ENCLOSURE 1

CONCEPTUAL DESIGN
FOR A
DEDICATED SAFE SHUTDOWN SYSTEM
SAN ONOFRE NUCLEAR GENERATING STATION
UNIT 1

April, 1984

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1.0 INTRODUCTION

This report presents the results of a study performed to identify and develop a conceptual design for a dedicated safe shutdown system for Unit 1 of Southern California Edison's San Onofre Nuclear Generating Station (SONGS 1). The report is divided into six sections and one Appendix. In addition to this introductory section, this report includes a problem statement (Section 2.0), a description of the system proposed as the solution to the problem (Section 3.0), a description of the plant modifications that would be necessary to implement the proposed system (Section 4.0), and the conclusions drawn concerning the feasibility and licensability of the proposed system (Section 5.0). The references used in the study are presented in Section 6.0. The calculations which serve as a preliminary basis for the proposed system's performance are contained in Appendix A.

1.1 Objective

The objective of the dedicated safe shutdown system design is to provide, in conjunction with existing plant systems, the capability to achieve safe shutdown for any postulated fire in accordance with the safe shutdown requirements of 10CFR50 Appendix R [1].

The systems normally used for safe shutdown at SONGS 1 include reactor coolant, auxiliary feedwater, main steam, chemical and volume control, residual heat removal, component cooling water, and salt water cooling. Based on earlier fire hazards analyses, fires postulated to occur in any one of several of the plant's fire zones have the potential for making one or more of these systems unavailable as a result of fire damage to system components, associated electrical power circuits, instrument air supplies, system instrumentation, and controls.

SCE has evaluated the design of the existing systems required for safe shutdown and has identified the scope of modifications that would be necessary to furnish them the level of protection required by Appendix R [2]. These modifications, which include cable rerouting, equipment relocation, fire barrier installations, fire enclosure and fire suppression system installations, and new shutdown system equipment were proposed in an attempt to meet broad safety goals by resolving the large set of problems expected from the Systematic Evaluation Program (SEP) in addition to complying with the Appendix R requirements. To date, the expected large set of problems has not resulted from SEP Integrated assessment. This situation established an added objective for the design of the dedicated safe shutdown system: that is, to minimize the scope and schedule necessary for implementation by resolving only those problems presented by Appendix R.

1.2 Approach

The approach taken in the design of the dedicated safe shutdown system is based on the following concepts:

A. It should be possible to achieve and maintain cold shutdown by using the main steam generators for decay heat removal.

Normally, the steam generators are operated in conjunction with the auxiliary feedwater system and steam dump system to reject decay heat through the generation and controlled release of steam. When the reactor coolant system has been cooled to 350°F and 365 psia, operation of the residual heat removal system is initiated to bring the unit to cold shutdown. Calculations performed in this study, however, indicate that cooldown can be continued with the steam generators, and that cold shutdown (RCS temperature less than 200°F) can be achieved and maintained by operating the steam generators in a single-phase (liquid) heat transfer mode.

Using the steam generators for decay heat removal to establish and maintain cold shutdown is an approach which has also been adopted by Yankee Atomic Electric Company for their Rowe Plant [3].

The advantage of using the steam generators to acheive and maintain cold shutdown is that this approach does not require the residual heat removal, component cooling, or salt water cooling systems to be operable following a fire. This, in turn, avoids a number of difficult and time consuming modifications that would have otherwise been necessary to meet Appendix R requirements for these systems.

B. Fires may be postulated having the potential for the following consequences:

- Unavailability of the control room
- Destruction of switchgear and cables used for supplying power to existing normal safe shutdown equipment
- Failure of power, instrumentation, and control cables normally used to achieve and maintain safe shutdown.

By recognizing the potential consequences of all major fire scenarios, the design of the dedicated safe shutdown system represents one unique combination of systems capable of being used in the event of any fire having the potential of making the existing normal safe shutdown systems unavailable.

Relative to a design approach which would allow separate systems to provide shutdown capability for different fire scenarios (see Paragraph III.2.3 of 10CFR 50 Appendix R), this approach offers the advantage of using a single system and a single procedure for any fire which would cause the normal systems to be unavailable. In order to provide this advantage, the dedicated safe shutdown system incorporates:

- Remote shutdown capability
- Independent onsite power source
- Independently powered instrumentation and controls

C. Paragraph III.L.6 of 10CFR50 Appendix R allows that "shutdown systems installed to ensure postfire shutdown capability need not be designed to meet seismic Category I criteria, single failure criteria, or other design basis accident criteria..."

Since 10CFR50 Appendix R allows that shutdown systems installed to ensure postfire shutdown capability need not be designed to meet design basis accident criteria, the components which comprise the dedicated safe shutdown system will not be required to meet safety-related seismic and equipment qualification criteria, except where necessary to isolate the dedicated safe shutdown system equipment from existing safety-related systems, components and associated circuits.

In comparison with a design approach relying on modifying existing safety-related systems this approach has a much lesser impact on the existing safety systems and offers the advantage of lower equipment and materials cost, shorter procurement lead times, and less complicated installation.

D. Relatively simple modifications will allow certain components of the existing safe shutdown systems to be used as part of the dedicated safe shutdown system without compromising the design integrity of either system.

As part of this study, field walkdowns were conducted which, in conjunction with a review of system design details, indicated that with relatively minor modifications, certain components of the existing safe shutdown systems could be used as part of the dedicated safe shutdown system without compromising the design integrity of either system.

The advantage of this approach is that it provides a means of avoiding the procurement lead times associated with new equipment which, in turn, can reduce project schedule.

Consistent with this approach, the dedicated safe shutdown system design incorporates the use of one existing centrifugal charging pump, the motor driven auxiliary feedwater pump, the existing remote shutdown panel, and, through the establishment of local control stations, several existing control valves.

1.3 Results

The results of this study, which are detailed in the following sections, include a description of the dedicated safe shutdown system and the plant modifications necessary to implement it. The design approach is consistent with that described in Section 1.2 and meets the objectives presented in Section 1.1.

The calculations performed and presented in Appendix A serve as a preliminary basis for the proposed systems performance requirements. Based on these results it has been concluded that the dedicated safe shutdown design is feasible and licensable.

In summary, the proposed "dedicated" safe shutdown system:

- Will satisfy 10CFR50 Appendix R Section III.L requirements,
- Can be engineered and installed prior to the end of the 1986 refueling outage
- Will cost approximately 5 million dollars for engineering, procurement and construction.

2.0 STATEMENT OF PROBLEM

The problem which the dedicated safe shutdown system is intended to solve includes the technical, schedule and cost elements discussed below.

2.1 Existing Design vs. Appendix R Requirements

The original design criteria for SONGS I did not include physical and electrical separation requirements which would satisfy Appendix R of 10CFR50. Therefore, the current plant design does not comply with the safe shutdown requirements of Section III.G.2 of Appendix R. The specific areas of non-conformance include:

- Separation of cable and equipment by a three-hour fire barrier
- Separation of cables and equipment by 20 feet (horizontal) with no intervening combustibles and detection and suppression systems
- Enclosure of cables and equipment in a one-hour barrier with detection and automatic suppression.

Since the design modifications required to meet this criteria for existing systems would involve a major redesign of the plant, the upgrade of existing equipment will be limited to items which cannot be replaced in a more cost effective manner by alternate "dedicated" equipment. The equipment to be upgraded is primarily safety related and used for the mitigation of other design basis accidents. New equipment for the dedicated safe shutdown system will be safety related only at points of interface with existing safety-related equipment. All other equipment will be non-safety related.

The proposed safe shutdown system will meet the requirements of Section III.L of Appendix R, and therefore, will conform to Appendix R physical and electrical separation requirements. The electrical and control equipment, which is shared between existing safety-related systems and the proposed system, will be electrically isolated from the "dedicated" electrical system during normal operation and from site normal/emergency power systems during "dedicated" system operation by a manual isolation device (transfer switch).

As discussed in the following sections, the dedicated system will comply with safe shutdown and cooldown (72 hours) requirements without offsite power. The proposed system will also be capable of maintaining the plant in cold shutdown for an extended period, beyond 72 hours.

2.2 Schedule

It is estimated that the proposed system can be installed and operational prior to the end of the refueling outage scheduled for 1986. Detailed engineering, equipment procurement, installation and testing of the proposed system can be accomplished within this period. By completing the engineering phase of this schedule in parallel with the NRC approval process, the implementation schedule can be shortened significantly.

2.3 Cost of Modifications

An objective of this study was to provide a "creative" design which satisfies Appendix R requirements and could be installed for a reasonable cost. An estimate was prepared for engineering, procurement and construction of the system.

Efforts were made to minimize the scope of proposed modifications. Since an Appendix R fire, which could disable all existing safe shutdown capability is a low probability event, credit has been taken for manual operation of equipment whenever possible. Based on site and radiological concerns, operator action in containment has not been assumed for 72 hours. The proposed instrumentation is limited to that required to operate the "dedicated" system and does not include redundant or diverse methods of detection or alarm.

Although a complete cost estimate has not yet been prepared (this is expected to be a Phase II activity), it is estimated that the cost of engineering, procurement and construction for the proposed modifications will be approximately 5 million dollars.

3.0 SYSTEM DESCRIPTION

This section contains a description of the proposed system, a review of the functional requirements, and identifies required components. The results of the thermohydraulic calculations (Appendix A) are included where relevant to equipment selection or resource availability.

3.1 Overview

The proposed dedicated safe shutdown system is shown on Figure 3-1. It consists of four subsystems: primary, secondary, electrical, and instrumentation and control. The functions of the safe shutdown system are:

- Decay Heat Removal
- Reactivity Control
- Primary Coolant Inventory Control
- Primary Coolant Pressure Control

Decay heat will be removed from the core by natural circulation. The experience gained by the Westinghouse Owners Group study of natural circulation cooldown transients for Westinghouse plants [4] was considered in addition to the existing operating procedures for natural circulation cooldown at Unit 1. Heat (reactor decay and sensible) will be removed from the Reactor Coolant System (RCS) through one or more steam generators utilizing two different steam generator operating modes: a steaming mode and a single-phase heat transfer mode.

The steaming mode will commence immediately following reactor trip. Heat will be transfered to the feedwater in one or more steam generators. Steam will be generated and released under the control of the existing atmospheric dump valves (CV-76, CV-77, CV-78 and CV-79). Water will be supplied to the steam generator(s) by motor driven Auxiliary Feed Water (AFW) pump G-10S from the Auxiliary Feedwater Storage Tank (AFWST). After the steam generator bulk temperature reaches approximately 212°F, the steaming mode will be terminated and a transition made to the single-phase mode of operation.

The single-phase mode of operation involves heat transfer from the RCS to cooling water being supplied by AFW pump G-10S through the AFW supply headers. The steam generator will act as a once through, single-phase heat exchanger. Water will be discharged through a valve which will be "teed" into the turbine driven AFW pump turbine steam supply piping upstream of CV-113 and an existing manual isolation valve. This water will be "letdown" to an existing outfall point.

Using this method, cold shutdown can be achieved within 72 hours as required by Section III.G.1b and III.L.1 of Appendix R. The single-phase mode of operation will be continued until the normal residual heat removal system is restored to service.

Reactivity control will initially be provided by the reactor trip function, which is assumed not to be affected by any postulated fire. As the RCS is cooled-down, the required shutdown margin will be maintained by injecting borated water from the refueling water storage tank (RWST). This water will be supplied by the north centrifugal charging pump (G-8A) by way of the reactor coolant pump seals. The normal charging flow path will be available as an alternate.

The primary coolant inventory will be controlled by limiting reactor coolant pump seal leakage while injecting a sufficient amount of water through the RCP seals and/or normal charging path to maintain pressurizer level and compensate for shrinkage during cooldown. With even only the minimum required concentration of boric acid in the RWST, the water injected for primary coolant inventory control exceeds that required to maintain an adequate shutdown margin for reactivity control.

Primary Coolant Pressure will be controlled by maintaining a bubble in the RCS pressurizer. The heat loss from the pressurizer is sufficiently low that during the initial hours of RCS cooldown, pressurizer heaters are not necessary to maintain adequate system overpressure. On the contrary, based on the results of Appendix A, pressure must be relieved from the system so that the cooldown may proceed without exceeding RCS nil ductility transition temperature (NDTT) limits. This pressure relief will be accomplished by way of a pressurizer power-operated relief valve (PORV)/block valve combination.

Later during the cooldown, as the RCS approaches cold shutdown, a nitrogen bubble will be established to preserve the system overpressure. Provisions will also be made to restore one group of pressurizer heaters using power from the dedicated safe shutdown source, or, after 72 hours, an offsite source.

The following assumptions were used in the design of the proposed system:

1. A fire could occur in any area of the plant containing combustibles or cable. No other accident has been assumed to occur simultaneously.

2. Reactor power is initially at 100%.

3. Reactor and turbine trip functions are not disabled by any postulated fire and occur at time t=0.

4. All offsite power is lost for the first 72 hours.

5. Electrical isolation devices perform their design function, and therefore, a fire involving an electrical load normally used to achieve shutdown (AFW pump, CVCS pump, etc.) does not disable the associated supply bus.

6. A fire in zone 8 (4kv Room) or 9 (Lube Oil Reservoir and Conditioner area) prevents the emergency diesel generators from powering the existing safety-related 4KV and 480VAC equipment.

7. A fire affecting a component of the "dedicated" safe shutdown system does not disable the ability to safely shutdown and cooldown the plant using existing, redundant plant equipment.

   (For example, a fire in area of the auxiliary feedwater pumps is assumed not to affect the availability of the normal feedwater system. The assumption is considered valid for this case because: 1) the east feedwater pump G-3A is physically separated from the auxiliary feedwater pumps; and, 2) by Assumption 5, the fire does not affect the normal or emergency onsite distribution system which provides power to the east feedwater pump. Therefore, a normal plant shutdown/cooldown can be performed after a postulated AFW pump fire.)

Using the above assumptions, the proposed system satisfies the required functions of the dedicated safe shutdown system. The subsystems which comprise the dedicated safe shutdown system, their functional requirements, and operation are discussed in Sections 3.2 through 3.5.

3.2 Primary Subsystems

The primary subsystem is designed to transport heat to the secondary system for decay heat removal, and maintain reactivity control, primary coolant inventory control, and primary coolant pressure control.

The primary subsystem includes the following components:

- The pressure boundaries of the RCS.

- The existing refueling water storage tank (D-1) and the piping and motor-operated valves (LCV-1100C and D) necessary to supply the charging pump suction header.

- The existing north Centrifugal charging pump (G-8A) and associated suction and discharge piping and manual valves.

- The existing seal water supply piping, control valves (FCV-1115A, B, and C) and associated manual valves.

- The existing seal water return piping, isolation valves (CV-527 and CV-528), and safety relief valve (RV-2004).

- The existing Thermal Barrier Emergency Cooling Pump and associated suction and discharge piping and manual valves.

- The existing normal charging supply piping and isolation valves (FCV-1112 and CV-304).

- The existing normal letdown piping and isolation valves (CV-525 and CV-526).

- The existing pressurizer power operated relief valve (CV-546) and block valve (CV-530).

- The existing pressurizer steam space sample line and associated isolation valve (CV-953).

- The pressurizer heater group D.

3.2.1 Functional Requirements

<u>Decay Heat Removal</u>

After the reactor trip and assumed loss of offsite power, the reactor coolant pumps trip and are unavailable. The core flow will be reduced from 78,000,000 lbm/hr (100% power) as shown on Figure 3-3. Calculations have shown that the reduced core flow is sufficient to remove decay heat without local boiling or void formation as long as:

- RCS pressure is maintained by a bubble in the pressurizer between curves P_A and P_B as shown on Figure 3-4;

- The initial cooldown rate is less than 25°F/hour to 350°F with a 20 hour soak at 350°F; and,

- From 350°F to cold shutdown, the cooldown rate is less than 5°F/hour.

The 25°/hour maximum rate and 20 hour soak period is recommended by the St. Lucie study [4] to prevent void formation. The maximum allowable cooldown rate, T_B, is shown on Figure 3-4.

At approximately t=55 hours, the decay plus sensible heat rate decays to 2,100,000 Btu/hr at which point the secondary subsystem may be transitioned to the single-phase mode of operation. The heat transfer capacity in the single-phase mode of operation is limited by the AFW pump, which must operate at or near the pump's run out limit of 400 gpm to continue the cooldown. It is noted that additional cooling is provided by the 80°F charging flow into the RCS. However, relative to the heat transfer to the steam generators, the effect of the charging flow is minimal and has been conservatively ignored.

The primary subsystem equipment required for decay heat removal using natural circulation is limited to the RCS pressure boundary components.

Reactivity Control

In order to achieve the required margin for cold shutdown following sustained operation at 100% power, approximately 6,200 gallons of boric acid solution must be added to the RCS from the RWST. This additional boron will bring the RCS concentration to 700 ppm which is sufficient to maintain K_{eff} less than 0.95.

The additional boron will be charged into the RCS using Charging Pump G-8A. The charging pump will be aligned to take suction from the RWST. The 6,200 gallons of borated water necessary to establish and maintain the required shutdown margin is based on the minimum RWST concentration required by Technical Specifications: 3750 ppm. The amount of water required to be added to the RCS vs. time to establish safe shutdown is shown in Figure 3-5. A second curve on Figure 3-5 shows the charging rate to account for RCS shrinkage during cooldown. It is significant to note that the boron injection flowrate is bounded by the charging flowrate necessary to maintain pressurizer level during cooldown. Therefore, inventory control and reactivity control requirements are not in conflict with one another.

The equipment required for reactivity control includes the Charging Pump, RWST, and associated valves.

