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SUBJECT: Forwards 90-day response to GL 97-04, "Assurance of Sufficient NPSH for ECC & Containment Heat Removal Pumps," 971007.

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January 5, 1998

PG&E Letter DCL-98-002

U.S. Nuclear Regulatory Commission
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Washington, D.C. 20555-0001

Docket No. 50-275, OL-DPR-80
Docket No. 50-323, OL-DPR-82
Diablo Canyon Units 1 and 2
90-Day Response to NRC Generic Letter 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps"

Dear Commissioners and Staff:

NRC Generic Letter (GL) 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," was issued on October 7, 1997, requesting that licensees submit information necessary to confirm the adequacy of the net positive suction head (NPSH) available for emergency core cooling and containment heat removal pump operation. PG&E's response to GL 97-04 is enclosed.

In February 1997, PG&E established administrative controls to increase the minimum refueling water storage tank (RWST) level. This action followed an extensive review of the design basis of the containment recirculation sump and the original analyses that assure emergency core cooling system pump NPSH during the recirculation phase of a loss-of-coolant accident (LOCA). Although the current RWST minimum level required by Technical Specifications (TS) assures that adequate water is available in the containment recirculation sump, PG&E concluded, based on its review, that an increase in the RWST minimum water volume was desired to provide additional margin beyond the margin of safety in the licensing basis. At the time GL 97-04 was issued, PG&E was preparing to submit a license amendment request (LAR) to raise the minimum required RWST level specified in TS 3.5.5, "Refueling Water Storage Tank."

A076/1

Based on the request in GL 97-04, it is PG&E's understanding that the NRC intends to generically pursue post-LOCA debris impacts on pressurized water reactor (PWR) recirculation sumps. Consequently, PG&E is currently evaluating if the LAR revising TS 3.5.5 should be submitted at this time. It is apparent that while our current analyses are based on the latest information applicable to PWRs, the calculation methods do not consider the lessons learned by boiling water reactors (BWR) owners and the NRC.

PG&E plans to work with industry groups and the NRC to develop debris analysis methods necessary to assess the applicability of the information and technology developed by the BWR owners, and as appropriate apply these methods to the Diablo Canyon design. In the interim, PG&E plans to maintain minimum RWST water volume at a level that provides conservative analytical margin.

Sincerely,

Robert P. Powers

Robert P. Powers

Subscribed and sworn to before me
this 5th day of January, 1998
County of San Luis Obispo
State of California

Amy J. Calloway

Notary Public

Attorneys for Pacific Gas
and Electric Company
Roger J. Peters
Richard F. Locke

Richard F. Locke

AMY J. CALLOWAY
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NOTARY PUBLIC CALIFORNIA
SAN LUIS OBISPO COUNTY
My Comm. Expires April 28, 2000

cc: Edgar Bailey, DHS
Steven D. Bloom
Ellis W. Merschoff
Kenneth E. Perkins
David L. Proulx
Diablo Distribution

Enclosures

KEJ

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KEJ

RESPONSE TO GENERIC LETTER 97-04, "ASSURANCE OF SUFFICIENT NET POSITIVE SUCTION HEAD FOR EMERGENCY CORE COOLING AND CONTAINMENT HEAT REMOVAL PUMPS"

Generic Letter (GL) 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," was issued to request licensees to submit information necessary to confirm the adequacy of the net positive suction head (NPSH) available for emergency core cooling and containment heat removal pumps. Information for Diablo Canyon Power Plant (DCPP), Units 1 and 2, relative to information requested by GL 97-04 is provided below:

<u>*Requested Information*</u>

1. *Specify the general methodology used to calculate the head loss associated with the ECCS suction strainers.*

<u>PG&E Response</u>

The general methodology used by PG&E to determine limiting emergency core cooling system (ECCS) suction strainer/containment recirculation sump head loss and limiting ECCS pump NPSH margin is provided in two parts:

- An analysis that determines the NPSH available to the ECCS pumps assuming that a conservative level is maintained in the recirculation sump.

