.

2.1 Design Criteria

The basic criteria to be satisfied in determining the adequacy of overpressure protection is that no single equipment failure or operator error shall result in violation of the operating curve limitations. This is in accordance with the criteria as originally stated in Reference 8.1. The applications of these criteria are addressed in Section 6.0, after the specific means of overpressure protection have been presented.

2.2 Basis for Pressure Limits

The MPT operating curves (from Technical Specification Figure 3.4-2b) for the 10 to 40 year period of full power operation are used as a basis for maximum allowable pressure during a heat up or cool down. The transient LTOP pressure limits are 12 EFPY curves based on draft Reg. Guide 1.99, Rev. 2. (Reference 8.2.). These curves will be updated to final Reg. Guide 1.99, Rev. 2 and submitted to the NRC in a future license amendment request. These curves will replace the 10-40 year curves currently in the technical specification. A PORV setpoint of 384.4 psia (based on protecting 422.7 psia in the pressurizer) and an MPT enable temperature of 319^{o}F are calculated in References 8.3 and 8.4. These pressure limits are in accordance with 10 CFR Appendix G.
The MPT enable temperature and PORV setpoint will be adjusted as necessary to reflect future results of the reactor vessel surveillance program.

3.0 DESCRIPTION OF ANALYTICAL MODELS

Overpressurization analyses were performed as follows:

- The worst case overpressurization scenarios were identified for both mass and energy addition events;
- The effectiveness of the PORV to terminate an overpressurization event was evaluated; and,
- The effectiveness of maintaining a pressurizer steam volume as a means of preventing or delaying overpressurization was investigated.

The worst case events were identified and reported in Reference 8.1. To determine the worst case events, solid water RCS conditions were considered. This was/is a conservative assumption since the time delay in the transient due to a non-solid system is eliminated. Also, all letdown flow paths which could mitigate or terminate a particular overpressurization event were assumed isolated. The following subsections discuss the solid system mass and energy input analysis, the reactor coolant pump transient model, and the effectiveness of either the PORVs or pressurizer steam bubble to mitigate an LTOP event.

3.1 Solid RCS Mass Addition Analysis

The following mass addition events were postulated:

- Inadvertent High Pressure Safety Injection (HPSI) pump start;
- Inadvertent HPSI and Charging pump start; and,
- Inadvertent mismatch of charging and letdown flow.

3.2 Solid RCS Energy Addition Analysis

The following addition events were postulated:

- Decay heat addition due to shutdown cooling system isolation;
- Inadvertent pressurizer heater actuation; and,
- Energy addition from the steam generator secondary side to the RCS due to a start of an RCP pump when the steam generators are at a higher temperature than the reactor vessel inventory.

Energy additions which are constant with time include inadvertent pressurizer heater actuation and decay heat addition. Hand calculations were sufficient to model the resulting transients.

3.3 RCP Start Transient Model

Energy addition analysis of a single RCP start with a positive secondary-to-primary delta T was performed to determine the RCS pressure response as a function of time using the RETRAN computer code (Reference 8.5). Assumptions include isolated letdown and no sensible heat absorption by the RCS component metal mass. These assumptions yield results which are considered the upper bounds of anticipated RCS pressures.

3.4 Effect of PORV Protection

The effectiveness of a single PORV was examined for 1) the RCP start transient, and 2) an inadvertent mass addition from a HPSI and charging pump. These incidents are considered the design basis events as will be discussed in Section 4.0.

3.4.1 For the case of mass addition, the equilibrium pressure at which the HPSI and charging pump deliveries match a single PORV discharge is determined.

3.4.2 For the RCP pump start transient, the analysis examined the effect of a single PORV upon the pressure transient. Saturated liquid conditions are assumed in the pressurizer.

In both transients, valve discharge rates are determined as a function of upstream RCS pressure, using a maximum backpressure (P_B) of 115 psia.