Primary Coolant Inventory Control

With the RCP seals intact, and RCS leakage less than 1 gpm (a Technical Specification limit assumed for the study), in order to prevent an unacceptable decrease in pressurizer level, CVCS system operation must be initiated within five hours of the reactor trip. As discussed above, under functional requirements for reactivity control, Charging Pump (CHP) G-8A will be aligned to take suction from the RWST. Water will be charged into the loops through the reactor coolant pump (RCP) seals. The flow path from pump G-8A to the RCP seals is through valves FCV-1115A, B and C.

Under normal operating conditions, 7 gpm is provided to each RCP. Five gpm, the minimum acceptable seal water flow rate with RCS temperature greater than 350°F, flows through the labyrinth seal into the RCS for cooling. Two gpm flows through the #1 seal and is normally collected for return to the seal water heat exchanger and charging pump suction.

Under the postulated conditions, however, the seal water return path will be isolated. Therefore, any leakage through the #1 seal will pressurize the seal water return header, activate relief valve RV-2004 and be discharged to the RCS drain tank.

Since the seals for all three RCP must be cooled, the minimum charging flow rate must be greater than 2 gpm per pump. This flow exceeds the seal leakage rate.

In addition, flow must be charged into the RCS to compensate for thermal shrinkage of the primary coolant. During the cooldown from 550°F to 350°F, a total of 8,300 gallons must be added for shrinkage compensation. This corresponds to an average injection flow rate of 14 gpm.

Therefore, the charging pump will be providing approximately 21 gpm during the initial cooldown phase including:

14 gpm to match shrinkage (Figure 3-5)	14
1 gpm RCS leakage	1
2 gpm per pump seal water flow through the #1 seal	6
	21 gpm

In case a high injection flow rate is required, the normal charging path through FCV-1112 and CV-304 will be available. To ensure operability during the cooldown phase it will be necessary to upgrade FCV-1112. Alternately, provisions for manual override could be included in the emergency procedure. CV-304, the charging line isolation valve inside containment, can be opened with a differential pressure greater than 200 psid. Charging pump capacity is 173 gpm at 5400 feet of head. This capacity is more than adequate to overcome the line backpressure and deliver the required flow.

The existing charging pump G-8A can be used in the proposed system with some modifications. A preliminary hazards assessment indicates that removable fire barriers and curbs can be installed to prevent a fire affecting one pump from disabling the other. It will also be necessary that the local bearing oil cooling fan for Charging Pump 8A be powered from the dedicated power supply. This modification is be discussed in Section 4.0.

Power to Charging Pump G-8A and auxiliary equipment must be routed in accordance with the requirements of Appendix R. The proposed electrical system is discussed in Section 3.4.

The proposed system does not require upgrading of the normal letdown flow path. If for some reason it became necessary to remove mass from the RCS this would be accomplished through the power operated relief valve (CV-546) and block valve (CV-530).

To maintain RCP seal integrity with seal water unavailable and RCS temperature greater than 350°F (as it will be prior to manual initiation of the charging pump), cooling water must be provided to the RCP thermal barriers within five minutes of event initiation. Therefore, the existing thermal barrier emergency cooling pump has been incorporated into the design of the proposed system. The thermal barrier pump is presently powered from the station battery and can provide cooling water to the RCP thermal barriers for a period of two hours. Thus for fire scenarios which result in the loss of CVCS and normal thermal barrier cooling (CCW) the time available to restore the charging pump to operation is reduced from five hours to two hours. A preliminary review indicates that there is no postulated fire that will disable both the CVCS system and the thermal barrier pump. Therefore, seal water cooling to the thermal barriers will be maintained at all times. A fire hazards analysis of thermal barrier pump cable routing will be performed in Phase II.

The equipment required for Reactor Coolant inventory control includes:

- RWST
- LCV-1100C and D
- Charging Pump (G-8A)
- FCV-1112
- CV-304
- FCV's 1115A, 1115B, and 1115C
- Thermal Barrier Pump
- CV-530
- CV-546

Primary Coolant Pressure Control

Under the postulated accident conditions, the pressurizer spray line will be failed closed and pressurizer heaters will be unavailable. However, as shown in Figure 3-4, the pressurizer cooldown rate T_P is slow in comparison with the postulated RCS cooldown rate. Pressurizer temperature degrades slowly due to the 4 inch insulation blanket around the shell and 4 inch "brick" insulation on the head. As a result, a bubble can be maintained in the pressurizer without heaters for the postulated cooldown period.

However, as shown in Figure 3-4, pressurizer pressure will exceed NDTT limitations if no action is taken to relieve system pressure. With the proposed system, pressure will be relieved through the release of steam from the pressurizer. This will be accomplished through operation of the power operated relief valve CV-546 to maintain RCS pressure within allowable limits. This range is bounded by the "void formation" curve P_B on Figure 3-4 and the NDTT curve P_A.

Since the proposed system does not include the normal letdown path, solid operations are not recommended. To avoid solid operation, provisions will be made so that after RCS temperature (T_{HOT}) has reached 200°F, nitrogen can be injected through the pressurizer steam space sample line and isolation valve CV-953 to form a "hard bubble" in the pressurizer during long term cooling. As an alternate to the nitrogen bubble, provisions will also be made to allow power from the proposed system or, after 72 hours, from offsite sources, to be restored to pressurizer heater group D. These options are only necessary if normal pressure control has not been recovered.

The pressurizer steam space in-containment isolation valve CV-953 would require modification or manual operation (inside sphere) to initiate use of a "hard bubble" for pressure control. This action would not be required within 72 hours after accident initiation.

The pressurizer heater group D power supply would require modification (i.e., the installation of a transfer switch, and cable rerouting) to be used for pressure control.

The equipment required to ensure Reactor Coolant Pressure Control is:

- The pressurizer
- CV-530
- CV-546
- CV-953

3.2.2 Operation

The proposed safe shutdown system is independent of the normal and emergency diesel-powered distribution system. The primary system components can be operated from the charging pump room (Auxiliary Building lower level), doghouse, and the remote shutdown panel (RSP).

Following initiation of the postulated fire, operators will be sent to the charging pump room, doghouse, and remote shutdown panel. After opening the atmospheric dump valves, the temperature of the RCS will decrease due to sensible heat removal. As the RCS volume "shrinks" charging flow must be initiated. It is desirable to reinitiate charging flow as soon as possible to provide cooling water to the RCP seals. Charging flow must be restored in less than two hours if CCW is not available.

The operator will manually align the charging pump suction to the RWST for boron injection. Power will be made available to the pump motor through a "dedicated" manual transfer switch. Flow can be initiated through valves FCV-1115A, B and C to provide cooling to the RCP seals. Flow will be throttled using the manual isolation valves upstream and/or downstream of FCV-1115A,B and C and a local pressurizer level indication which will be added as part of the proposed system. Flow must be balanced to ensure seal water supply to all RCP seals.

The operator at the remote shutdown panel will have control of the atmospheric dump valves (CV-76, CV-77, CV-78 and CV-79). The PORV (CV-546) and block valve (CV-530). CV-530 and CV-546 must be operated as required to maintain pressure in the acceptable range, between P_A and P_B of Figure 3-4. To accomplish this pressurizer pressure indication will be required at the RSP. This indication currently exists at the RSP.

This arrangement will permit operation of the primary portion of the dedicated safe shutdown system during cooldown. Additional manual actions are required, after approximately 72 hours, if the RCS is to be placed on a nitrogen bubble float.

3.3 Secondary System

The secondary system is designed to remove decay heat from the reactor coolant system by way of the main steam generators. The secondary system includes the following components:

- The existing condensate storage tank (D-2)
- The existing auxiliary feedwater storage tank (D-2A)
- The existing motor driven feedwater pump (G-10S) and associated suction and discharge piping and manual valves
- The existing auxiliary feedwater system flow control valves (FCV-2300, -2301, -3301 and -3300) and associated piping to the steam generators
- The existing main steam generators (E-1A, -1B, and -1C)
- The existing main steam system piping from the steam generators to the manual isolation valves (24"-600-27BG and -27EG) on the steam headers outside containment

- The existing steam generator safety relief valves (RV-1 through RV-10)
- The existing steam generator atmospheric dump valves (CV-76, CV-77, CV-78 and CV-79) on the atmospheric steam dump headers.
- The existing steam supply piping to the turbine-driven auxiliary feedwater pump turbine up to and including the manual turbine isolation valve 3"-600-129
- A manual flow control valve and flow discharge manifold to be added to turbine driven auxiliary feedwater pump turbine steam supply piping upstream of CV-113

3.3.1 Functional Requirements

The secondary system will be required to remove a sufficient amount of heat from the reactor coolant system to achieve and maintain cold shutdown. The cooling water requirements are shown in Figure 302. Water stored in the auxiliary feedwater and condensate storage tanks will be supplied to the steam generators by the motor-driven auxiliary feedwater pump. Flow to each steam generator will be controlled by the existing emergency auxiliary feedwater flow control valves.

For the few minutes following reactor/turbine trip that it will take to initiate operation of the auxiliary feedwater pump, RCS temperature will be controlled at 600°F by the heat removed through the production of steam from the initial inventory of water stored in the steam generators and escaping through the steam generator safety relief valves outside containment. After the auxiliary feedwater pump is started and flows are established to recover normal steam generator levels, the cooldown of the RCS is initiated through the operation of the power-operated atmospheric steam dump valves. The dump valves will be controlled to increase the flow of steam from the steam generators, resulting in a reduction in steam generator pressure to a point that will allow the safety relief valves to close. The steam flow through the dump valves is then adjusted to establish an RCS cooldown rate of 25°F/hr, while auxiliary feedwater flow is adjusted to maintain steam generator level.

The 25°F/hr cooldown rate is maintained until an RCS temperature of 350°F is reached, approximately 10 hours following reactor/turbine trip. The steam flow through the dump valves is reduced at this point to allow this temperture to be maintained for a period of approximately 20 hours. Following this 20 hour "soak" period, cooldown at the 25°F/hr rate is resumed.

When RCS temperature has been reduced to 220°F, approximately 55 hours following reactor/turbine trip, auxiliary feedwater flow is increased so that steam generators and main steam headers are flooded. Sometime prior to this, the manual isolation valves on the main steam headers outside containment should be closed to limit the extent of flow to the piping downstream.

As the headers are being flooded, the steam dump valves remain open to provide a means of venting the steam bubble trapped in the headers. As the headers approach a full condition, the valves are throttled closed and the manual flow control valve to be installed on the turbine driven auxiliary feedwater pump turbine steam supply piping is opened. The turbine is isolated from the supply piping, which, at this point, will be serving as the steam generator feedwater "letdown" line, by closing the manual isolation valve 3"-600-129.

Water flow is now established by the manual flow control valve on the feedwater letdown line at a rate that will permit the RCS cooldown to continue at approximately 5°F/hr. In the single-phase mode of operation, the cooldown rate is limited to 5°F/hr by the capacity of the AFW pump. When RCS temperature has been reduced to less than 200°F, approximately 72 hours following reactor/turbine trip, cold shutdown is achieved and maintained by continuing the flow of auxiliary feedwater through the steam generators and out through the letdown flow control valve. RCS temperature will be maintained at 200°F using the AFW pump until normal RHR systems are restored. From 200°F, the ability of the system to further reduce RCS temperature is limited by AFW pump capacity and the decreasing steam generator terminal temperature difference.

Downstream of the new manual letdown flow control valve, a manifold will be attached which will allow several 2 1/2" fire hoses to be connected. Through these hoses, feedwater can be "letdown" to an outfall point.

The following requirements must be met by the secondary system and its components:

- Water inventory:

- To 72 hours (cold shutdown)	600,000 Gallons
- To 100 hours	1,300,000 Gallons
- To 9 days	3,500,000 Gallons

The inventory of auxiliary feedwater required to achieve cold shutdown will be supplied by the Auxiliary Feedwater Storage Tank, which will be required by SONGS 1 Technical Specifications to hold a minimum inventory of 150,000 gallons, the Condensate Storage Tank, which has a capacity of 240,000 gallons, and makeup water which is available to the Condensate Storage Tank from the following sources:

- The service water reservoir	(3,000,000 Gallons)
- The Units 2&3 makeup water plant	(400 gpm)
- The San Clemente municipal water system	(400 gpm)

The inventory of water onsite, including the 3,000,000 gallon service water reservoir, is sufficient to maintain cold shutdown conditions for a period of approximately 9 days. Offsite sources of water will allow the system to continue to maintain cold shutdown for an indefinite period. Within this period, however, it will be desirable to restore the systems normally used to maintain cold shutdown (residual heat removal, component cooling, and saltwater cooling) to normal operability, thereby allowing operation of the "dedicated" secondary system to be discontinued.

- Pump Requirements

- Immediately following reactor/turbine trip:
  235 gpm @ 1035 psig

- At 55 hours (transition to single phase heat transfer
  mode: 400 gpm @ 600 psig

These values are within the rated capacity of the motor-driven auxiliary feedwater pump. The required NPSH at 235 gpm is 10 feet. At 400 gpm, the pump is approaching its runout limit. At 400 gpm, the required NPSH increases to approximately 18 feet. The NPSH available should be adequate at 400 gpm by keeping the condensate storage tank level at or above the suction pipe connection.

- Piping and Valve Requirements

  During the first 55 hours following reactor/turbine trip, functional requirements for the piping and valves which already exist as part of the auxiliary feedwater, main steam, and steam dump systems, will remain the same as required by the current system design. After 55 hours, the main steam system piping will be required to support water loads at or below 190°F and 600 psig and the steam header isolation valves will be required to isolate flow of water downstream of the valves. The auxiliary feedwater system flow control valves will be required to deliver a minimum of 400 gpm distributed equally between the three steam generators. The feedwater letdown line and manual flow control valve must be capable of withstanding the loads associated with passing a minimum of 400 gpm through the letdown line outlet manifold and fire hoses. Pressure downstream of the valve may not exceed the rated pressure of the hose. Upstream pressure will be nominally less than 600 psig but rated for full steam header pressure.

- System Startup

  It will be necessary to start-up the secondary system before the initial post-trip inventory of feedwater in the steam generators is depleted. It should be possible to complete the system startup within 20 minutes. The period of time that it would take for the steam generators to boil dry is approximately 30 minutes.

3.3.2 Operation

To operate the secondary system, it will be necessary to position an operator at the auxiliary feedwater flow control valves and the remote shutdown panel. The dedicated safe shutdown system diesel generator will be required to be started (see Section 3.4, Electrical System) and a power switch at the shutdown panel energized to supply power to the panel instrumentation and controls (see Section 3.5, Instrumentation and Controls).

To operate the motor driven auxiliary feedwater pump, it will first be necessary to deenergize or verify deenergized the normal and dedicated sources of power and then to manually align the no-load transfer switch, which will be located near the motor-driven auxiliary feedwater pump, with the dedicated source. With the dedicated diesel-generator running, the pump is then started by closing the circuit 480V dedicated source circuit breaker. Flow is established to each steam generator by manually operating the auxiliary feedwater flow control valves. Steam generator level indication is required and will be provided at the feedwater flow control valve station.

To operate the atmospheric steam dump valves it will first be necessary to transfer control over the valves to the remote shutdown panel. This includes power for a transfer solenoid and a source of air or nitrogen at the remote panel. Provisions already exist at the remote panel to control the valves. Indication of reactor-coolant T_{AVG}, T_{HOT}, and T_{COLD}, pressurizer pressure and level will be required at the remote shutdown panel. With the exception of T_{HOT}, whose signal is present but not indicated, these indications already exist at the panel. A neutron flux source range monitor indication is also presently located at the remote shutdown panel.

To make the transition to operation in the single-phase heat transfer mode (55 hours after reactor/turbine trip) it will be necessary to station an operator at the new manually-operated steam generator feedwater "letdown" flow control valve, located near the turbine driven feed pump. Prior to making the transition, the station must be prepared by installing fire hoses to direct the letdown flow to an outfall point.

The operator at the feedwater flow control station slowly increases flow to the steam generators allowing the generators to flood. The operator at the auxiliary shutdown panel slowly closes the steam dump valves while observing the header pressure and maintaining it constant. When the header is flooded the valve should be closed. The operator at the letdown valve opens the valve slowly as the header floods. The desired flow rate is established through the coordinated action of the operators at the supply and letdown valve stations. Subsequently, flow is controlled at the letdown line alone.

Before reaching cold shutdown, makeup water will be required to re-fill the condensate and/or auxiliary storage tank. The condensate tank can be gravity fed from the service water reservoir. However a portable engine-driven pump may be required to provide sufficient flow. Water may also be provided from the Unit 2 makeup water system through fire hoses. Make-up from the San Clemente Water System is available to the service water reservoir.

3.4 Electrical System

The electrical system, shown schematically in Figure 3-6, is designed to generate and supply the power necessary to operate the dedicated safe shutdown system electrical loads. The electrical system includes the following components:

- A diesel-generator set rated for approximately 1000 kw continuous load at 4,160V, 3 phase, 60 hz including instrumentation and controls, an output circuit breaker, and the auxiliary systems required for starting, cooling, lube and fuel oils, engine air and exhaust, and generator excitation.
- The existing "abandoned" diesel generator fuel oil storage tank
- A 4KV load bus including two 4KV circuit breakers rated approximately 750KVA and 400KVA, respectively
- A 4KV/480V air cooled power transformer rated at approximately 400KVA
- A 480V load bus including three 480V circuit breakers rated for approximately 350KVA, 75 KVA, and 50KVA, respectively
- A 480V distribution bus including two circuit breakers rated for approximately 25KVA and 10KVA, respectively
- A 480V/208V/120V distribution transformer rated for approximately 25KVA
- A 120V power supply regulator rated for 10KVA
- A 4KV no-load manual transfer switch rated for approximately 750KVA (safety related)
- A 480V no-load manual transfer switch rated for approximately 400KVA (safety related)
- A 480V no-load manual transfer switch rated for approximately 75KVA
- A 480V no-load manual transfer switch rated for approximately 1KVA (safety related)
- Power distribution cable for the generator, the other electrical system equipment, and the dedicated safe shutdown system loads.
- Miscellaneous wiring, terminations, switches, and circuit protection devices

The dedicated safe shutdown system electrical loads include:

- The north centrifugal charging pump motor (G-8A)
- The south (motor driven) auxiliary feedwater pump motor (G-10S)
- The north centrifugal charging pump bearing oil cooling fan
- The pressurizer heater group D
- The remote shutdown panel controls and instrumentation
- The remote shutdown panel lighting load
- The charging pump room lighting load
- The auxiliary feedwater flow control valve station lighting load
- The dedicated diesel-generator lighting load
- The Dog House Lighting (if required)

3.4.1 Functional Requirements

The dedicated safe shutdown electrical system will be required to generate and supply the power necessary to operate the dedicated safe shutdown system electrical loads until normal electrical power from an offsite source can be restored to them. The minimum operating time is 72 hours, and, depending on the extent of fire or damage to the normal plant electrical system equipment, a longer period of time.