- An analysis that determines the head loss across the containment recirculation sump screens. This calculation demonstrates a conservative recirculation sump level to ensure that postulated post-loss-of-coolant accident (LOCA) debris blockage will not prevent sufficient water from draining to the sump. As a result, post-LOCA ECCS pump flow requirements are met.

It is necessary to perform the calculations separately since the limiting scenarios for each analysis are different. The limiting residual heat removal pump (RHRP) NPSH margin condition occurs during the hot leg recirculation phase following a large break LOCA. One RHRP is assumed to fail, maximizing the flow of the remaining RHRP and minimizing its NPSH margin. However, with only one RHRP running, this scenario does not maximize total recirculation sump flow, and consequently is not a limiting condition for head loss through the recirculation sump screen. The head loss through the containment recirculation sump is greatest during a large break LOCA with all ECCS flows maximized.

ECCS and Containment Recirculation Sump Design

The ECCS in each DCPP Unit consists of two RHR trains, two safety injection (SI) trains, and two centrifugal charging (CC) trains. The residual heat removal (RHR), SI, and CC trains provide low head, intermediate head, and high head SI, respectively. The RHR and SI trains are normally lined up to the refueling water storage tank (RWST). The CC trains are normally lined up to the volume control tank in support of reactor coolant system (RCS) chemical and volume control. The containment spray pumps (CSPs), which start on a high-high containment pressure signal, are aligned to take suction from the RWST.

Following a SI signal, the CC pumps (CCPs) automatically align to take suction from the RWST and all ECCS trains inject to the RCS cold legs if the RCS pressure is less than the shutoff head of the pumps. When the RWST is at approximately 33 percent level, the RHRPs automatically trip. Operators then manually realign the RHRPs suction to the containment recirculation sump. The operators align suction of the SI and CC trains to the discharge of the RHRPs. The CSPs are shut down by operators when the RWST low-low level alarm of 4 percent is received. Operators may align the discharge of one RHRP to the containment spray header. The CSPs cannot be aligned to take a suction from the containment recirculation sump or the ECCS.

Each Unit has one recirculation sump that is located in the annulus area of the containment between the crane wall and the containment liner at the 91-foot elevation (see attached Figure). The floor of each sump is at the 88 foot elevation and is approximately 27 feet long and 7 feet wide. Two 14 inch diameter recirculation supply lines that supply separate RHRPs, are on opposite sides of the sump, and rise above the floor to further minimize the ingestion of debris. A lower debris screen, in the form of an inverted-V, is directly above the RHR recirculation supply lines and runs the length of the sump. This debris screen includes a 3/16 inch mesh screen. In the center of this inner screen is a triangular grating and 3/16 inch mesh screen, separating the two RHR recirculation lines.

At the 91 foot elevation, a baffle arrangement, consisting of a wall 5 feet high with a 6 inch high opening at floor level, and a 6 inch curb enclose the front of the sump to restrict the flow of debris into the sump. The Unit 1 sump outer screen has a 1/8 inch mesh screen. The Unit 2 outer sump screen has 3/16 inch mesh. The Unit 2 sump will be modified to match the Unit 1 sump during the next Unit 2 refueling outage. The outer screen

[illegible]

assembly is pitched at an angle of approximately 68 degrees towards the containment wall from the floor and rises to the 96 foot elevation. The total unobstructed area of the inclined outer screen is approximately 130 square feet.

Calculation of NPSH Margin

The general methodology used by PG&E to calculate the pump suction head available from the top of the recirculation sump pipe to the ECCS pumps is the following basic equation for calculating available NPSH:

$NPSH_{available} = h_c - h_{vpa} + h_{st} - h_{fs}$

where:

h_c = absolute containment pressure

h_{vpa} = head corresponding to the water vapor partial pressure of the liquid at the temperature being pumped

h_{st} = static height that the liquid supply level is above or below the pump centerline or impeller eye

h_{fs} = suction line losses including entrance losses and friction losses

To calculate the available NPSH in the recirculation mode for the RHRPs, PG&E conservatively assumes that containment pressure equals the vapor pressure of the liquid in the sump. This assumption does not credit the subcooling of the sump fluid and ensures that the actual available NPSH is always greater than the calculated NPSH.