3.5 Pressurizer Steam Bubble Analysis

In 1977, analyses were performed to determine the effectiveness of a pressurizer steam volume relative to terminating or mitigating the overpressurization events noted in Sections 3.1 and 3.2. The analyses were based on the assumption that the pressurizer steam will not instantaneously condense with a sudden mass insurge, and consequently pressure will rise. The steam bubble, therefore, was considered to be a non-condensible volume, resulting in considerable conservatism. An update of this analysis for the RCP start transient was performed by BG&E in 1987 using the RETRAN computer code. A non-equilibrium pressurizer model was used to determine the effectiveness of the steam bubble in mitigating LTOP events.

4.0 RESULTS OF ANALYSIS

As indicated, the design basis events assuming a water solid system are:

- A RCP start with hot steam generators; and,
- An inadvertent HPSI actuation with concurrent charging.

Any measures which will prevent or mitigate the design basis events are sufficient for any of the less severe incidents. Therefore, this section will discuss the results of the RCP start and mass addition transient analyses. Also discussed is the effectiveness of a procedurally controlled pressurizer steam bubble and a single PORV relative to mitigating the design basis events.

4.1 RCP Start Transient

The RCP start transient is a severe LTOP challenge assuming a water solid RCS. Therefore, during water solid operations all 4 RCPs are tagged out of service. However, analysis indicates that the transient is adequately mitigated by a pressurizer steam bubble. The approximate size of the required volume is 900 ft^3 or 60 percent of the pressurizer volume. The steam bubble allows the operators at least 10 minutes to initiate corrective action. Other overpressurization incidents which are mitigated by maintaining the 900 ft^3 pressurizer bubble are:

- Charging pump input with insufficient letdown;
- Letdown isolation;
- Shutdown cooling isolation; and,
- Inadvertent actuation of all pressurizer heaters.

4.2 Inadvertent Safety Injection Transient

The inadvertent actuation of one or more HPSI pumps in conjunction with up to three charging pumps is the most severe mass addition overpressurization event. Analyses were performed for a single HPSI pump and either one or 3 charging pumps assuming one PORV available with the existing orifice area of 1.29 in^2. For the limiting case, only a single PORV is considered available due to single failure criteria. Figure 1 shows the calculated RCS pressures that occur when the discharge of one PORV reaches equilibrium with the HPSI and charging mass inputs. Sufficient overpressure protection results when the equilibrium pressure does not exceed the limiting Appendix G curve pressure. Because the equilibrium pressure exceeds the LTOP PORV setpoint, HPSI flow is throttled to no more than 350 gpm when the HPSI pump is used for mass addition. No more than one charging pump (45 gpm) is allowed to operate during the HPSI mass addition.

4.2.1 Three 100% capacity HPSI pumps are installed at Calvert Cliffs. Procedures will require that two of the three HPSI pumps be disabled (breakers racked out) at RCS temperatures less than or equal to 319°F and that the remaining HPSI pump handswitch be placed in pull-to-lock. Additionally, the HPSI pump in pull to lock shall be throttled to less than 350 gpm when used to add mass to the RCS. Exceptions are provided for ECCS testing and for response to LOCAs. These cases are discussed in Sections 5.4.1 and 5.4.3.

4.2.2 Comparison of the PORV discharge curve of Figure 1 with the critical pressurizer pressure of 422.7 psia indicates that adequate protection is provided by a single PORV for RCS temperatures above 70°F when all mass input is limited to 470 gpm. HPSI discharge is limited to 350 gpm to allow for one charging pump and system expansion due to decay heat.

4.3 Summary of Results

A pressurizer steam volume or a single PORV will provide satisfactory control of all transients with the exception of a spurious actuation of full flow from a HPSI pump. Overpressurization due to this transient will be precluded for temperatures below 319°F by disabling two HPSI pumps, placing the third in pull-to-lock, and by throttling the third pump when used to add mass to less than 350 gpm flow. Note that only the design bases events are discussed in detail since the less severe transients are bounded by the RCP start and inadvertent HPSI actuation analysis.