Immediately upon discovery of a fire which would threaten the operability of normal safe shutdown systems, the dedicated diesel-generator unit would be started. This diesel-generator will be a self contained unit. There should be fuel available to the diesel for a minimum of 8 hours when operating under full-load conditions. For a 1,000 kw diesel generator, full load fuel flow will be approximately 70 gallons per hour. Thus a 560 gallon storage tank should be a part of the diesel generator unit.

The "abandoned" diesel fuel oil storage tank located underground south of the plant is expected to be useable for storage of the required fuel. The capacity of this tank is 2,000 gallons, or 28 hours at rated capacity. Fuel would be added to this tank on a daily basis from the existing safety related emergency diesel generator fuel oil tanks or by way of a tanker truck until normal offsite power was restored. The emergency diesel fuel oil tanks, with 75,000 gallons of onsite storage, would permit continuous operation for 1,000 hours. The dedicated diesel generator would be located near the abandoned storage tank to facilitate the fuel transfer process to the diesel-generator "day" tank (limited to 200-300 gallons) which would be a part of the D-G package.

The 4KV load bus will supply power to two 4KV circuit breakers. One breaker will be dedicated to the 600 horsepower, 4KV charging pump motor load; the other will be dedicated to 4KV/480V transformer and its associated loads. The 480 volt loads will include the 250 horsepower, 480V auxiliary feedwater pump motor load, the 3/4 horsepower charging pump bearing oil cooler fan load, pressurizer heater group D and the 480V/208V/120V distribution transformer. These loads will be serviced by the 480V distribution bus and separate circuit breakers.

The distribution transformer will handle instrument and control loads through the 120V power supply regulator and lighting loads by way of a 120V distribution panel.

The switchgear and transformers will all be located in proximity to the diesel generator unit. Control power for the 4KV and 480V switchgear will be provided from the respective load buses. All other switching devices will be manual.

The three no-load transfer switches will be located near the loads which they service. The switches should be under key-lock control. The switches must be designed to meet requirements of Class 1E electrical equipment.

3.4.2 Operation

To operate the dedicated safe shutdown electrical system, it will be necessary to position an operator at the dedicated safe shutdown diesel generator unit and switchgear and dispatch one or more additional operators to align the no load transfer switches to the dedicated source. Prior to operating the transfer switches, it will also be necessary to de-energize normal sources of power to the dedicated system loads. This provides a measure of protection from spurious actuations while the transfer switches are operated. It also provides a greater degree of isolation between the normal and dedicated systems. The dedicated diesel will be started with all breakers initially open. After the transfer switches have been aligned to the dedicated source, the generator output breaker is closed. After verifying bus frequency and voltage, the loads are manually sequenced on to their respective load buses. The instrumentation and control loads and the lighting loads would be started first, followed by the charging pump and its bearing oil cooling fan and the motor driven auxiliary feedwater pump.

An operator would remain stationed at the diesel generator unit to provide continuous monitoring of the engine's operation and fuel transfer operations until normal offsite power is restored.

3.5 Instrumentation and Controls

3.5.1 Instrumentation

The instrumentation and controls identified to operate the proposed safe shutdown system have been selected to minimize required upgrades. Where possible, manual action has been identified to satisfy requirements. As an example, level indication is not required for the CST, RWST or, AFWST.

Table 3-1 lists the instrumentation required to operate the proposed safe shutdown system. Auxiliary feedwater flow indication is desirable but not absolutely necessary for the operation of the dedicated safe shutdown system.

RCS T_{HOT} and T_{COLD} indication, a source range monitor and steam generator pressure have been specifically requested by the staff in a position paper [6]. T_{HOT} and T_{COLD} signals are available at the remote shutdown panel. A local steam generator pressure gage can be installed in the letdown connection off the AFW turbine supply header.

3.5.2 Control Valves

Since operation of the proposed safe shutdown system is primarily manual, remote valve operations will be limited to those valves in containment and those requiring immediate operation. These valves are listed in Table 3-2.

The valves listed in Table 3-2 are the actual control valves. These valves are air operated. A backup air or nitrogen supply will be available for required valve operations. The associated solenoid valve will be powered from the remote shutdown panel.

3.5.3 Remote Shutdown Panel (RSP)

The RSP is located in the south end of the turbine building at grade elevation. This panel was installed per design change 74-4 and was designed to contain the instrumentation necessary to maintain the reactor in a hot standby condition in the event of control room inaccessibility. This panel at its installed location, is the primary control station for the proposed system.

The panel has the physical space to accomodate the new instrumentation and controls. Some modifications to the panel internals may be required. The panel also contains its own power supply which can be powered through a transfer switch from the dedicated diesel generator. The routing of all required cables and sensing lines must be traced to ensure compliance with the requirements of Appendix R.

The RSP would be manned continuously after identification of the postulated fire. The AFW pump can be operated from the RSP after opening the normal breaker and energizing through the transfer switch from the emergency power source. The instrumentation and controls required to operate the secondary subsystem are available at the RSP.

RCS pressure control will be achievable from the RSP with the addition of the PORV (CV-546) and Block valve (CV-530) remote controllers and transfer switch. The operator will be required to maintain pressure within acceptable limits as defined in the emergency procedure.

TABLE 3-1

INSTRUMENTATION

Function	Range	Location	Safety Class	New or Existing
RCS T_{AVG}	Wide	RSP	2	E
RCS T_{HOT}*	Wide	RSP	2	E
RCS T_{COLD}	Wide	RSP	2	E
Pressurizer Pressure	Wide	RSP	2	E
Pressurizer Level	Wide	CHP	2	N
Neutron Flux	Source	RSP	2	E
Steam Generator Level	Wide	RSP	2	E
	Wide	AFV	2	E
AFW Pump Flow	Wide	AFV	2	N
Radioactive Effluent Monitor	Wide	AFP	2	N
Steam Generator Pressure	Wide	AFP	2	N
RCP Seal Water Flow	Narrow	DH	1	E
Main Steam Header Pressure Wide	Wide	RSP	2	N

AFP - Auxiliary Feedwater "Letdown" Line

AFV - Auxiliary Feedwater "Throttle" Valves

C - Containment

CHP - Charging Pump Room

RSP - Remote Shutdown Panel

DH - Dog House

* Signal presently available at remote shutdown panel but not indicated

TABLE 3-2

CONTROL VALVES

System	Mark No.	Valve Location	Controller Location	New or Existing
Main Steam	CV-76-79	Atmospheric Dump	RSP	E
RCS	CV-530	Containment	RSP	N
RCS	CV-546	Containment	RSP	N
CVCS*	FCV-1112	Doghouse	local	E
CVCS*	FCV-1115A,B,C	Doghouse	local	E
Sampling	CV-953	Containment	local	E