$NPSH_{calculated} = h_{st} - h_{fs}$

The NPSH available is compared to the NPSH required to determine the NPSH margin. NPSH required is determined from curves provided for each ECCS pump by its manufacturer. The NPSH margin for each pump was evaluated for normal plant operation, for the injection phase of post-LOCA operation, and the cold leg and hot leg recirculation modes of operation. The recirculation modes of operation, with the single failure of one RHRP, provide the limiting NPSH margin case for the RHRPs (the injection phase is the most limiting NPSH margin case for the SIPs and CCPs). The running RHRP is assumed to inject through the path of minimum system resistance. In the cold leg recirculation mode, no credit is taken for

[illegible]

recirculation sump level. This is conservative since calculations demonstrate that for large and small break LOCA scenarios, sump level will be a minimum of four feet. During hot leg recirculation, which is initiated approximately 10 hours into the LOCA, the minimum static head of 4.5 feet of water above the sump floor is credited.

The NPSH for the SI pumps (SIPs) and the CCPs was evaluated for both the injection and recirculation modes of operation. The end of the injection mode of operation gives the limiting NPSH margin for the SIPs and CCPs due to the low RWST level. Following switchover to the recirculation mode, significant NPSH margin is provided by the boosted pressure from the RHRPs.

The suction line and system losses were determined using industry standard methodology that includes consideration of pipe roughness, length of pipe, fluid velocity, and numbers and types of valves and fittings. The analysis methodology is based on Crane Technical Paper 410 and performed with the aid of modeling software. The analysis has been verified against DCPP ECCS performance. The friction losses are conservatively calculated assuming a sump water temperature of 70 degrees F. This assumption provides a higher friction term resulting from higher fluid density, and consequently a conservatively lower NPSH margin.

Head Loss Associated With the Containment Recirculation Sump

PG&E Calculation M-591, determines the head loss across the containment recirculation sump following the design basis large break LOCA and seven sizes of small break LOCA events.

The head loss through the recirculation sump is calculated by:

- Determining the submerged portion of the recirculation sump screen following large break and small break LOCA events.

- Estimating the amount of insulation debris generated by the LOCA that is transported to the sump in the form of mats and loose fibers.

- Estimating the portion of the screen blocked by paint debris.

- Calculating the recirculation sump flow area by subtracting the screen area that is blocked by sump structure (i.e. sump screen wire diameter, grating, and concrete structure), paint debris and insulation mats from the total area submerged.

- Determining the ECCS flow requirements for each event.

- Calculating the head loss through the loose fiberglass insulation debris that is assumed to be uniformly distributed over the sump screen.

- Determining the total recirculation sump head loss by adding the head loss across the fiberglass insulation with the head loss across the sump screens and structure.

Calculation M-591 verifies that the flow velocity of the fluid approaching the sump remains less than one foot per second and demonstrates that head loss is less than one foot.

In February 1997, minimum RWST water volume was administratively raised from 81.5 percent to 91 percent level. This was done to address issues of containment recirculation sump level instrumentation uncertainties and to add margin for debris blockage. Raising the RWST level assures higher post-LOCA containment flood level, increasing the submerged portion of the recirculation sump screen.

The following are brief summaries of the methods used to calculate the submerged portion of the recirculation sump screen, paint blockage, and the impacts of insulation debris.

<u>Submerged Portion of the Recirculation Sump Screen</u>

PG&E Calculation N-227 provides the minimum post-LOCA containment flood levels. The calculation provides post-LOCA flood levels for the design basis large break LOCA and seven sizes of small break LOCA events. Features of the calculation are:

- A conservative calculation of the volume of water transferred from the RWST before the initiation of the recirculation mode.