5.0 PROVISIONS FOR OVERPRESSURE PROTECTION

LTOP is provided at Calvert Cliffs by a combination of administrative controls and hardware provisions. The hardware provisions include the incorporation of a dual setpoint capability in the PORV control circuitry and enabling the PORVs during low temperature operations. Although the PORVs are the primary means of protection, it is desirable to avoid challenging the PORVs discharge. Therefore, maintenance of a pressurizer steam bubble whenever possible during heatup and cooldown operations is integral to the overpressure protection measures, especially when the RCPs are available for service during heatup. Finally, disabling components when unnecessary for plant operation will prevent their inadvertent actuation and therefore minimize their potential for causing overpressurization. This section discusses specific administrative and hardware modifications including procedural limitations for plant operation during startup, shutdown, surveillance testing, and RCS filling.

5.1 Administrative Measures

This subsection discusses the administrative measures being taken to preclude RCS overpressurization.

5.1.1 Maintenance of a Pressurizer Steam Volume

Where RCS pressure, temperature, and other operating considerations permit, a minimum pressurizer steam volume of 60% pressurizer volume (170 inches level or less) will be maintained. This is considered the most positive means of overpressure protection, encompassing nearly all contributing cases. Limitations which govern pressurizer operations are heatup and cooldown rates, spray valve temperature differentials, and pressurizer-to-hot leg temperature differentials. A steam bubble may be formed and maintained as long the pressurizer operations do not exceed these limits. There is a general precaution in applicable procedures to instruct operating personnel to minimize the time in which the RCS is in a water solid condition.

5.1.2 De-activation of Non-Essential Components

In general, any component capable of an energy or mass input which would result in RCS overpressurization will be disabled when its operation is not essential to plant operations. The following are specific limitations:

5.1.2.1 Reactor Coolant Pumps - shall be disabled during water solid operations. A pressurizer steam volume will be drawn and secondary to primary delta T less than or equal to 150°F will be verified prior to operation of an RCP. Primary temperature is read using Shutdown Cooling System temperature indication in the Control Room; steam generator secondary temperature is determined by either reading the steam generator pressure and using the corresponding saturation temperature, or using the steam line temperature indication, or using a hand- held surface instrument at the steam generator head.

5.1.2.2 HPSI Pumps - Two of the HPSI pumps are disabled and one is placed in pull to lock at RCS temperatures equal to and below 319°F. Also, the eight HPSI loop motor operated valves are prevented from operating automatically, typically by placing their handswitches in pull-to-override. This ensures that no SIAS can cause flow to the RCS given a single failure. In addition, when the RCS is solid and cold, either the HPSI header isolation valves (SI-654-MOV and SI-656-MOV) or equivalent valves in the HPSI discharge flowpath are locked shut or equivalent protection is provided by racking out and tagging the third HPSI pump breaker. Caution tags are used where operation of a pump or valve could result in RCS overpressurization.

5.1.2.3 Pressurizer heaters are disabled and tagged during solid system operations, except as provided by procedure to allow drawing a bubble.

5.1.2.4 Charging pumps that are not required during water solid operations are disabled and tagged. Typically only one charging pump is required to be operating under cold shutdown conditions. Whenever the RCS is below MPT enable temperature and a HPSI pump is being used to inject into the RCS for testing, at least two charging pumps shall be maintained in pull-to-lock.

5.1.3 <u>Secondary to Primary Temperature</u>

To ensure that an RCP start does not challenge MPT limits, a secondary to primary temperature differential of less than or equal to 150°F is verified prior to RCP start. Preventive measures are taken as follows:

5.1.3.1 Procedures require that steam generator temperatures be reduced to 220°F concurrently with allowing the RCS to be cooled by the shutdown cooling system. Once 220°F has been achieved, a delta T of less than 150°F is assured since the lowest RCS service temperature is 70°F.

5.1.3.2 Verification of differential temperature less than 150°F is required prior to starting a pump. This is accomplished by comparing RCS temperature to either the saturation temperature corresponding to steam generator pressure, or steamline temperature indication, or a direct temperature measurement made with a hand-held instrument.

5.1.3.3 Reactor coolant pumps will be secured and tagged when RCS temperature is less than 130°F during a cooldown.

5.1.4 <u>Testing of ECCS Components</u>

No testing of components is permitted during water solid operations.