* May be manually overridden

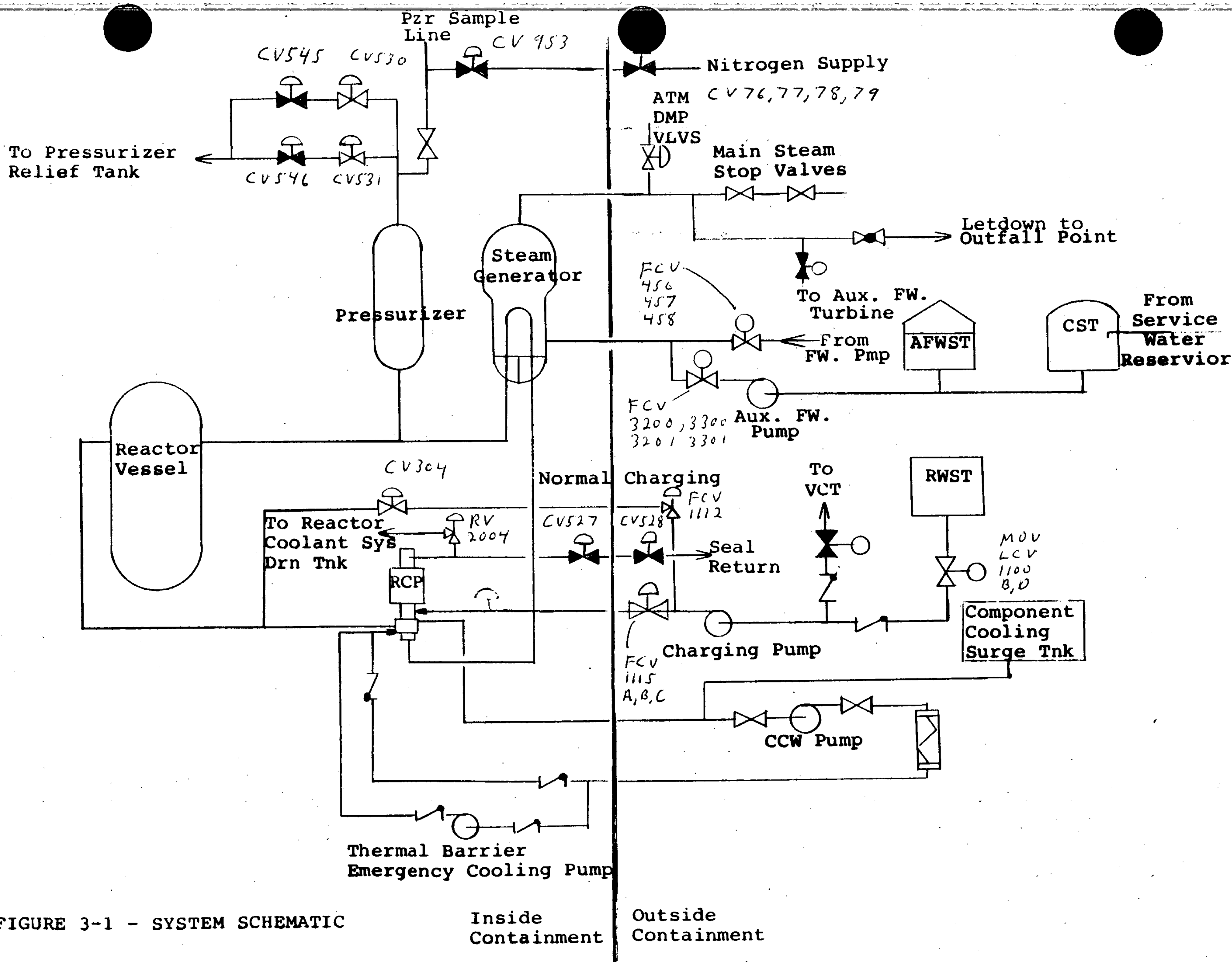

FIGURE 3-1 - SYSTEM SCHEMATIC

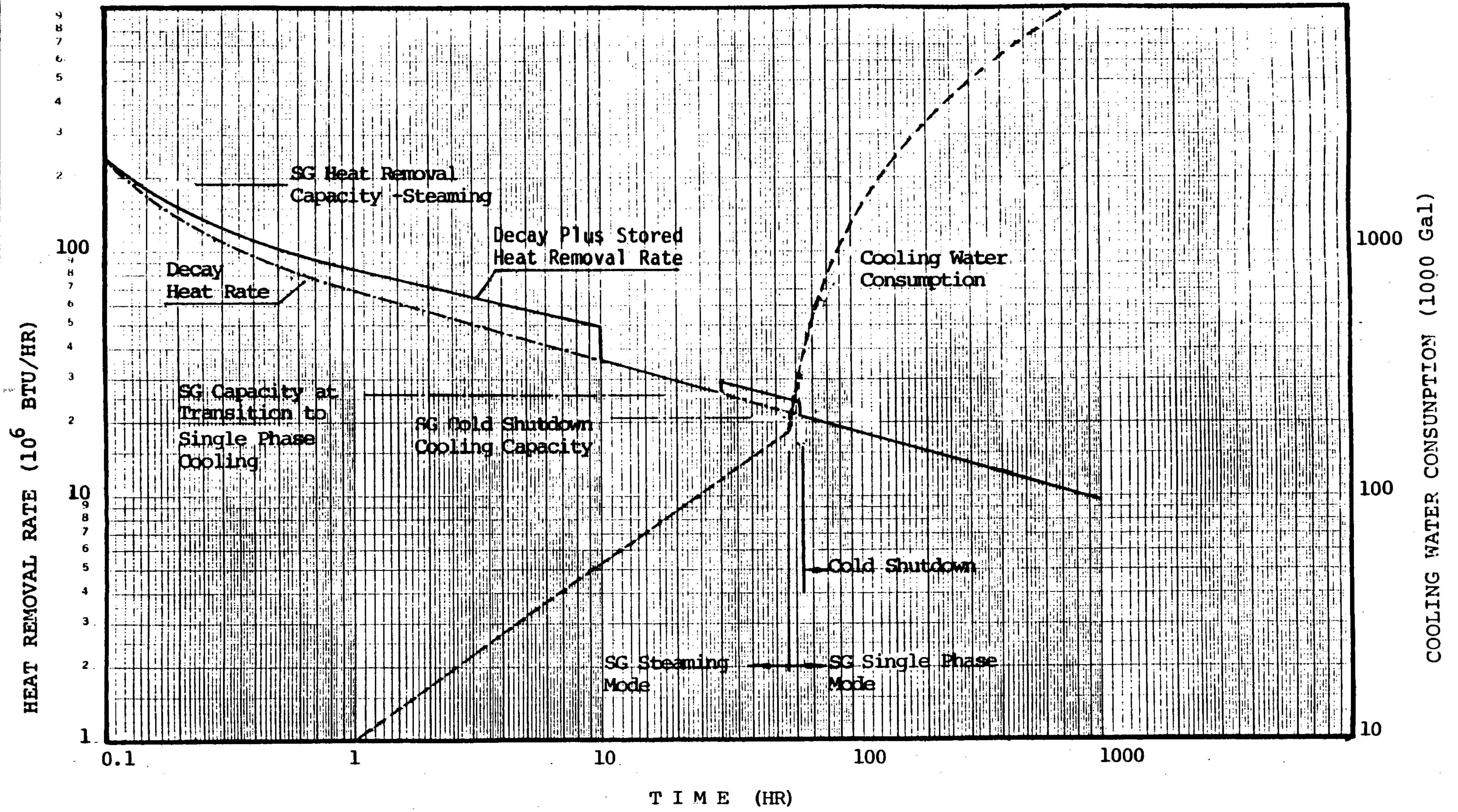

FIGURE 3-2 - PRIMARY SYSTEM COOLING REQUIREMENTS

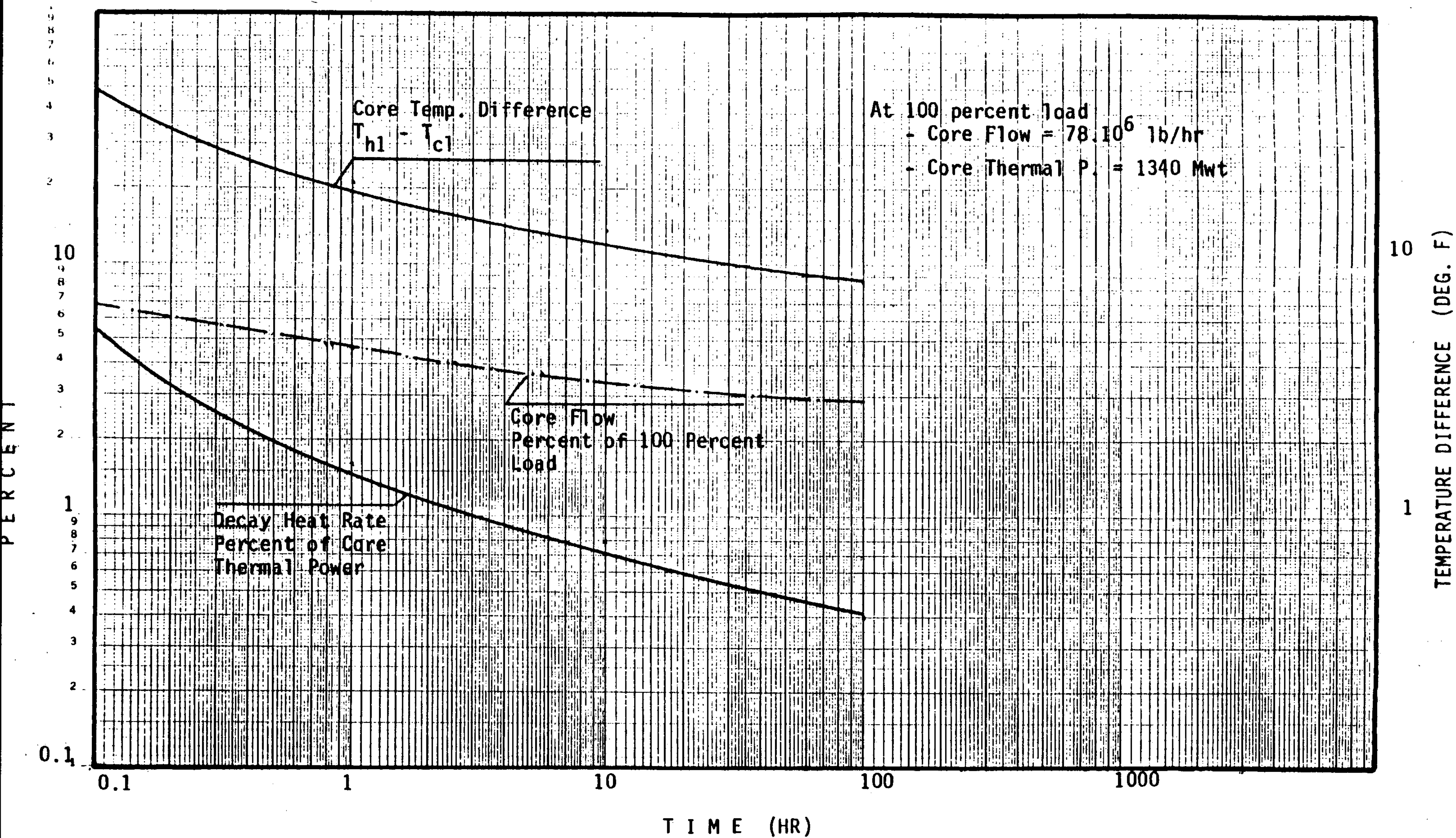

FIGURE 3-3 NATURAL CIRCULATION CORE FLOW RATE AND TEMPERATURE DIFFERENCE

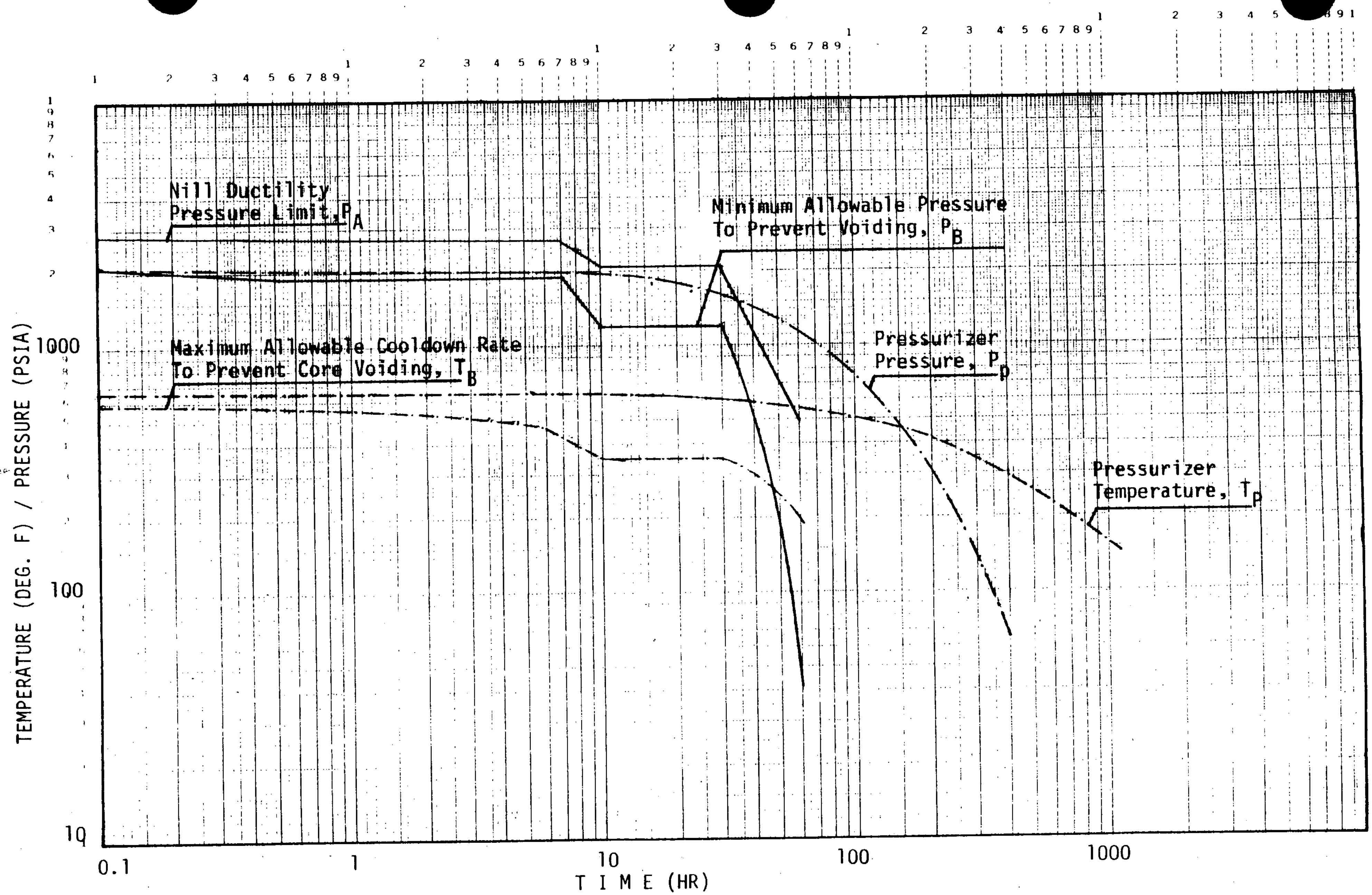

FIGURE 3-4 - PRIMARY SYSTEM COOLDOWN RATE LIMITATIONS

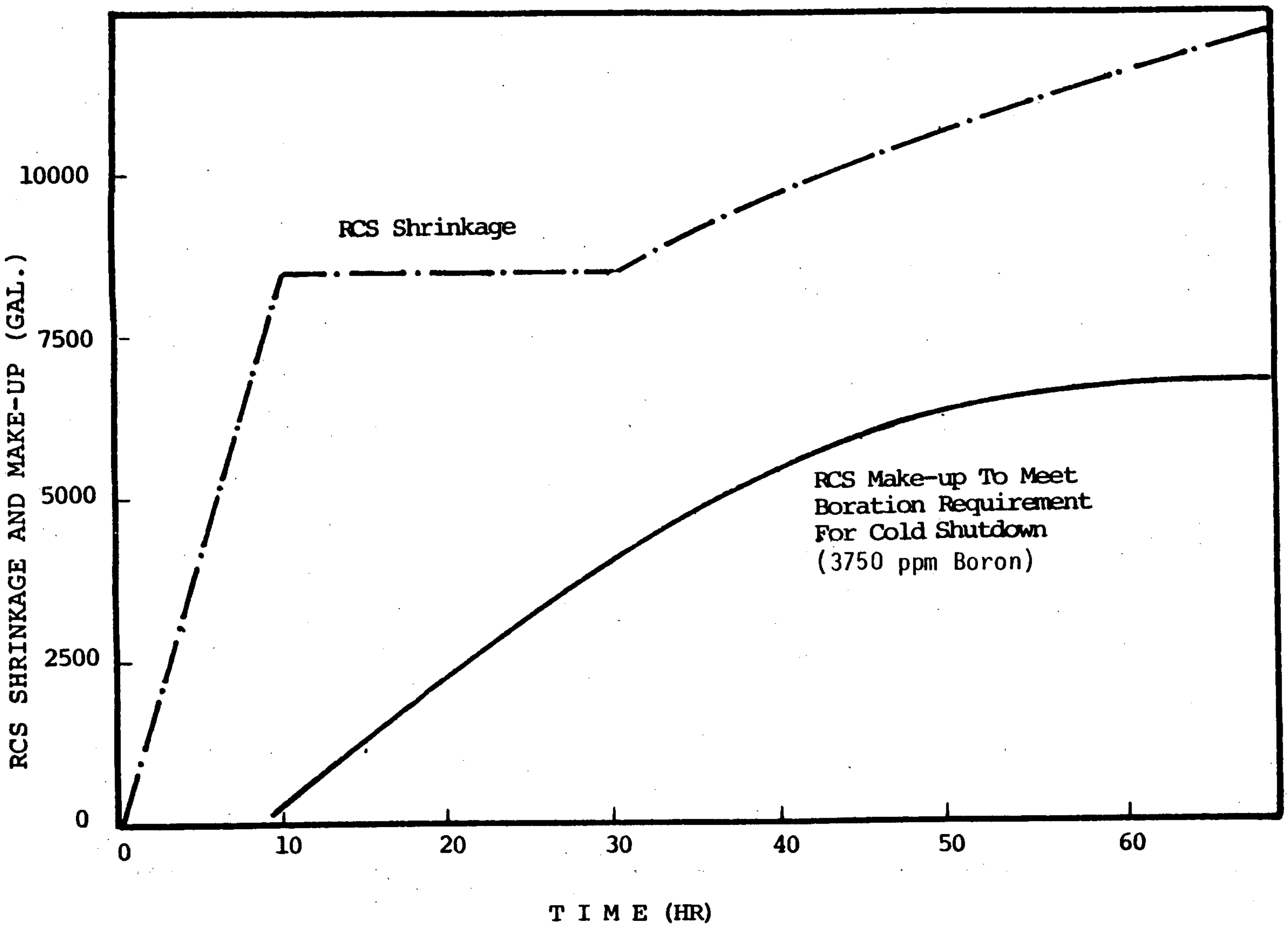

FIGURE 3-5 - PRIMARY SYSTEM MAKE-UP REQUIREMENTS

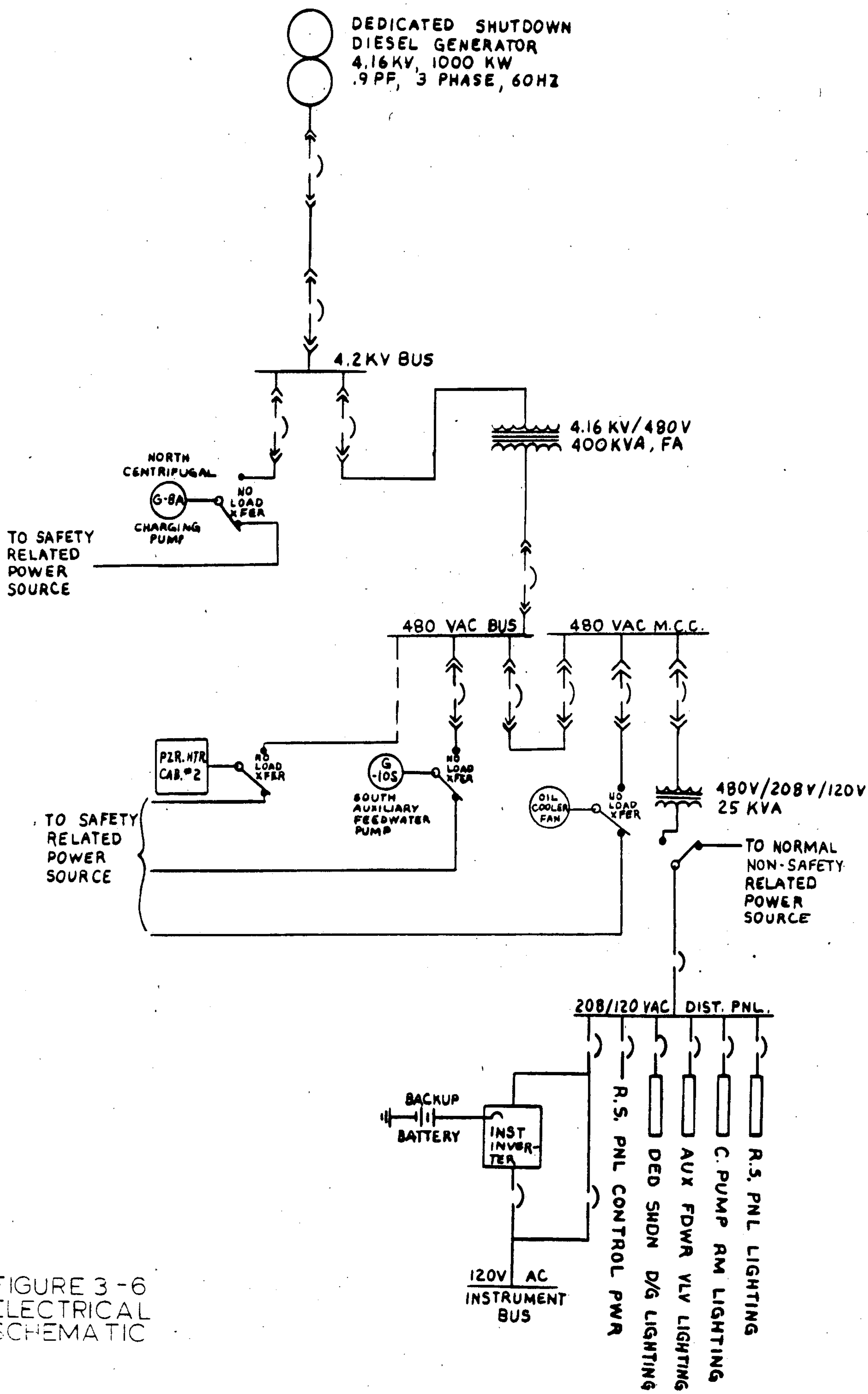

FIGURE 3-6
ELECTRICAL
SCHEMATIC

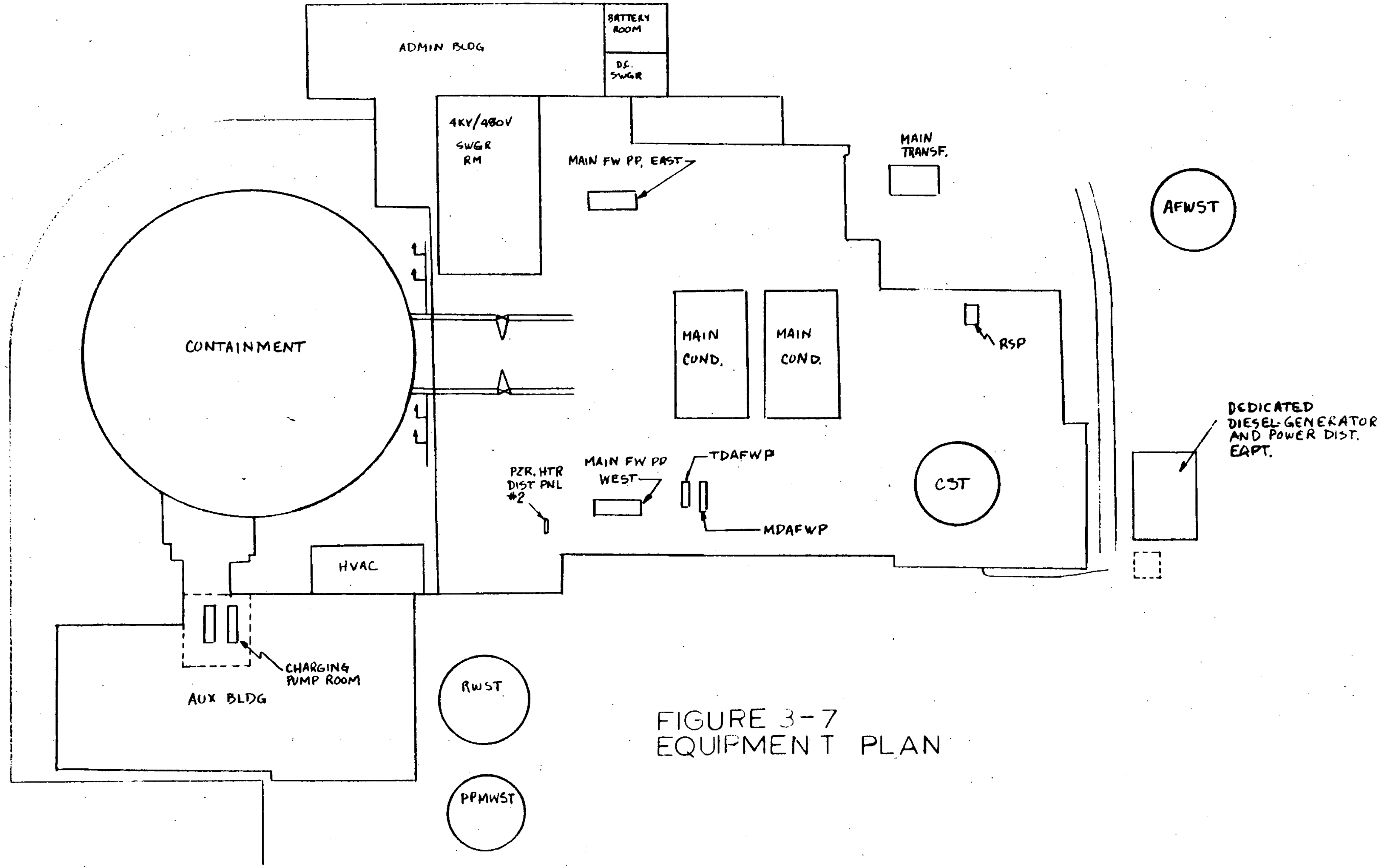

FIGURE 3-7
EQUIPMENT PLAN

4.0 PLANT MODIFICATIONS

The required plant modifications to implement the proposed safe shutdown system are discussed in the following sections. Refer to Figure 3-7 for a general plant layout.

4.1 Reactor Coolant System

There are only three reactor coolant system modifications required to make the system operable for the dedicated safe shutdown system. The first requires upgrading of the power supply to the solenoid valves for the Power Operated Relief Valve (CV-546) and Block Valve (CV-530) to allow the operator a positive means of controlling reactor coolant system pressure. As can be seen in Figure 3-4, the pressurizer pressure must be reduced to stay below the nil ductility transition temperature (NDTT) requirements.