- An estimate of the volume of water in transit to the recirculation sump, including steam, condensation, and water in pools.

- The LOCA contribution to the sump from a small break LOCA event will be offset by the ECCS makeup to the RCS necessary to maintain level and compensate for RCS cooldown.

[illegible]

- Credit for accumulator injection when RCS pressure drops below the accumulator injection setpoint, but only the amount injected up to the point when the RWST low level RHRP trip is received.

Paint Debris

During the later stages of initial plant licensing, it was identified that a significant amount of paint and surface primer had been applied inside containment that was not properly qualified. PG&E documented the amount of unqualified paint in the Final Safety Analysis Report (FSAR) and maintains an active account of the quantity of unqualified paint in Calculations N-216 for Unit 1, and N-217 for Unit 2.

PG&E assumes that all unqualified paint fails following a LOCA and that 50 percent of the paint is transported to the recirculation sump following a LOCA. No qualified paint is assumed to fail. The paint establishes a 45 degree slope angle as it collects at the sump screen. The volume of the paint is doubled to establish a 50 percent compaction ratio. No flow is assumed through the paint pile.

Insulation Debris

PG&E assumes that only fibrous insulating material is transported to the recirculation sump following a LOCA. Calculations N-42 for Unit 1, and N-51 for Unit 2, determine the maximum amount of fibrous insulation available for debris generation during a LOCA. The calculation uses unit specific jet impingement studies to identify the high energy line break zones of impact. Insulation debris generation calculations and behavior at the sump are based on the guidance provided in NUREG/CR-2791, "Methodology for Evaluation of Insulation Debris Effects." Insulation debris transport behavior is based on the guidance provided in NUREG/CR-2982, "Buoyancy, Transport, and Head Loss of Fibrous Reactor Insulation." The individual fiber debris that reaches the sump screen is assumed to be uniformly distributed over the entire wetted surface of the screen after the RHRPs are started in the recirculation mode and recirculation water flows towards the sump. The head loss across the fibrous insulation is based on guidance provided in NUREG/CR-2791.

Requested Information

2. *Identify the required NPSH and the available NPSH.*

[illegible]

PG&E Response

PG&E Calculation N-100 provides both required NPSH and limiting available NPSH for the RHRPs during the recirculation phase. The limiting NPSH margin for the SIPs, CCPs, CSPs occurs during the injection phase, when they take suction from the RWST. In the recirculation phases the CSPs are not used and the SIPs and CCPs are supplied from the RHRPs and provide significant NPSH margin. The following table provides the current limiting NPSH margin for each pump in the recirculation mode based on currently available calculations and demonstrates that NPSH margin is available as required by Regulatory Guide (RG) 1.1.

Pumps	Mode	Flow and Condition	Available NPSH, ft	Required NPSH, ft	NPSH margin, ft
RHR	cold leg recirculation	4542 gpm	23.8	19	4.8
RHR	hot leg recirculation	4900 gpm (runout)	27.6	24	3.6
SI	cold leg recirculation	567 gpm	79	19	60
CC	cold leg recirculation	451 gpm	54	19	35

Requested Information

3. *Specify whether the current design basis NPSH analysis differs from the most recent analysis reviewed and approved by the NRC for which a safety evaluation was issued.*

PG&E Response

NPSH Analyses

The current design basis NPSH margin analysis was performed using methods consistent with the original NPSH margin analysis reviewed and approved by the NRC. The NPSH margin results have changed to a limited extent since initial licensing due to system design changes and analysis of new scenarios.

Documentation of the NRC's review and acceptance of PG&E's NPSH margin analysis is limited. The original Safety Evaluation Report, issued on October 16, 1974, which appears to provide the most recent analysis reviewed and approved by the NRC, stated: "For both the high head and

[illegible]

low head [ECCS] pumps, the system is designed to provide adequate NPSH, considering the water temperatures and containment pressure calculated to be present during the accident."