5.2 <u>Hardware Features</u>

This subsection discusses the hardware provided to mitigate overpressurization events. High setpoint (2400 psia) PORV's and Code Safety Valves prevent exceeding the MPT pressure limits at temperatures above 319°F. Below this temperature, the low setpoint relief capabilities of the system must be enabled. A discussion of this operation and related hardware considerations follows.

5.2.1 Indication and Alarms

An automatic computer-activated high pressure alarm is set to alarm at an increasing RCS pressure. The alarm is automatically enabled, by the plant computer, whenever the RCS temperature is less than the MPT enable temperature. This alarm provides audible and visual alarm on C06 and a typewritten message on the alarm typewriter. The pressure sensors used for this alarm function are PT103 and PT103-1. Each sensor loop provides a separate input to the computer. Additionally, a computer-activated high pressure alarm is manually set to alarm at an increasing pressure based on existing RCS temperature. By procedure, the plant operator resets this alarm incrementally as RCS temperature changes. This alarm provides the plant operator with a flashing display on the plant computer and is designed to provide three alarm levels upon sensing increasing RCS pressure; i.e., "warning," "alert," and "critical." The pressure sensors for this alarm function are also PT103 and PT103-1.

5.2.2 The mitigation system against RCS overpressurization at low RCS temperatures is based on the use of the existing PORV's (ERV-402 and ERV-404) enabled to provide relief capability at low pressures. In conjunction with specific procedural controls, each PORV will provide sufficient and therefore redundant relief capacity to ensure that RCS pressure remains within the operating limit curves. The PORV low pressure setpoint will be 384.4 psia, which will be manually aligned when RCS temperature decreases below 319°F. Assurance of preventing inadvertent PORV actuation at RCS temperatures above 319°F is provided by the inclusion of a temperature interlock in the circuitry which prevents the low pressure setpoint from actuating the PORV's at RCS temperatures above MPT enable The mitigating system is provided with separate and independent pressure-temperature signals, bistables and power supplies to each PORV. This approach is consistent with separation and single failure criteria used in the original design of the plant.

5.3 Summary of Operation

The following discussion summarizes the sequence of events that ensures overpressure protection is available:

5.3.1 By normal plant cooldown procedures the RCS temperature and pressure are decreased to 330°F and 360 psia, respectively. An annunciator light will come on to indicate that MPT enable is required. Prior to cooling the RCS below 319°F, normal operating procedures will require the activation of the manual computer-generated high pressure alarm, the resetting of the hand switch to the "MPT Enable" position, checking that the PORV block valves indicate "open", disabling of 2 HPSI pumps by racking out their supply breakers, placing the third HPSI pump in pull-to-lock, and placing the HPSI loop MOV handswitches in pull-to-override. When the PORVs are reset to the LTOP setpoint the annunciator window light will clear, indicating that the low temperature PORV mode of operation is in service. The setpoint of the plant computer high pressure alarm is manually adjusted as called for in procedures so that the operator will be alerted whenever RCS pressure approaches the Appendix G operating limit curves. Upon entering MODE 4, shutdown cooling may be used to cool the RCS. Steam generators must continue to be cooled to 220°F. RCPs are disabled by locking and tagging out their supply breakers when RCS temperature is less than 130°F. This ensures assumptions in the LTOP analysis are valid.

5.3.2 During plant heatup, normal operating procedures will maintain the RCS pressure below 360 psia until the RCS temperature is greater than 319°F. When the RCS temperature exceeds MPT enable, normal operating procedures will require that the PORVs be reset to the normal (high) relief setpoint of 2,385 psig. At the same time, alarms will be deactivated by procedure, and the temperature interlock will activate; thereby preventing the lifting of the PORVs at the low setpoint. Prior to exceeding 350°F, two HPSI pumps must be returned to automatic service. Prior to starting an RCP for the heatup, secondary to primary delta T less than 150°F is verified.