The upgrade would require that the Solenoid Pilot Valves for CV-530 and CV-546 be provided with emergency power from the dedicated safe shutdown electrical system. A backup, safety-related nitrogen bottle supply is available for required valve operation. New control switches need to be added to the remote shutdown panel.

The second modification will provide the ability to add nitrogen to the pressurizer head for pressure control. This would be needed only if the operator lost the ability to maintain a steam bubble in the pressurizer at low RCS pressure. A nitrogen connection is already available outside containment through the test connection from the east sphere nitrogen test header. However, this would require that valve CV-953, which is inside containment, be opened. There are two alternatives for opening CV-953. First, CV-953 can be manually opened which would require containment entry. Since CV-953 is not required until after 72 hours, entry should be possible. The second alternative would be to provide the Solenoid Pilot Valve to CV-953 with emergency power and to hook up an emergency bottled nitrogen source or take credit for the emergency diesel-driven air compressor to allow valve operation.

The third modification would affect the pressurizer heater circuits for group D. A transfer switch will be installed at pressurizer heater cabinet #2 to make it possible to energize the heater in group D from the dedicated source. Some cable rerouting may be necessary. Also, depending on the fire postulated other actions may be necessary in the form of post-event casualty procedures.

4.2 Chemical Volume and Control System

Components in the CVCS are required in the dedicated safe shutdown system for reactor coolant inventory control and reactivity control. Makeup to the primary system is provided by the reactor coolant pump seal injection lines through FCV-1115A, 1115B and 1115C. These valves can be manually opened by failing the air supply to the valve operators. Seal injection flow can be balanced manually by throttling the upstream and downstream isolation valves around the flow control valves. This approach precludes the need to provide power to the flow controllers.

During initial cooldown, additional charging may be required through the normal charging line. FCV-1112 can be forced open manually or opened with air/nitrogen from a portable source so no modifications are necessary. No changes are required for CV-304, since the valve is designed to permit charging pump discharge pressure to overcome the closing force exerted by valve operator when in a failed condition.

In order to take credit for Charging Pump 8A, a transfer switch needs to be installed to provide emergency power from the dedicated safe shutdown electrical system for the charging pump and its bearing oil cooling fan. A preliminary assessment of the fire potential in the charging pump room indicates that a new spray shield/radiant heat shield be placed between Charging Pumps 8A and 8B. The shield would be seismically designed and mounted on angle iron supports so that they are easily removable for pump maintenance. The exact dimensions of the shield will be determined after examining the spray pattern from the 8B pump lubricating oil reservoir.

Extending from the spray shield should be a small curb (on the order of 1/2" high) to prevent pooling of sprayed or leaking oil from the 8B pump from draining to the 8A pump and vice-versa. A small curb should also extend from the existing shield between charging pump 8A and test pump G-42 for the same reason. A cable tray running along the north side of the room should be wrapped with Kaowool or Cera Blanket with a 1 1/2 hour fire rating to eliminate it as a potential fire source. Any required Appendix R exemption requests will be provided.

4.3 Auxiliary Feedwater System

The Auxiliary Feedwater Pump is already controlled from the Remote Shutdown Panel, which will be provided with emergency power. Therefore, the only modifications required to make it operable for the dedicated safe shutdown system is a transfer switch to provide the auxiliary feedwater pump G-10S and its auxiliaries with emergency power from the dedicated safe shutdown electrical equipment. FCV's 3300, 2301, 3301 and 2300 can be manually operated.

4.4 Atmospheric Steam Dump Valves

The steam dump valves CV-76 through -79 are required for decay heat removal in the dedicated safe shutdown system. They are already controlled from the remote shutdown panel, which will be provided with emergency power from the dedicated safe shutdown electrical equipment. Air to operate the dump valves is already provided by an emergency diesel-driven air compressor.

4.5 Steam Generator Feedwater "Letdown"

When the steam generators are used in the single phase cooling mode (approximately 72 hours after the fire), the steam line to the turbine driven auxiliary feed pump will be used to letdown the auxiliary feedwater. The manual valve downstream of CV-113 as well as the 24" manual isolation valves on the main steam lines outside containment will be manually closed prior to initiating this cooling mode. For feedwater letdown during the single-phase mode of operation, a piping tee, manual valve, and manifold need to be added just upstream of CV-113. The manifold would provide a series of connections to attach fire hoses. Calculations will have to be performed to determine if the piping and supports can withstand approximately 20 ft/sec fluid velocity.

4.6 Electrical System

The modifications to the electrical system for the dedicated safe shutdown system are described in Section 3.4 of this report. Studies will have to be performed to determine the most economical method of transferring fuel from the emergency diesel generator fuel oil tanks to the "abandoned" 2000 gallon diesel fuel storage tank. The optimum design for the electrical system will be determined during Phase II to locate equipment and route cable. This will be done in conjunction with a fire hazards analysis of affected plant areas.

Emergency 8-hour lighting (battery-powered) will have to be provided for all required equipment in accordance with Appendix R requirements.

4.7 Instrumentation and Control

Instruments taken credit for in the dedicated safe shutdown system are listed in Table 3-1. Only four new instruments have to be added. Routing of power and control cables for the instrumentation will be finalized after a fire hazards analysis.

4.8 Auxiliary Systems

Taking credit for opening certain valves may require the use of backup air from the diesel driven emergency air compressor or the use of nitrogen. In all cases, credit will first be taken for existing equipment and manual actions. If this cannot be done, appropriate connections to the air/nitrogen supply lines will be made to make use of nitrogen bottles.

5.0 CONCLUSIONS

5.1 System Feasibility

5.1.1 Technical

The proposed system satisfies the requirements of Section III.L of 10CFR50 Appendix R as a "dedicated" safe shutdown system. This system can safely shutdown and cooldown the plant within 72 hours assuming a loss of all normal, emergency and offsite A.C. power. Existing plant equipment, which is assumed as part of the "dedicated" system, is not disabled by any Appendix R fires which also disable the plant normal and emergency, power systems. Therefore, SONGS I can comply with the safe shutdown requirements of Appendix R.

The proposed system can be placed in operation in a timely fashion to establish positive control over:

- Decay Heat
- Reactivity
- Primary Coolant Inventory
- Primary Coolant Pressure

The number of operators required for operation of the proposed system is within normal shift complements. Containment access is not required within 72 hours or until cold shutdown has been achieved.

Boron can be injected to establish and maintain a 5% shutdown margin without reliance on the Boric Acid Storage Tank, Mixing Tank, Injection or Transfer systems.

Water is available from onsite sources to achieve cold shutdown in 72 hours and maintain cold shutdown for at least 9 days.

The "dedicated" electrical system can provide A.C. power to required system components indefinitely. Diesel fuel is available on site for up to 1000 hours of full power operation.

Credit has been taken for one of the existing diesel-driven air compressors. This compressor can supply sufficient air for all required valve operations.

A positive means of pressure control exists during all phases of plant shutdown and cooldown. In addition, extended operation at cold shutdown using a nitrogen bubble in the pressurizer is achievable using onsite equipment and personnel. The proposed method of pressure control will preclude local boiling and void formation during hot shutdown, cooldown and extended operation at cold shutdown.

5.1.2 Schedule

The proposed system can be designed, procured, installed and tested prior to the end of the 1986 refueling outage. The safety-related equipment is limited to transfer switches, instrument power supplies and isolation devices. No excavation or major structural modifications are required. Only one minor piping modification is anticipated.

Modifications to the existing electrical distribution system, to comply with the physical and electrical separation requirements of Appendix R, are limited to the following:

- 2 valves in containment
- Charging pump room
- Aux feed pump
- Remote shutdown panel
- Instruments outside containment
- Non-safety related power, instrumentation and control cables

Therefore, the 4KV and 480V switchgear rooms will not be affected.

5.1.3 Cost

The proposed system makes maximum use of existing equipment and therefore reduces major equipment purchases. The proposed electrical system is non-safety related with the exception of the safety-related transfer switches (manual). The expected costs of the proposed system (engineering, procurement and construction) is 5 million dollars.

5.2 Licensability

The proposed system will satisfy the dedicated safe shutdown requirements of Appendix R. The NRC staff has previously reviewed this approach for the Yankee Atomic Electric Company Rowe station and accepted it in principal.

The only licensing issue unique to this design is use of transfer switches for safety-related equipment. The design of the electrical system will ensure that the normal and emergency plant A.C. systems are not affected by the "dedicated" system. Manual safety-related transfer switches will ensure electrical separation of safety and non-safety buses. The "dedicated" electrical system will only be energized after a loss of normal, emergency and offsite power.

The single phase heat transfer approach for cold shutdown is technically defensable as discussed in Section 3.0 and Appendix A.

In summary, this system should be acceptable to the staff as an alternative to the previously recommended system in the Engineering Report on Safe Shutdown Capability Relating to Appendix R of 10CFR50. The approach is technically and operationally feasible and meets the applicable schedular constraints.

6.0 REFERENCES

1. Title 10, Code of Federal Regulations, Part 50, Appendix R, Fire Protection Program for Nuclear Power Facilities Operating prior to January 1, 1979.

2. Letter, K. P. Baskin, SCE, to D. M. Crutchfield, NRC, dated June 30, 1982, "Fire Protection Program Review, San Onofre Nuclear Generating Station Unit 1" and the attached "Engineering Report on Safe Shutdown Capability Relating to Appendix R of 10CFR50", dated June, 1982.

3. Yankee Atomic Electric Company letter to USNRC, dated 6/9/83, "Cooldown Capability of Proposed Integrated Shutdown Systems", J.A. Kay, YAEC, to Dennis M. Crutchfield, NRC.

4. "St. Lucie Cooldown Event Report", Attachment to American Electric Power to NRC Letter No. OG-57, Dated April 20, 1981, from Robert W. Jurgensen, Westinghouse Owners Group, to Paul S. Check, NRC.

5. San Onofre Nuclear Generating Station Unit 1, Technical Specifications.

6. Staff Position Paper to Roger J. Mattson from L. S. Rubenstein entitled "Statement of Staff Position Regarding Source Range Flux, Reactor Coolant Temperature, and Steam Generator Pressure Indication to Meet Appendix R, Alternate Capability", dated January, 1983.

APPENDIX A

Calculation No: TH1 Dedicated Safe Shutdown (Rev. 0)

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: TH1

Title: DEDICATED SAFE SHUTDOWN SYSTEM

Client: SCE Project: SONGS 1

Job No: 0310-027-1373

Design Input/References: STATED WITHIN

Assumptions: STATED WITHIN

Method: STATED WITHIN

Remarks:

REV. NO.	REVISION	APPROVED	DATE
0	ORIGINAL	Gary A. Weber	4/13/84

EDS 0008 5/78

TABLE OF CONTENTS

1.0 INTRODUCTION

The purpose of this calculation is to determine the feasibility of establishing and maintaining cold shutdown at SONGS 1 by using one or more steam generators in conjunction with a source of cooling water, such as the Main or Auxiliary Feedwater System for the removal of heat from the Reactor Coolant System. If shown to be feasible for SONGS 1, then the design of a dedicated safe shutdown system to meet requirements of 10CFR50 Appendix R would not be required to include provisions for RCS cooldown by way of forced circulation of the primary coolant through the Residual Heat Removal System

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IMPELL CORPORATION

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CALC NO 7H1

2.1 Approach

Mass and energy balance calculations are performed for the major primary and secondary system components which are essential for achieving and maintaining the cold shutdown. Consideration is given to constraints and limitations imposed by:

- Technical specifications
- Pressurizer steam bubble
- Possibility of voiding in the reactor vessel
- Available inventory of:
  - condensate
  - seal water make up
  - boric acid make-up
- Maintenance of an adequate natural circulation for the transport of the decay heat and stored thermal energy from the primary system

The calculation has combined these constraints to determine the acceptable and achievable cooldown rates using the steam generators as the only heat sink.

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JOB NO 0310-027-13[illegible]
CALC NO 7H-1

2.2 ASSUMPTIONS

The major assumption used in this calculation are:

1. The reactor is initially at full power

2. At time equals zero:
   - the reactor is tripped with all rods inserted
   - reactor coolant pumps are tripped
   - pressurizer heaters and sprays are tripped and are no longer available
   - Letdown is isolated
   - turbine is tripped
   - decay heat removal is initiated via the steam generators and atmospheric dump valves

3. At time greater than zero:
   - The RCS is intact except for reactor coolant pump seal leakage
   - The RCS pressure, temperature and pressurizer level vary from their normal initial values as a function

of mass and heat addition/extraction

- The charging system is making up through the reactor coolant pump seals and either a normal or safety injection flow path to make-up for mass losses due to seal leakage and volume contraction due to cooldown.
- The steam generator secondary side is isolated, except for cooling water supply and atmospheric dumps
- Residual Heat Removal system is not available
- The feed water supply line and the blowdown line are both available for admitting the cooling water into the active steam generator(s)
- Boron injection is provided from the Refuelling Water Storage Tank which has a Boron concentration of 3750 ppm.

3.0 ANALYSIS

In the following sections the parameters that are essential to achieving cold shutdown are calculated. These calculations are performed based on the assumptions stated in the preceeding section.

A schematic of the system being considered is given in Figure 3-1. Rather than attempting to present the full details, this figure presents interconnection of basic components and the coolant flow.

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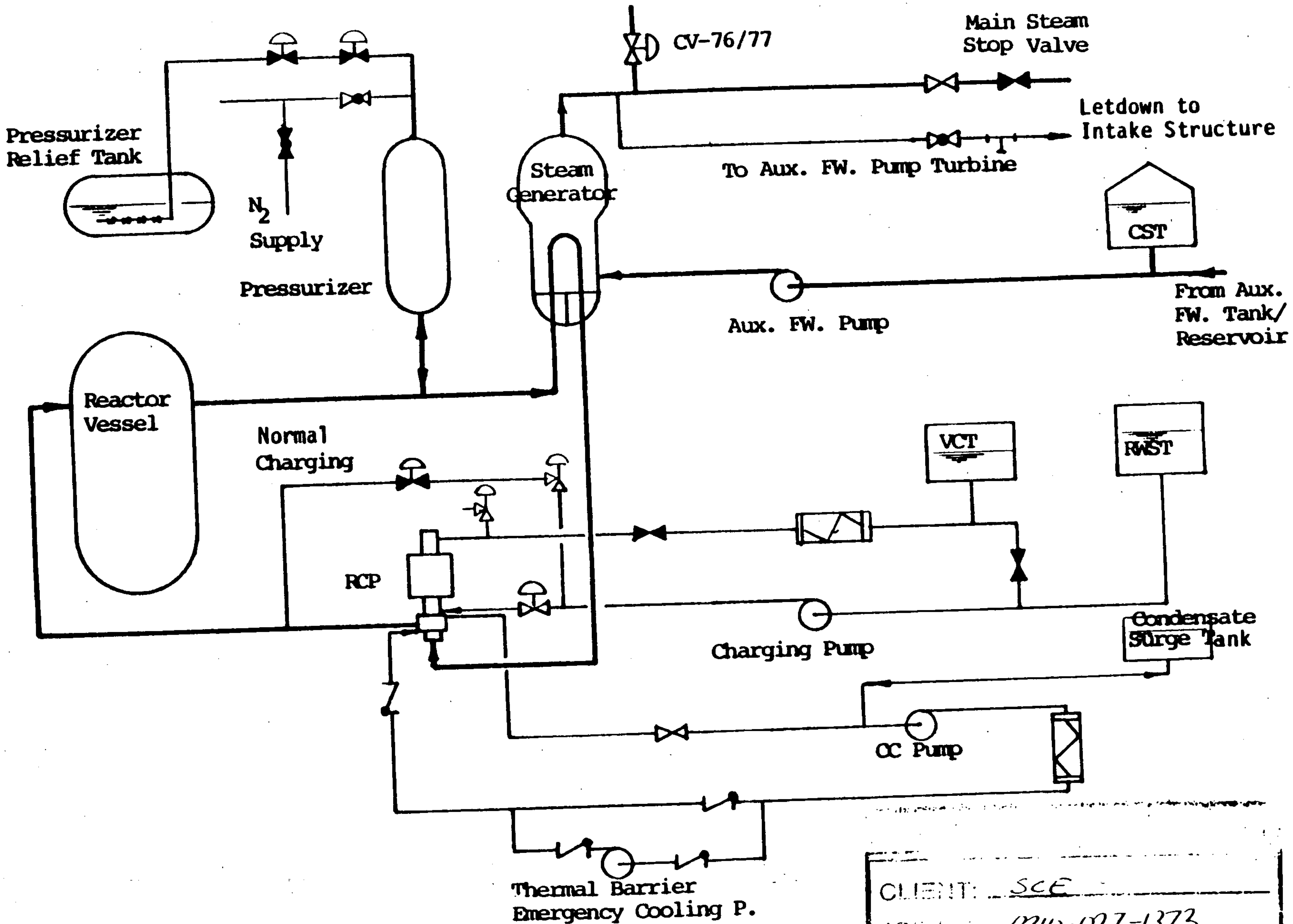

FIGURE 3-1 - SYSTEM SCHEMATIC

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JOB NO.: 0310-027-1373	
CALC/PROB NO.: TMI	
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3.1 Decay Heat Rate

The decay energy release following the reactor trip was obtained from Reference 2 and is plotted in Figure 3-2 on the following page. The integrated decay energy release is also shown on this figure. The integrated decay energy release has been obtained from Reference 2.