In Supplemental Safety Evaluation Report (SSER 26), issued July 1984, in review of paint debris concerns, the NRC stated; "There is a minimum margin for NPSH of 4 feet of water for the worst case, post-accident configurations of equipment." This review of paint debris concerns was subsequently revised in SSER 33, after PG&E notified the NRC that the volume of unqualified paint considered in its analysis had increased. The evaluation in SSER 33 found the paint debris volume acceptable based on an assessment of the remaining free area of sump screen and not in terms of NPSH available. As provided in response to Question 2, the minimum margin is 3.6 feet of water.

Head Loss Through the Containment Recirculation Sump

The current design basis for head loss through the recirculation sump differs from the analyses reviewed and approved by the NRC for which a safety evaluation was issued. The significant differences are discussed below.

Paint Debris

During the later stages of initial plant licensing, it was identified that a significant amount of paint and surface primer had been applied inside containment that was not properly qualified. PG&E documented the amount of unqualified paint in the FSAR and maintains an active account of the quantity of unqualified paint in calculations. As documented in a PG&E letter to the NRC dated February 9, 1985, all unqualified paint was assumed to fail during a LOCA and was transported to the containment recirculation sump. PG&E assumed that the paint pile would be fully compacted into a pile that developed a 45 degree slope towards the screens, fully blocking flow up to the highest point on the screen achieved by the paint pile. The NRC accepted this analysis in SSER 33, dated May 1986.

The original post-LOCA flood height calculations, based on a large break LOCA, determined that the minimum flood height would be to the top of the recirculation sump. In 1989 and 1991, more limiting flood heights were identified, reducing the available flow area. In response to these issues, PG&E reassessed the assumptions for paint debris transport to the sump. Calculation M-591 was revised to

assume that 50 percent of the unqualified paint debris would be transported to the sump. This revised assumption was based on a study that had been performed for Comanche Peak. This study determined that approximately 15 percent of the unqualified paint for this plant would be transported to the sump. The study assumed that all of the paint inside containment failed and used NUREG/CR-2791 methodology to determine transport of paint debris. The judgment that 50 percent paint transport was reasonable was based on a general comparison of the DCPP and Comanche Peak containments.

An integrated 10 CFR 50.59 safety evaluation was performed for the changes to paint debris assumptions in December 1996. The evaluation concluded that the changes did not represent an unreviewed safety question.

In a subsequent revision to Calculation M-591, performed in May 1997, compaction of paint at the recirculation sump was conservatively changed from 100 percent to 50 percent, effectively doubling the paint blockage at the recirculation sump. This change was made when PG&E recognized a difference between the calculated volume of paint debris submitted to the NRC for review and the calculated volume NRC had included in SSER 33. SSER 33 assumed twice the volume of paint debris as PG&E had originally calculated. The basis for the increase of paint volume was not provided in the SSER. The May 1997 revision to Calculation M-591 accounted for this difference by assuming that the paint at the recirculation sump would be less dense.

Insulation Debris

The original design of the containment recirculation sump predated NRC RG 1.82, Revision 0, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident." The original licensing basis analysis, provided in Revision 0 to the FSAR, stated that the recirculation sump screen could continue to function when it is 95 percent blocked. Revision 0 of the FSAR identified that there were two types of insulation inside containment: reflective metal insulation and steel jacketed calcium silicate insulation. An analysis was performed that determined that some quantity of each type of insulation would be blown off by the jet impingement of a LOCA. However, it was determined that neither type of insulation would be able to reach the recirculation sump.

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Revision 0 of the FSAR also identified that a worst case rupture of a 50 degree elbow at the steam generator could dislodge up to 96 square feet of insulation. The analysis postulated that even if all this insulation reached the sump, it would only cause 64 percent blockage.