5.4 Operating Guidelines

5.4.1 Surveillance and Component Testing

When ECCS system HPSI testing is required at RCS temperatures less than 319°F, testing will be performed such that no new mass is introduced to the RCS unless HPSI flow is throttled to no more than 350 gpm and a pressurizer bubble exists or an adequate vent exists. When HPSI suction is taken from the shutdown cooling system, no limit is placed on discharge to the RCS since no new mass is being added. If addition of non-recirculated mass to the RCS in excess of 350 gpm is required for testing, then the reactor coolant system must be vented through at least 2.6 in^2 for one pump or 8 in^2 for multipump testing. Testing of Safety Injection and CVCS system components (i.e., pumps, valves, automatic signals, etc.) that are affected by LTOP controls will only be accomplished with a non-solid RCS. Such testing is only performed in accordance with approved procedures which establish adequate overpressure protection prior to component testing. No ECCS testing is allowed when water solid.

5.4.2 Reactor Filling

Reactor coolant system filling operations during a heatup are normally accomplished by using the containment spray pumps which have a shutoff head that is well below the limiting pressure of the MPT curve. To collapse the steam bubble during a cooldown, a single charging pump is used.

5.4.3 LOCA Response

In response to unidentified RCS leakage HPSI flow will be controlled to maintain pressurizer level and avoid overpressurization events. Depending on the size of the RCS leakage, flow greater than 350 gpm may be required.

5.4.4 Operator Training

Operator training through required reading and/or on shift briefings will ensure adequate operator awareness of the latest approved LTOP controls.

6.0 DESIGN CRITERIA

The design criteria for LTOP protection system were addressed in Reference 8.1. A brief discussion of the criteria follows:

6.1 Operator Action

In each of the transient analyses, operator action was not credited for the first 10 minutes. The pressure alarms detailed in Section 5.2.1, in addition to other plant condition indications, will make the operator aware of the transient.

6.2 Single Failure

A single failure must be considered in the overpressure mitigation system response to an initiating event.

6.2.1 The sensing/actuating/relieving system consists of two redundant and independent trains.

6.2.2 For the energy addition design basis event (RCP start with a hot steam generator), the PORV setpoint is not challenged within 10 minutes provided primary-to-secondary delta T is less than 150°F and a pressurizer bubble is present; failure of a PORV does not result in overpressurization. At least two procedural controls have to be violated for starting an RCP with secondary to primary delta T greater than 150°F i.e., failure to cool the steam generators to 220°F and failure to measure the secondary to primary differential temperature. Thus the single failure criteria is met for the energy addition design basis event.

6.2.3 For the mass addition design basis event (HPSI actuation), a single PORV provides protection provided that 2 of the 3 HPSI pumps are disabled and the remaining pump's flow is throttled.

If we assume that the LTOP system single failure is failure to throttle the HPSI, then two PORVs are available to limit the pressurization below MPT limits.

6.3 Seismic and IEEE-279 Design Criteria

Presently installed PORV's meet seismic criteria consistent with the basic objective of preventing a potential LOCA pathway. Design of equipment added for overpressure mitigation is consistent with existing plant design criteria, and with the single failure criteria previously discussed. Design is such that (1) no additional risk of LOCA or other accident is imposed, and (2) design criteria of existing safety related systems are maintained, and these systems are not degraded.

6.3.1 In addition, the intent of seismic and IEEE-279 criteria is met for the operability and effectiveness of the mitigating system in that a single failure which initiates an overpressurization event does not disable the mitigating system.

6.3.2 Power is supplied to the PORVs from vital supplies designed to operate during a seismic event and following loss of off-site power. Cable raceways for this equipment are supported to withstand a seismic event.

6.4 Testability

The system is designed to be tested with a frequency that will ensure the system is operable when needed.