Time (hr.)	Decay Heat (10^6 Btu/hr)	Interval Avg. (10^6 Btu/hr)	Integrated Decay Heat (10^6 Btu)
1/6	248		
1	73	94 66	93.8
2	58.5	53	
4	48.2	47	
5	45.4		
8		42	426
10	37.9		
24		34	961
25	29.1	28	
32	27.1		
36		25.3	1290
48			1534
50	23.5	21	
100	18.5	17	
150	15.7		
168			3760

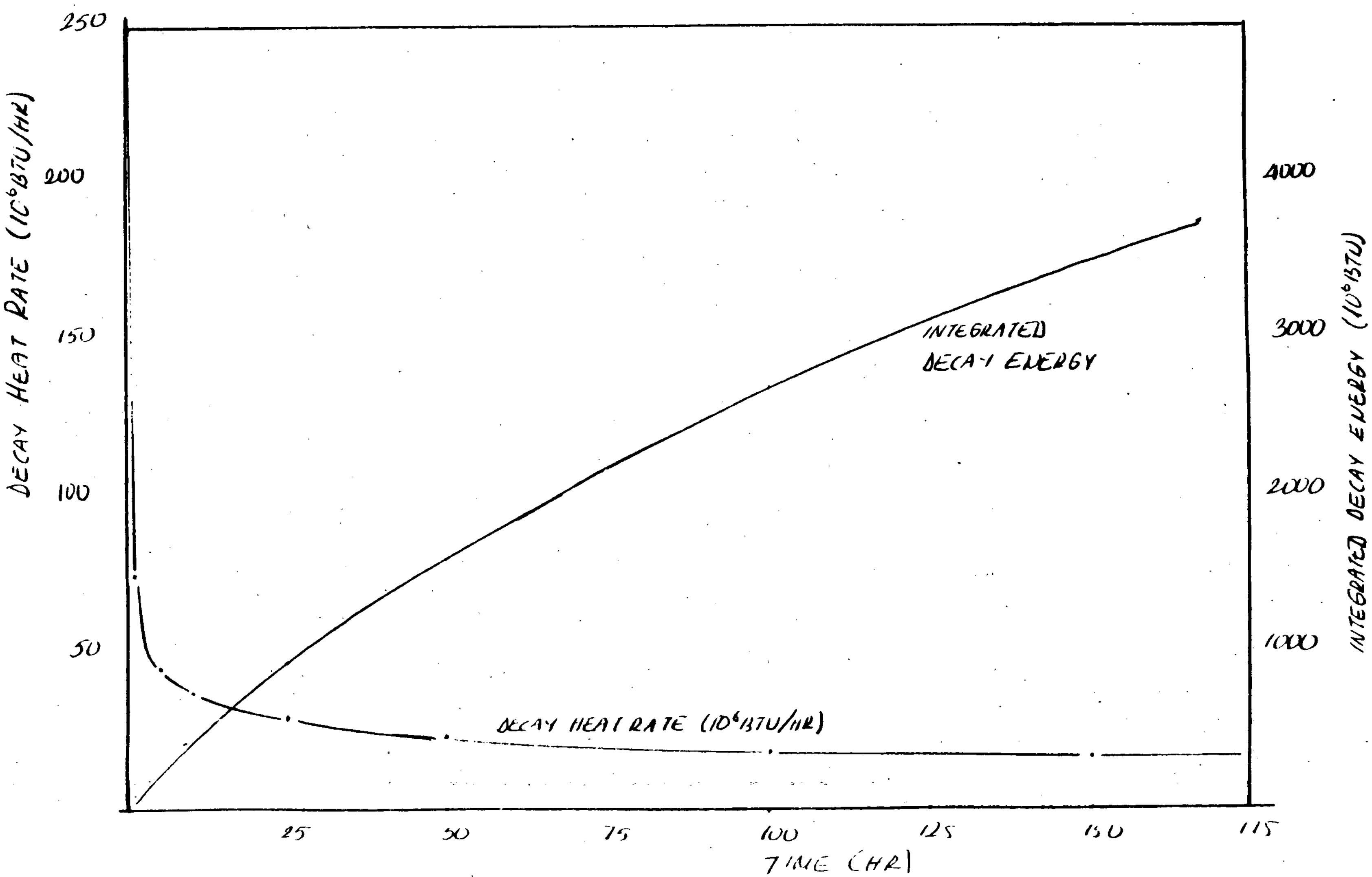

FIGURE 3-2 – DECAY HEAT TRANSIENT
(FOR TIME BEYOND 175 HRS SEE FIGURE 3-6)

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3.2 Stored Heat

In order to achieve - cold-shutdown the steam generators must remove not only the decay heat but also the stored head in the primary system. This amounts to,

$$q'_{ST} = (M_w C_w + M_S C_S) \frac{dT}{dt} = C \frac{dT}{dt}$$

where,

M = Mass (lb)

C = Specific heat, Btu/lb-°F

q'_{ST} = Stored heat removal rate

from Reference 3, p:17

$M_w = 3\times10^5$ lb

$M_S = 2\times10^6$ lb

Using,

$C_w = 1$ Btu/lb

$C_S = 0.11$ Btu/lb-°F

$$C = 3\times10^5\times1 + 2\times10^6\times0.11 = .52\times10^6 \text{ Btu/°F}$$

$$q'_{ST} = .52\times10^6 \frac{dT}{dt}$$

3.3 Upper Head Voiding

During the natural circulation cooldown, the reactor upper head region is relatively stagnant and cools down at a much slower rate than the rest of the system. As a consequence of this void may form in the upper head region if cooldown and depressurization rates are not properly selected.

The possibility of voiding in the upper head has been investigated by Westinghouse and the findings and recommendations are given in Reference 1. Based on the conservative assumptions that:

- The upper head is initially at the hot leg temperature,
- The control rod drive mechanism (CRDM) fans are not available to assist cooling of the head externally,

the referenced document predicts an upperhead cooldown rate of 10°F/hr and recommends that the primary system cooldown rate should not exceed 25°F/hr in order to prevent void formation. The 25°F/hr cooldown rate is furthsubjected to constraints set by the subcooling requirements.

The recommended cooldown rate of Reference 1 is illustrated in Figure 3-3 until the point where RHR system can be put into operation. If the natural circulation cooldown is to be continued it must be realized that the cooldown rate is limited by the upper head cooldown rate which is approximately 10°F/hr according to Reference 1. In this study beyond 30th hour cooldown has been continued at approximately 5°F/hr until cold shutdown is achieved.

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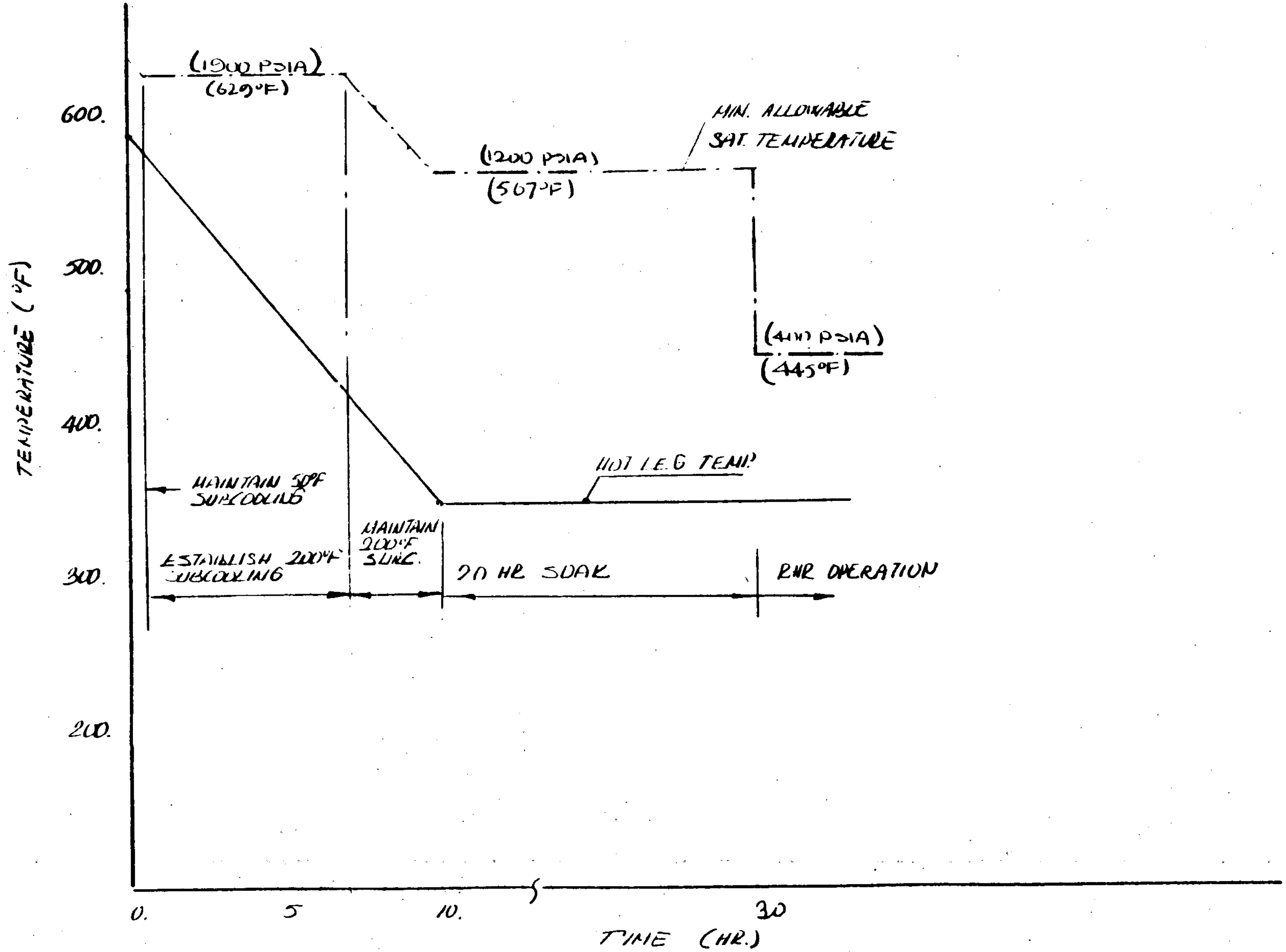

FIGURE 3-3 - RCS COOLDOWN RATE TO PREVENT VOIDING

3.4 Pressurizer Cooldown Rate

The pressurizer cooldown rate is important for maintaining the proper primary system pressure which in turn controls the pressurizer steam bubble, reactor vessel upper head voiding in nil ductility requirements. The cooldown rate is determined by assuming that:

- Pressurizer water and steam are in thermodynamic equilibrium,
- Pressurizer heaters, spray and relief valves are not available
- Cooling due to the in-surge at the hot leg is negligible.

The first two assumptions are well justified. The third assumption may become invalid depending on when during the shutdown and how much in-surge takes place.

With these assumptions and the pressurizer data as given on the following two pages the cooldown rate is determined from the energy balance for the pressurizer:

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$$\frac{d}{dt}(U) = Q'$$

where,

U = Internal energy of the pressurizer assembly, Btu
Q' = Heat loss rate, Btu/hr

The heat loss rate Q' is made up from the following components:

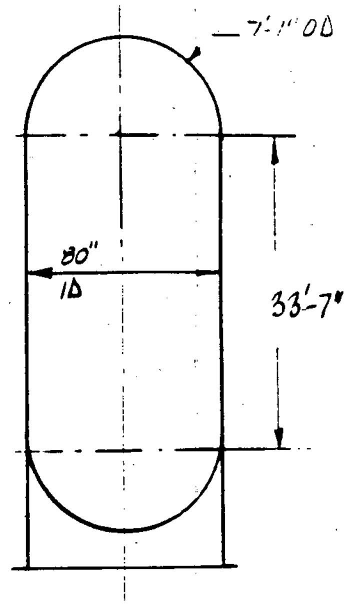
$$Q' = q_i'' A_i + q_s' P_s + Q_m'$$

where,

q_i'' = heat loss per unit area of the insulated portion - excluding the skirt (Btu/hr-ft²)
A_i = Area corresponding to q_i'' (ft²)
q_s' = heat loss per unit length of the skirt, (Btu/hr-ft)
P_s = perimeter of the skirt, (ft)
Q_m' = miscellaneous heat losses, Btu/hr

These components are determined on the following pages

Pressurizer Dimensions / parameters (Ref. 7, 19)



Total volume : 1300 ft^3

Water Vol. : 630 ft^3 **

Material : Steel

$k = 31$ Btu/hr-ft-°F

$\rho = 490$ lb/ft^3

$c = 0.11$ Btu/lb-°F

Insulation : 4" Glass wool (1.5 lb/ft^3)

(See p: 20 for k)

Conditions : $P = 2100$ psia *

$T = 643$°F

Thickness (Ref. 7) : Beltline = 5-7/16" (5.45")

Upper head = 3-1/4" (3.25")

Lower head = 2-5/8" (2.6")

---

* At $P = 2100$ psia

$T = 643$°F

$\rho_f = 38.2$ lb/ft^3 $\quad h_f = 684$ Btu/lb

$\rho_g = 5.7$ lb/ft^3 $\quad h_g = 1131$ Btu/lb

** According to Reference 11,

Water Volume at Minimum Level = 230 ft^3

Water Volume at Nominal Level = 630 ft^3

Water Volume at High Al. level = 670 ft^3

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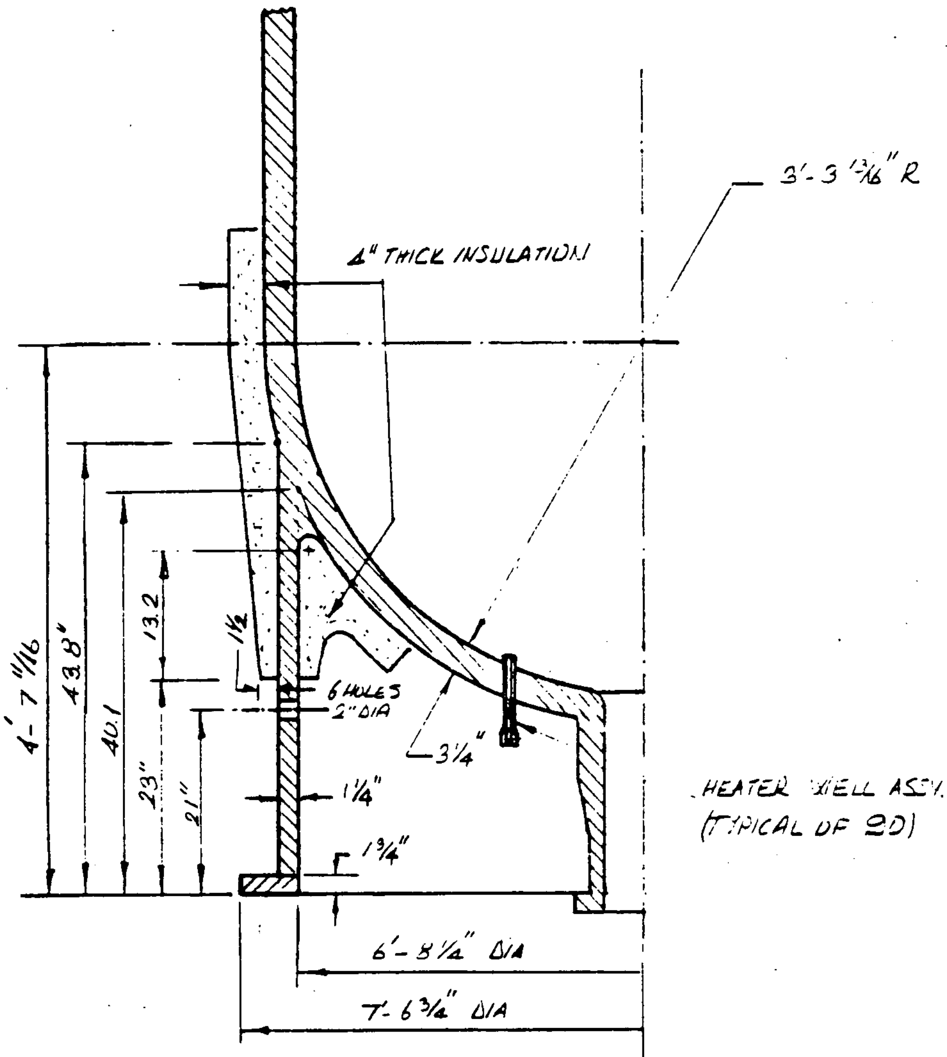
Source: Ref. 10



Pressurizer Skirt and Insulation Details

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Skirt Length

$$x^2+y^2 = \left(3\times12+3+\frac{13}{16}+3+\frac{1}{4}\right)^2 = 43.06^2$$

$$x = \frac{1}{2}\left(6\times12+8+\frac{1}{4}\right) = 40.13$$

$$y = (43.06^2 - 40.13^2)^{1/2}$$

$$= 15.6 \text{ in}$$

$$l = 4\times12+7+11/16 - 15.6$$

$$= 40.1 \text{ in}$$

Length from the 7/8" R fillet

$$x = \frac{1}{2}\left(6\times12+8+\frac{1}{4}\right) - 2\times 7/8$$

$$= 38.4 \text{ in}$$

$$y = (43.06^2 - 38.4^2)^{1/2}$$

$$= 19.5 \text{ in}$$

$$l = 4\times12+7+11/16 - 19.5$$

$$= 36.2 \text{ in}$$

Insulated length = 13.2 in

Uninsulated length = 27 in

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Insulation Material (Source : Ref. 20)

Material : Owens/Corning Fiberglass Insulation
Thermal Conductivity, k

Temp. (°F)	k Btu/hr.ft.°F	k* (2nd order)	k* (1st order)
100	.021	.021	.017
200	.026	.026	.026
300	.033	.033	.035
400	.040	.041	.044
500	.052	.051	.053
600		.064	.062
650		.070	.067

* calculated using a second order polynomial fit to the data under column 2.