SSER 3, dated September 18, 1975, accepted this evaluation and stated: "Jet effects could dislodge some of this insulating material from piping and equipment. However, the arrangement of floor, walls, and compartments would prevent some portion of this dislodged insulation from reaching the containment sump." In conclusion, the SER stated: "Based on our evaluation of the information submitted by the applicant, we have concluded that the use of reflective metal insulation and steel jacketing around conventional insulation, coupled with the design features of the containment sump, provide adequate assurance that the sump will not be blocked by displaced insulation during a loss of coolant accident."

During a review of NRC Information Notice 90-07, "New Information Regarding Insulation Material Performance and Debris Blockage of PWR Containment Sumps," PG&E determined that fiberglass insulating material had been added to containment on a temporary basis for piping instrumentation for the pressurizer surge line. In addition, blanket fiberglass was being used as a substitute for damaged reflective metal insulation. Surveys were performed to document the fiberglass insulation used inside containment.

Subsequently, calculations were performed for both Units that determined the quantity of fibrous insulation debris that could be generated during a LOCA. The calculations compared the containment insulation surveys to the jet impingement studies that had been previously performed. Insulation was assumed to block an area of the sump equivalent to the area it covered on the pipe from which it had been knocked off. The calculations qualitatively assessed the combined impacts of small break LOCAs, paint debris, and insulation debris. Although a small break LOCA can result in less submerged sump area, lower flow velocities reduce the amount of insulation debris transported to the sump and a less harsh containment environment reduces the rate that paint debris is generated.

NRC Bulletin 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers," required licensees to identify fibrous air filters or other temporary sources of fibrous material installed or stored in containment. PG&E responded that fibrous insulation had been used

in special situations where space limitations made installation of reflective metal insulation impractical, such as at rupture restraints and pipe supports, or as an interim measure until permanent reflective metal insulation could be installed. PG&E determined that adequate screen area existed to handle the additional fiberglass insulation debris generated in addition to the unqualified paint debris. The NRC acknowledged this response in a letter dated June 30, 1993, and concluded that PG&E's actions in response to the NRC Bulletin were complete.

PG&E reassessed the insulation calculations in late 1996 when concerns regarding the combined impacts of small break LOCA events, paint debris, and insulation debris were reviewed. PG&E applied the guidance provided in NRC GL 85-22, "Potential for Loss of Post-LOCA Recirculation Capability Due to Insulation Debris Blockage." GL 85-22, which resolved Unresolved Safety Issue A-43, distributed revisions to RG 1.82 and Standard Review Plan Section 6.2.2, "Containment Heat Removal Systems." RG 1.82, Revision 1, referenced both NUREG/CR-2791 and NUREG/CR-2982. GL 85-22 recommended that RG 1.82, Revision 1, be used as guidance for the conduct of 10 CFR 50.59 reviews dealing with the change out and/or modification of thermal insulation installed on primary coolant system piping and components.

PG&E used the guidance recommended in GL 85-22 to perform this evaluation and reviewed the changes in accordance with 10 CFR 50.59. A description of PG&E's evaluation is contained in response to Question 1.

Requested Information

4. *Specify whether containment overpressure (i.e., containment pressure above the vapor pressure of the sump or suppression pool fluid) was credited in the calculation of available NPSH. Specify the amount of overpressure needed and the minimum overpressure available.*

PG&E Response

PG&E's calculations for available NPSH during the recirculation phase assume that containment atmospheric pressure is equal to the vapor pressure of the sump. No credit is taken for containment pressure above the vapor pressure of the recirculation sump fluid.