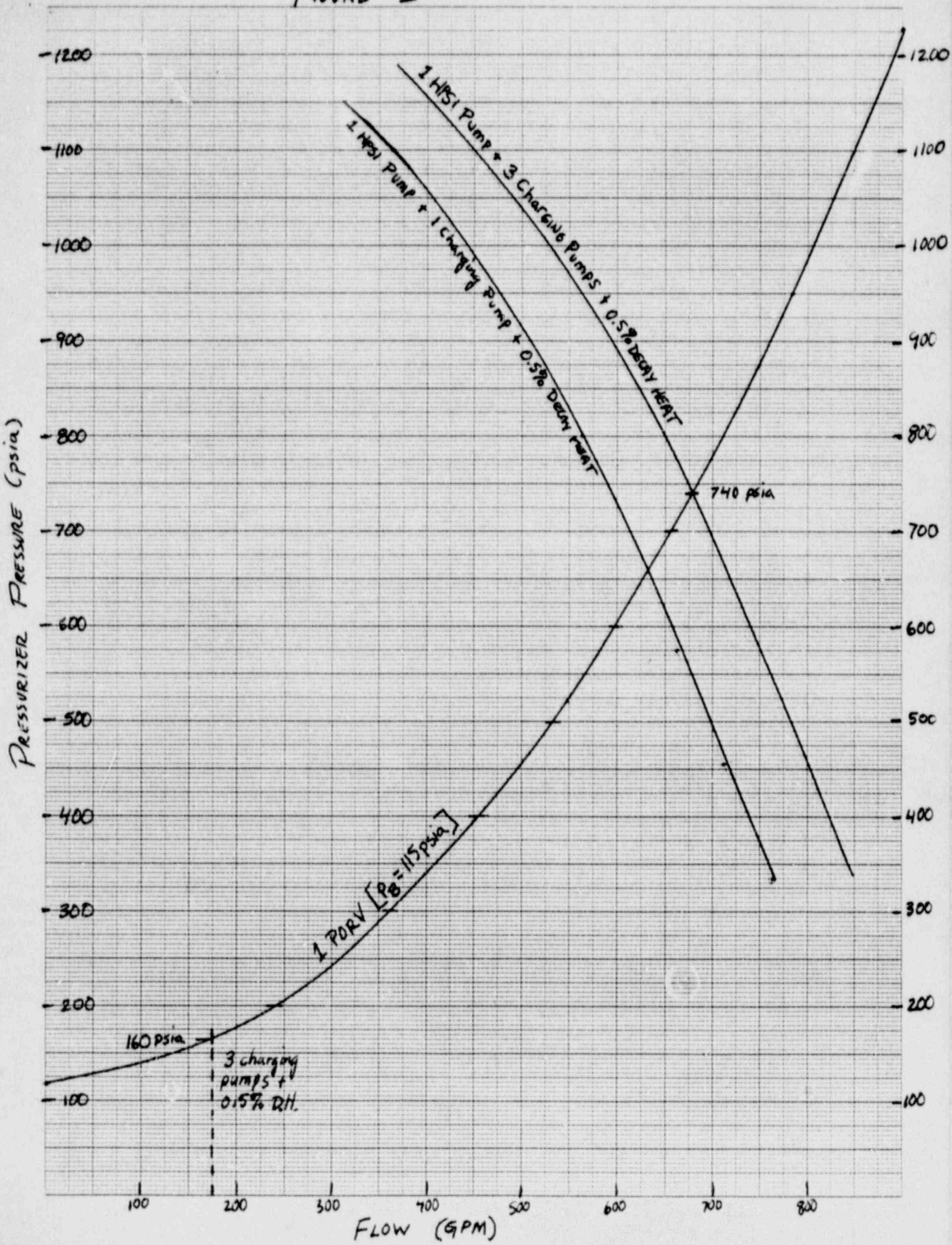
7.0 SUMMARY

Overpressure protection is provided by a combination of hardware and procedural controls. Two PORVs are set to lift at 384.4 psia (protecting 422.7 psia in the pressurizer) for temperatures at and below 319^{O}F. Alarms are provided to the operators to alert them to implement LTOP protective measures and to warn them when pressure limits are being approached. Components that can challenge MPT limits are disabled when not needed and in particular are disabled for water solid operations. Testing of components is controlled so as to minimize any potential challenge to MPT limits and testing is prohibited during water solid operations.

8.0 REFERENCES

8.1 Letter from V. R. Evans (BG&E) to D. K. Davis (NRC), dated July 21, 1977
8.2 Southwest Research Institute, SwRI Project No. 06-1278-001, dated November 1988, Pressure-Temperature Limits for Calvert Cliffs Nuclear Power Plant Unit 1
8.3 NEU Calculation 100-MS-8905
8.4 NEU Calculation 100-MS-8906
8.5 NEU Calculation 100-TH-8701

FIGURE 1



K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1510