$k = 8.93\times10^{-8}T^2 + 2.23\times10^{-5}T + .0178$ (2nd order)

$k = 8.21\times10^{-3} + 9.04\times10^{-5}T$ (1st order)

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Heat Loss Through 4" Insulation, q_i

Heat losses through the insulation have been calculated based on the following assumptions:

1. Pressurizer wall temperature is the same as the pressurizer bulk fluid temperature.
2. The outside film coefficient (including the radiation effects) is 1. Btu/hr-ft²-°F.
3. Heat transfer through the insulation can be approximated as a quasi-steady process.

Based on these,

$$\frac{d}{dx}\left(k\,\frac{dT}{dx}\right) = 0. \qquad (1)$$

Using,

$k = aT + b$ (with $a = 9.04 \times 10^{-5}$, $b = 8.21 \times 10^{-3}$ on p: 20)

$$\frac{a}{2}T^2 + bT = Cx + d$$

Using the boundary conditions

$x = 0, \quad T = T_0$

$x = t, \quad k\,\dfrac{dT}{dx} = -h\,(T - T_\infty)$

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from the first boundary condition

$$d = \frac{a}{2} T_0^2 + b T_0$$

from the second,

$$c = -h(T_s - T_\infty)$$

substituting back,

$$\frac{a}{2} T^2 + bT = -h(T_s - T_\infty)x + \frac{a}{2} T_0^2 + bT_0 \qquad (2)$$

since,

$$T = T_s \quad at \quad x = t$$

$$\frac{a}{2} T_s^2 + bT_s = -h(T_s - T_\infty)t + \frac{a}{2} T_0^2 + bT_0$$

or

$$T_s^2 + \left(\frac{2b}{a} + \frac{2ht}{a}\right) T_s - \left(\frac{2htT_\infty}{a} + T_0^2 + \frac{2bT_0}{a}\right)$$

which yields,

$$T_s = -\left(\frac{b}{a} + \frac{ht}{a}\right) + \sqrt{\left(\frac{b}{a} + \frac{ht}{a}\right)^2 + \left(\frac{2htT_\infty}{a} + T_0^2 + \frac{2bT_0}{a}\right)} \qquad (3)$$

and the heat loss is given by

$$q'' = h(T_s - T_\infty) \qquad (4)$$

Validity of equations (3) and (4) are checked against Reference 20 Table on p:20. Following is comparison of this check

Ambient temperature, $T_\infty = 80°F$
Insulation thickness, $t = 4$ inches
film coefficient, $h = 1$ Btu/hr-ft²-°F
$a = 9.04 \times 10^{-5}$ Btu/hr-ft
$b = 8.21 \times 10^{-3}$ Btu/hr-ft-°F

Operating Temperature (Deg. F)	Heat Flux, q'' (Btu/hr-ft²-°F) Ref. 20	Equations 3&4
300	16	16
350	21	21.3
400	26	27.3
450	32	34
500	39	41.2
550	47	49.1
600	56	57.6
650	65	66.8

The maximum deviation is six percent.

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Equations (3) and (4) when applied to the conditions of the pressurizer (T_∞ = 120°F) yield:

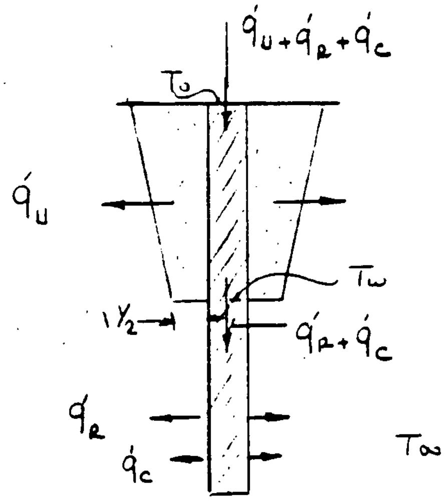
Operating Temp. (Deg. F)	Heat Flux, q_i'' (Btu/hr.ft²) 2" Insul.	3" Insul.	4" Insul.
150	3.3	2.3	1.7
200	9.7	6.7	5.2
250	17.4	12.	9.2
300	26.2	18.1	13.9
350	36.2	25.1	19.2
400	47.3	32.8	25.1
450	59.5	41.4	31.7
500	72.8	50.7	38.9
550	87.3	60.9	46.7
600	102.8	71.8	55.1
650	119.3	83.6	64.2

Heat Losses Through the Skirt, $\dot{q}_o$

The skirt is considered as a rectangular fin of uniform crossection composed of two parts:

1. Insulated upper section
2. Uninsulated lower section

The system configuration is illustrated below



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Upper Portion

The upper portion dissipates heat laterally through the insulation. It also conducts axially providing a heat flow path for the uninsulated lower portion. The conduction mode will be considered in conjunction with the lower portion.

The convection losses can be estimated by assuming using a linear temperature profile and a linearly varying insulation thickness. Since in reality the temperature along the skirt varies exponentially this assumption results in overestimation of the heat losses.

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$$q'_{cu} = \int_0^{l} U \cdot (T - T_\infty)\, dx$$

$$U = \left(\frac{1}{h} + \frac{t_i}{k_i}\right)^{-1}$$

where,

$h = 1\ Btu/hr\text{-}ft^2\text{-}°F$

$k_i = 0.067 \times 12\ Btu\text{-}in/hr\text{-}ft^2\text{-}°F$

$t_i = 4 - \frac{4 - 1.5}{20.8}(x + 6.8)$ (from Fig. on P.18)

$= 3.2 - 0.12x$

Therefore,

$$U = \left(1 + \frac{3.2 - 0.12x}{12 \times 0.067}\right)^{-1}$$

$$= (5 - 0.15x)^{-1}$$

Similarly,

$$T - T_\infty = T_o - \frac{T_o - T_w}{(14/12)}x - T_\infty$$

$$= (T_o - T_\infty) - \frac{12}{14}\cdot(T_o - T_w)\cdot x$$

$$= (T_o - T_\infty) - 0.86\,(T_o - T_w)\,x$$

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Substituting into the integral,

$$q'_u = \int_0^{14/12} \left[\frac{T_o - T_\infty}{5 - 0.15x} - 0.86 (T_w - T_\infty) \cdot \frac{x}{5 - 0.15x} \right] dx$$

$$= (T_o - T_\infty) \left[\frac{1}{-0.15} \ln(5 - 0.15x) \right]_0^{14/12} - 0.86 (T_w - T_\infty) \left[\frac{x}{-0.15} - \frac{5}{0.15^2} \ln(5 - 0.15x) \right]$$

$$q'_u = \underline{0.238 (T_o - T_\infty) - 0.12 (T_w - T_\infty)} \quad Btu/hr\text{-}ft\text{-}^\circ F$$

Using the values for T_w calculated for the lower portion, q'_u is tabulated in the Table on page 32.

Lower Portion (uninsulated)

The uninsulated lower portion dissipates heat to the surrounding by radiation and convection. By considering the skirt as a rectangular fin with uniform crossection, and by defining an equivalent surface heat transfer coefficient this problem can be solved as a standard convective fin problem. The equivalent heat transfer coefficient is determined as follows:

$$h_e (T-T_\infty) = h (T-T_\infty) + \sigma \epsilon (T^4 - T_\infty^4)$$

$$= h (T-T_\infty) + \sigma \epsilon (T-T_\infty)(T^3 + T^2 T_\infty + T T_\infty^2 + T_\infty^3)$$

$$h_e = h + \sigma \epsilon (T^3 + T^2 T_\infty + T T_\infty^2 + T_\infty^3)$$

with,

$h = 1$ Btu/hr-ft²-°F

$\sigma = 0.1714 \times 10^{-8}$ Btu/hr-ft²-°R⁴ , $\epsilon = 0.9$

$T_\infty = 120 + 460 = 580°R$

and

$(120+460) \leq T \leq (653+460)$

The maximum and minimum values of h_e are:

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$h_e(max) = 5.1$ Btu/hr-ft²-°F

$h_e(min) = 2.2$ Btu/hr-ft²-°F

The heat loss per unit length of the skirt is given by (Reference 1? p: 3-113)

$$q'_L = \sqrt{h_e k \delta}\left[2(\tanh mL + \sqrt{Bi})/(\sqrt{Bi}\tanh mL + 1)\right](T_w - T_\infty)$$

where,

δ = half thickness, $1.25/2\times12$ ft

$m = (h/k\delta)^{1/2}$

$B_i = h\delta/k$

L = length, $27/12 = 2.29$ ft

For the range of h_e considered, the expression inside the bracket varies from 2.0 to 1.9. To simplify the mathematics, therefore, q' can be conservatively taken as:

$$q'_L = 2\sqrt{h_e k \delta}\,(T_w - T_\infty)$$

The equivalent heat transfer coefficient, h_e,

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will be evaluated at the fin base temperature T_w. This will result in overestimation of the heat losses.

In solving the heat dissipation, q', it must be realized that it is transferred through the insulated upper portion in axial conduction mode. Therefore

$$q'_l = (2\delta \times 1) \cdot \frac{T_o - T_w}{l} \cdot k$$

$$= (1.25/12) \times \frac{T_o - T_w}{(13.2/12)} \times 31$$

$$= 2.94\ (T_o - T_w)$$

or,

$$T_w = T_o - q'/2.94$$

Summary:

The heat loss from the lower (uninsulated) portion of the skirt is determined from the following equations:

$$q'_l = 2\sqrt{h_e k \delta}\ (T_w - T_\infty) \quad , \quad k = 31\ Btu/hr\text{-}ft\text{-}^\circ F$$

$$h_e = h + \sigma\epsilon\ (T_w^3 + T_w^2 T_\infty + T_w T_\infty^2 + T_\infty^3)$$

$$T_w = T_o - q'_l/2.94$$

With the known parameters defined before, the solution is given below

$T_o - 460$ (°F)	$T_w - 460$ (°F)	h_e (Btu/hr-ft²-°F)	q'_l (Btu/hr-ft)	q'_u (Btu/hr-ft)	$q'_u + q'_l$ (q'_o)
650	332	3.04	939	101	1040
600	313	2.95	842	91	933
550	295	2.87	753	81	834
500	275	2.78	657	72	729
450	256	2.70	568	62	630
400	237	2.62	481	53	534
350	217	2.54	393	43	436
300	196	2.46	303	34	337
250	176	2.39	220	24	244
200	155	2.32	135	15	150
150	133	2.25	50	6	56

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Miscellaneous Heat Losses, $\dot{Q}_m$

In addition to the losses through the 4" insulation and skirt, there are losses through various attachments to the pressurizer. These attachments are:

- pipes
- Lugs
- Heater wells

At this stage the full geometrical and insulation details about these components are not known. The miscellaneous heat losses, $\dot{Q}_m$, therefore has been approximated using the information provided in Reference 2! . This reference states that at the normal operating conditions heat losses through the lugs amount to 10700 Btu/hr. It is assumed that this value represents the miscellaneous heat losses at the normal pressurizer temperature of 653°F. At lower temperatures a convective relation has been assumed which maximizes the total heat losses. Thus,

$$\dot{Q}_m = 10700 \times \frac{T_o - 120}{653 - 120}$$

where T_o is the pressurizer temperature

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Total Heat Loss, Q'

The total heat loss from the pressurizer is obtained by summing up the individual heat losses determined in the previous sections

$$Q' = q_i'' A_i + q_s' \pi D_s + Q_m'$$

where,

D_s = skirt diameter (6.9 ft)

A_i = insulated area excluding the skirt

$= \pi D^2 + \pi D h$

$= \pi \times 7.6^2 + \pi \times 7.6 \times 34.4$

$= 1003\ ft^2$

q_i'' = (p: 24)

q_s' = (p: 32)

q_m' = (p: 33)

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Temp. (°F)	q_i'' Btu/hr-ft²	q_o' Btu/hr-ft	Q_m' Btu/hr	Q' Btu/hr
650	64.2	1040	10700	97636
600	55.1	933	9691	85180
550	46.7	834	8681	73600
500	38.9	729	7672	62500
450	31.7	630	6662	52100
400	25.1	534	5653	42400
350	19.2	436	4643	33350
300	13.9	337	3634	24880
250	9.2	244	2625	17140
200	5.2	150	1615	100[illegible]
150	1.7	56	606	3525

$$Q' = 0.132\,T^2 + 8227\,T - 11612$$

or $$Q' = 187.2\,T - 27393$$

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Pressurizer Heat Capacity

$U = M_f U_f + M_g U_g + M_s U_s$

where

M = mass, lb_m
U = internal energy, Btu/lb_m
f = saturated water
g = saturated steam
s = steel

Heat capacity of attachments and insulation material has been ignored.

Assuming constant pressurizer inventory at normal operating conditions (630 ft^3 water, 670 ft^3 steam) (saturated)

$M_f = M_o - M_g$

$= M_o - \frac{V_g}{v_g}$

where,

M_o = initial water inventory, lb_m
V_g = pressurizer steam volume (670 ft^3), taken constant
v_g = saturated steam specific volume.

Thus,

$$U = \left(M_o - \frac{V_g}{v_g}\right) U_f + \frac{V_g}{v_g} U_g + M_s C_s (T-32)$$

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Rearranging,

$$U = M_o \left[U_f + \frac{V_g}{M_o v_g} (U_g - U_f) + \frac{M_s}{M_o} C_s (T-32) \right]$$

with $M_o = \frac{V_g}{v_{go}} + \frac{V_f}{v_{fo}}$

$$\frac{V_g}{M_o v_g} = \frac{V_g}{\left(\frac{V_g}{v_{go}} + \frac{V_f}{v_{fo}}\right) v_g} = \frac{1}{1 + \frac{V_f}{V_g} \cdot \frac{v_{go}}{v_{fo}}} \cdot \frac{v_{go}}{v_g}$$

Therefore,

$$U = M_o \left[U_f + \frac{1}{1 + \frac{V_f}{V_g} \cdot \frac{v_{go}}{v_{fo}}} \cdot \left(\frac{v_{go}}{v_g}\right) (U_g - U_f) + \frac{M_s C_s}{M_o} (T-32) \right]$$

with

$V_f = 630\ ft^3$

$V_g = 670\ ft^3$

$v_{fo} = 0.02618\ ft^3/lb_m$ } at 643°F

$v_{go} = 0.17456\ ft^3/lb$ }

$$U = M_o \left[U_f + 0.138 \left(\frac{v_{go}}{v_g}\right)(U_g - U_f)\right] + M_s C_s (T-32)$$

$$U = M_o \left[u_f + 0.138 \frac{v_{go}}{v_g} (u_g - u_f) + \frac{M_s}{M_o} c_s (T-32) \right]$$

Taking $T_{ref} = 32°F$ the temperature dependent terms of this equation are tabulated below:

T (°F)	v_g	u_f (Btu/lbm)	u_g	$u_f + 0.138 \frac{v_{go}}{v_g} (u_g - u_f) = x$ (Btu/lbm)	
650	0.16173	685.5	1052.8	740.2	733
600	0.2677	609.9	1090.	653.1	[illegible]
550	0.4268	545	1108.4	576.8	582
500	0.6761	485.1	1117.4	507.6	512
450	1.1011	428.6	1119.5	443.7	445
400	1.8661	374.27	1116.6	383.9	383
350	3.346	321.35	1109.8	327.	324
300	6.472	269.5	1100.	272.6	268
250	13.826	218.5	1087.9	220.	216
200	33.63	168.	1074.2	168.6	[illegible]
150	97.	118.	1059.3	118.2	123.5

$v_o = 0.0268 \ ft^3/lb$

$$x = 7.24 \times 10^{-4} T^2 + 0.64T + 11.16$$

or $x = 1.219T - 86.56$

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0	TD	3/20/84	[illegible]	[illegible]		CALC NO	

Pressurizer Heat Balance

$$-\frac{dU}{dt} = \dot{Q}$$

$$U = M_o(7.24\times10^{-4}T^2 + 0.64T + 11.16) + M_s C_s (T-32)$$

$$Q' = 0.132T^2 + 82.3\,T - 11612$$

$$-\frac{dU}{dt} = \left[M_o(1.45\times10^{-3}T + 0.64) + M_s C_s\right]\frac{dT}{dt}$$

with,

$M_o = 27885$ lb $(630 \times 38.2 + (1300-630) \times 5.7)$

$M_s = 205000$ lb *

$C_s = 0.11$ Btu/lb-°F

$$\frac{dU}{dt} = (40.4\,T + 40400)\frac{dT}{dt}$$

Therefore

$$-t = \int_{643}^{T} \frac{40.4\,T + 40400}{0.132T^2 + 82.3\,T - 11612}\,dT$$

---

* Per Ref 19 Dry weight = 210000 lb. 5000 lb has been allowed for the skirt, nozzles and lugs

REV	BY	DATE	CHECKED	DATE		
0	TD	3/20/84	[illegible]	[illegible]	IMPELL CORPORATION	JOB NO / CALC NO / PAGE 33 OF

$$\int \frac{ax+b}{Ax^2+Bx+C}\,dx$$

$$= a\left[\frac{1}{2A}\ln(Ax^2+Bx+C) - \frac{B}{2A}\left(\frac{1}{\sqrt{B^2-4AC}}\ln\frac{2Ax+B-\sqrt{B^2-4AC}}{2Ax+B+\sqrt{B^2-4AC}}\right)\right]$$

$$+ b\left[\frac{1}{\sqrt{B^2-4AC}}\ln\frac{2Ax+B-\sqrt{B^2-4AC}}{2Ax+B+\sqrt{B^2-4AC}}\right] + K$$

$$= \frac{a}{2A}\ln(Ax^2+Bx+C) + \left(b-\frac{aB}{2A}\right)\frac{1}{\sqrt{B^2-4AC}}\ln\frac{2Ax+B-\sqrt{B^2-4AC}}{2Ax+B+\sqrt{B^2-4AC}} + K$$

with,

$a = 40.4$

$b = 40400$

$A = 0.132$

$B = 82.3$

$C = -11612$

and $T = 643°F$ @ $t = 0$.