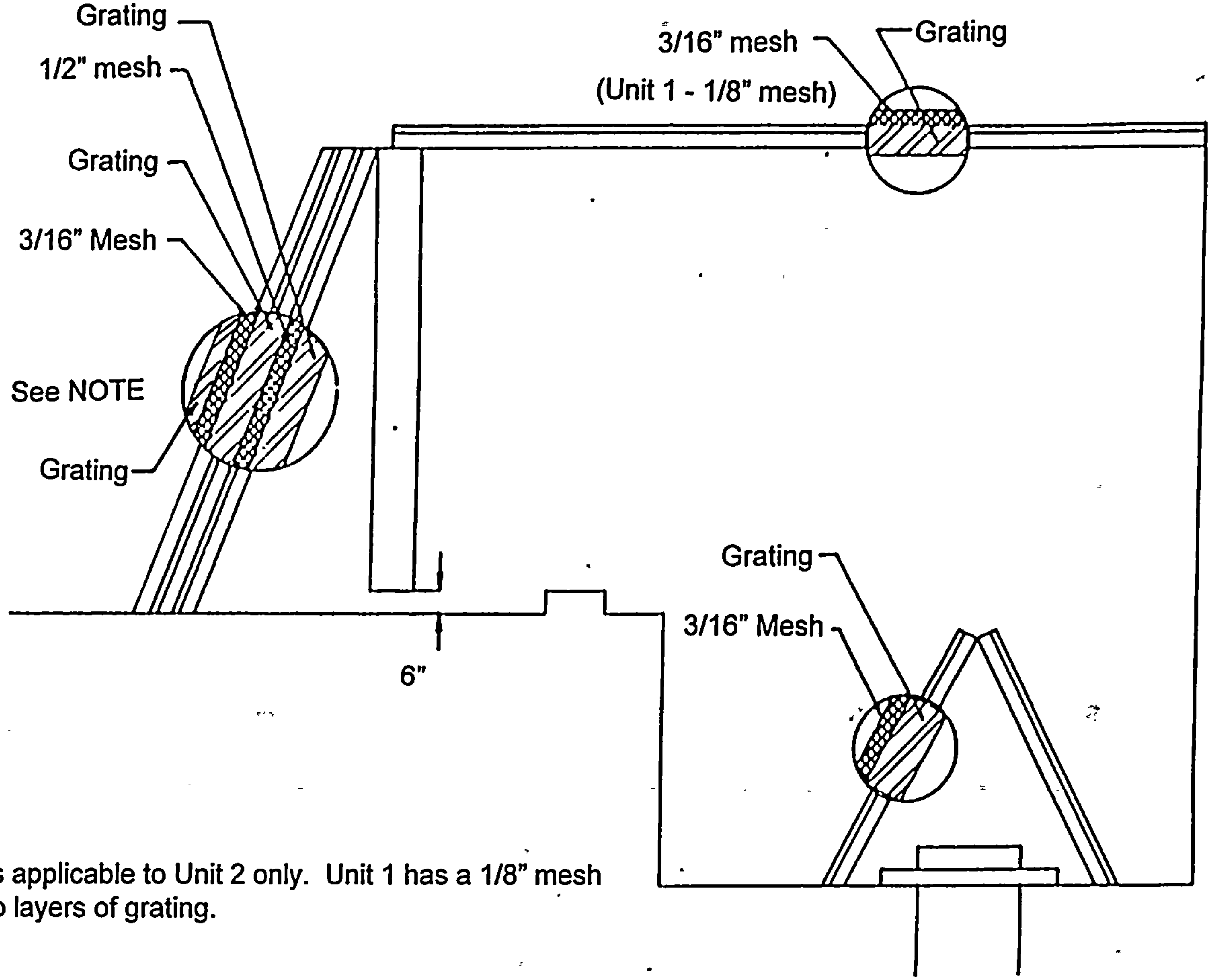
Requested Information

5. *When containment overpressure is credited in the calculation of available NPSH, confirm that an appropriate containment pressure analysis was done to establish the minimum containment pressure.*

PG&E Response

As noted in the response to Question 4, no credit is taken for containment overpressure.

Figure 1
PG&E Letter DCL-98-002



NOTE:

This detail is applicable to Unit 2 only. Unit 1 has a 1/8" mesh between two layers of grating.

Containment Recirculation Sump - Unit 2
(Cross Section)