$\sqrt{B^2-4AC} = 113.6$

0	77)	3/20/84			IMPELL CORPORATION
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JOB NO

CALC NO

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Therefore

$$t = \frac{40.4}{2 \times 0.132} \ln(0.132T^2 + 82.3T - 11612) + \left(40400 - \frac{40.4 \times 82.3}{2 \times 0.132}\right) \frac{1}{113.6} \ln \frac{2 \times 0.132T + 82.3 - 113.6}{2 \times 0.132T + 82.3 + 113.6} \Bigg]_T^{643}$$

$$t = 1517.3 - \left[153 \ln(0.132T^2 + 82.3T - 11612) + 244.8 \ln \frac{0.264T - 31.3}{0.264T + 195.9} \right]$$

solution is tabulated on the next page

0	TD	3/28/84	[illegible]	[illegible]	IMPELL CORPORATION
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CALC NO TH1

Time (hr)	Press. Temp. (Deg. F)	T_v (P_v) (Deg. F)		Press. Pressure (psia)
0	643	643	(2100)	2100
2.1	640	620	(1900)	2060
5.6	635	620	(1300)	1980
9.2	630	583	(1337)	1919
12.7	625	567	(1200)	1852
16.3	620	567	(1200)	1787
23.6	610	567	(1200)	1662
31	600	562	(1152)	1543
51	575	462	(476)	1275
71	550	362	(157)	1045
93	525	252	(31)	848
117	500			681
169	450			423
231	400			247
304	350			134
396	300			67
520	250			30
706	200			
1080	150			

T_v, (P_v): Minimum Allowable pressurizer temperature (pressure) to prevent voiding (pp: 12, 13, 14)

0	TU	3/20/84	NNS	3/29/84
REV	BY	DATE	CHECKED	DATE

IMPELL CORPORATION

JOB NO [illegible]

CALC NO [illegible]

3.5 Reactor Coolant Shrinkage

Cooldown of the reactor coolant system is accompanied by shrinkage of the coolant. In order to maintain the desired pressurizer level and avoid voiding of the primary system components make-up flow must be available at a rate to compensate for the shrinkage. In theory, additional factors, such as the pressurization and contraction of the primary system boundaries provide some compensation for the shrinkage. These effects, however, are small in magnitude and have been neglected in this calculation.

Therefore,

$$V = M v$$

where

V = Reactor coolant volume

M = Reactor coolant mass

v = Specific volume of the coolant.

Shrinkage effects are tabulated on the following page.

						JOB NO 0310-027-???	PAGE 43 OF 54
0	TD	1/16/84	[signature]	1/23/84	IMPELL CORPORATION	CALC NO THI	
REV	BY	DATE	CHECKED	DATE			

Temperature (°F)/Hr***	Spec. Vol. (ft³/lb)	Percent Change (*)	Volume Change (ft³)/Gal. **
550	.02176	0.	0.
500 / 4	.02043	-6.1	-398 / 3000
450 / 6	.01944	-10.7	-698 / 5200
400 / 8	.01864	-14.3	-933 / 7000
350 / 10,30	.01799	-17.3	-1120 / 8400
300 / 40	.01745	-19.8	-1292 / 9700
250 / 50	.017006	-21.9	-1430 / 10700
200 / 60	.016637	-23.5	-1534 / 11500
150	.016343	-25.	-1632 / 12200

* Referenced to 550°F average vessel temperature

** $\Delta V = M \cdot \Delta v$

$= V * \text{Percent change}$

$M = 3 \times 10^5$ lb (Ref. 3, page 17)

$V = M \times v = 3 \times 10^5 \times 0.02176$

$= 6528 \text{ ft}^3$

*** The time values correspond to the cooldown curve to prevent void formation (Section 3-3)

REV	BY	DATE	CHECKED	DATE
0	TD	1/16/84	gul	1/23/84

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JOB NO 0310-01?-???
CALC NO TH1

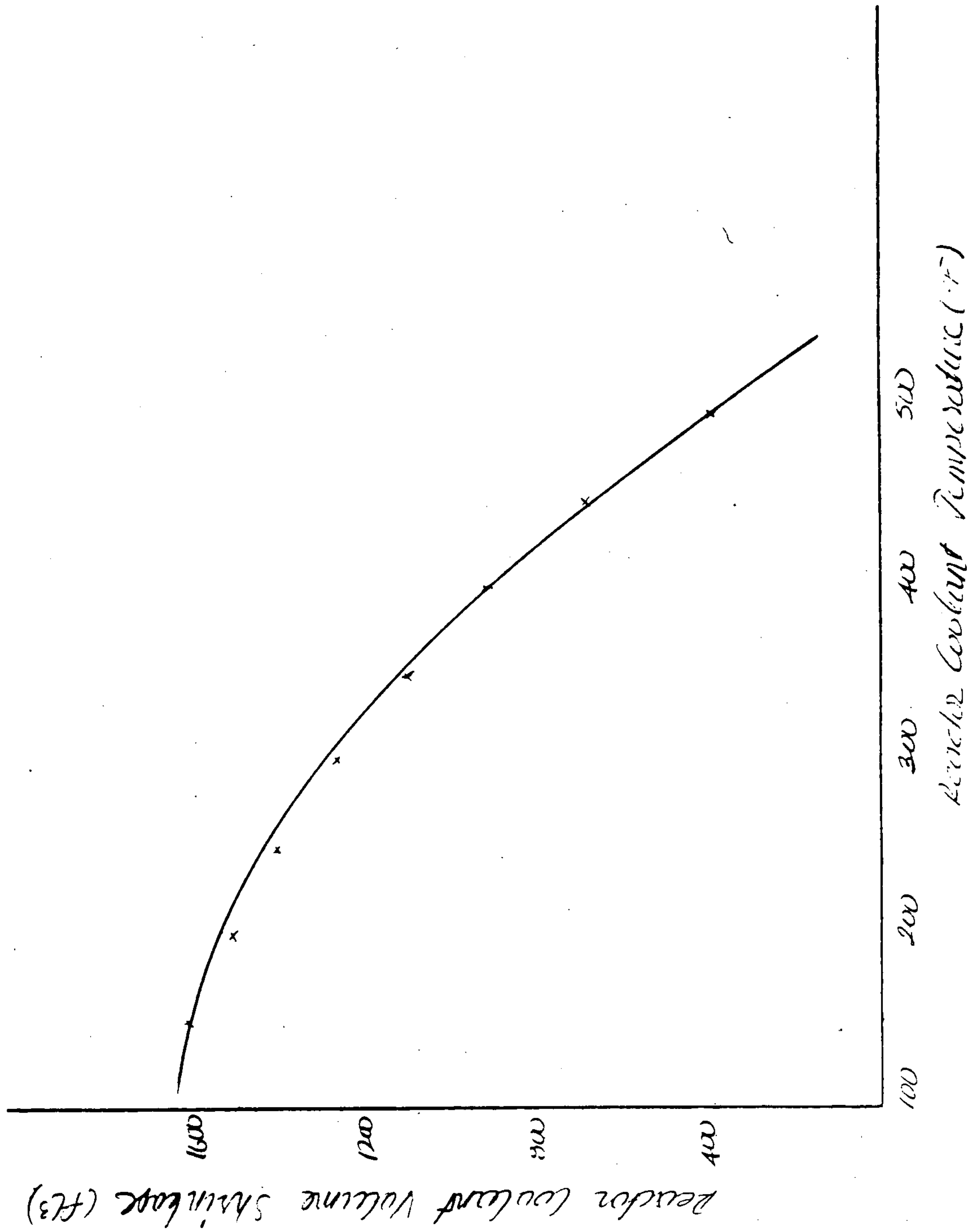


FIGURE 3.5 - REACTOR COOLANT VOLUME SHRINKAGE

REV	BY	DATE	CHECKED	DATE			
0	TD	1/16/84	[illegible]	1/23/84	IMPELL CORPORATION	JOB NO 0310-[illegible] CALC NO TH1	PAGE 45 OF [illegible]

3.6 Natural Circulation

Natural circulation is essential to the removal of the decay heat and the stored heat from the primary system. It is established and maintained by providing an appropriate temperature difference between the reactor and the steam generator. This temperature difference creates the necessary buoyancy force for the natural circulation.

The equation describing the natural circulation can be obtained by:

1. Momentum equation,

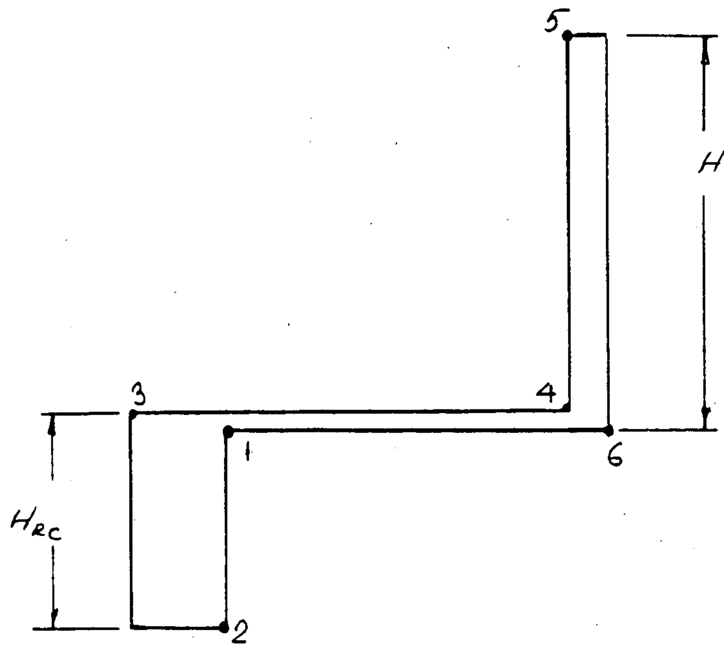
$$\oint \rho g \, dz = \frac{1}{2} \rho R Q^2$$

where,

ρ = density
g = gravitational acceleration
z = vertical coordinate
Q = volumetric flow rate
R = overall loop flow resistance

Integrating the left side of this equation with the help of the sketch on the following page,

C	TD	1/16/8?	[illegible]	1/23/84	IMPELL CORPORATION	JOB NO [illegible] CALC NO 7-41	PAGE 46 OF [illegible]
REV	BY	DATE	CHECKED	DATE			



SEGMENT	AVERAGE DENSITY	GRAVITY HEAD
1-2	ρ_c	$+\rho_c \cdot H_{RC}$
2-3	$\frac{1}{2}(\rho_c + \rho_H)$	$-\frac{1}{2}(\rho_c + \rho_H)\, H_{RC}$
4-5	$\frac{1}{4}(3\rho_H + \rho_c)$	$-\frac{1}{4}(3\rho_H + \rho_c)\, H_{SG}$
5-6	$\frac{1}{4}(3\rho_c + \rho_H)$	$+\frac{1}{4}(3\rho_c + \rho_H)\, H_{SG}$

REV	BY	DATE	CHECKED	DATE	
-	TD	1/18/84	[illegible]	1/23/84	IMPELL CORPORATION

JOB NO [illegible]
CALC NO [illegible]

$$\text{Total Head} = H_{RC}\left(\rho_C - \tfrac{1}{2}\rho_C - \tfrac{1}{2}\rho_H\right) g$$
$$+ \frac{H_{SG}}{4}\left(3\rho_C + \rho_H - 3\rho_H - \rho_C\right) g$$
$$= \frac{H_{RC}}{2}\left(\rho_C - \rho_H\right) + \frac{H_{SG}}{4}\left(2\rho_C - 2\rho_H\right) g$$
$$= \left(\rho_C - \rho_H\right)\left(\frac{H_{RC} + H_{SG}}{2}\right) g$$
$$H_B = \Delta\rho \cdot H_{EQ}\, g$$

where,

H_B = Buoyancy head

H_{EQ} = equivalent elevation difference

$= \frac{1}{2}(H_{RC} + H_{SG})$

$\Delta\rho = \rho_C - \rho_H$

The density difference, $\rho_C - \rho_H$, can be related to the corresponding cold leg and hot leg temperature through the thermal expansion coefficient β, as

$$\Delta\rho = \rho\beta\,\Delta T$$
$$\Delta\rho = \rho_C\,\beta\,(T_H - T_C)$$

yielding

$$H_B = \beta \cdot \rho_C\,(T_H - T_C)\,H_{EQ} \cdot g$$

The core energy balance gives

$$Q \cdot \rho_c \cdot C \cdot (T_H - T_C) = q'$$

where,

q' = decay heat rate
c = specific heat
Q = volumetric flow

Combining this equation with the previous

$$H_B = \frac{\beta q'}{Q c}$$

And finally substituting this into the momentum equation

$$\frac{\beta q'}{Q c} = \frac{1}{2} \rho_c R Q^2$$

Solving for Q

$$Q = \left(2 \beta g H_{EQ} q' / \rho_c C R\right)^{1/3}$$

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0	TD	1/16/84	[illegible]	1/23/84

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CALC NO THI
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Summary:

The natural circulation rate is given by

$$Q = \left(\frac{2 \beta g H_{EQ} q'}{\rho C R} \right)^{1/3}$$

where

Q = volumetric flow rate, ft³/sec

β = Thermal expansion coefficient, °F^{-1}

g = gravitational acceleration, 32.2 ft/sec^2

H_{EQ} = Equivalent elevation difference

$= \frac{1}{2} (H_{RC} + H_{SG})$

q' = Decay heat rate (per steam generator), Btu/sec

ρ = Cold leg density, lb/ft3

C = specific heat, Btu/lb-°F

R = Resistance Coefficient $\left(\sum \frac{k_i}{A_i^2} \right)$, ft^{-4}

The thermal expansion coefficient for water is a function of temperature. This variation is shown on the following page

0	TD	1/16/84	[illegible]	1/23/84	IMPELL CORPORATION	JOB NO 0300-02-1373
						CALC NO THI
REV	BY	DATE	CHECKED	DATE		PAGE 50 OF [illegible]

Temp. (°F)	β (°F^{-1})	ρ (lb/ft³)	C (Btu/lb-°F)
100	2×10^{-4}	62	1.
200	4×10^{-4}	60.1	1.
300	5.7×10^{-4}	57.3	1
400	7.8×10^{-4}	53.7	1.
500	11.2×10^{-4}	49.	1.2
600	19.6×10^{-4}	42.3	1.4

$H_{ec} + H_{SG} \simeq 50$ ft (from Fig. 2.1 of Ref. 7)

Using the values at the median temperature of 300°F,

$\beta = 5.7\times10^{-4}$
$\rho = 57.3$ lb/ft³
$C = 1.$ Btu/lb-°F

and noting that,

$q' = (DH/3)/3600$
$R = 0.54$ ft^{-4} (calculated on page 34)

$$Q = \left[2\times 5.7\times10^{-4}\times 32.2\times 50/2 \times DH/(3\cdot 3600) \Big/ 57.3\times 1.\times 0.54\right]^{1/3}$$

$= 0.014\,(DH)^{1/3}$ ft³/sec

where,

DH = Decay Heat (Btu/hr) as given on page 9)

0	TD	1/16/84	[illegible]	1/23/84	IMPELL CORPORATION	JOB NO 0300-012-??? CALC NO TH1	PAGE 51 OF 84
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Noting that this flow rate is per loop and that, there are three loops the core flow rate is,

$$\dot{m} = 3 \rho Q \times 3600$$

$$= 3 \times 0.014 (\Delta H)^{1/3} \times 57.3 \times 3600$$

$$= 8.7 \times 10^{3} (\Delta H)^{1/3} \quad lb/hr.$$

The corresponding temperature differential is,

$$\Delta T = T_H - T_C = \Delta H / \dot{m} C$$

$$= 1.2 \times 10^{-4} (\Delta H)^{2/3}$$

$$\dot{m} = 8.7 \times 10^{3} (\Delta H)^{1/3}$$

$$\Delta T = 1.2 \times 10^{-4} (\Delta H)^{2/3}$$

Values of core flow rate, $\dot{m}$, and temperature difference, ΔT, are calculated on the following page.

REV	BY	DATE	CHECKED	DATE
0	TD	1/16/84	JAW	1/23/84

Time (Hr.)	Decay Heat (10^6 Btu/hr)		Core Flow (10^3 lb/hr)		ΔT (°F)
1/6	248	(5.4)	5375	(6.9)	48
1	73	(1.6)	3580	(4.6)	21
2	58.5	(1.3)	3320	(4.3)	18
4	48.2	(1.1)	3110	(4.)	16
5	45.4	(1.)	3050	(3.9)	15.3
10	37.9	(.8)	2880	(3.7)	13.5
25	29.1	(.6)	2630	(3.4)	11.4
32	27.1	(.6)	2570	(3.3)	10.8
50	23.5	(.5)	2450	(3.1)	9.8
100	18.5	(.4)	2560	(2.9)	8.4
150	15.7	(.3)	2140	(2.7)	7.5

Numbers in parenthesis represent the percentages based on 100% Load Core Thermal Power (1340 MWt) and Core Flow Rate (78×10^6 lb/hr)

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Resistance Coefficient

The turbulent resistance coefficient, R, is estimated from the primary system design data as,

$$\Delta P = R \frac{1}{2 \times 144 g_c} \frac{\dot{m}^2}{\rho} \times \left(\frac{1}{3600}\right)^2$$

where,

ρ = Coolant density, 47. lb/ft³ (At T_c = 553°F)
$\dot{m}$ = Steam Generator flow Rate, 26×10^6 lb/hr
ΔP = Reactor coolant pump head, 65 psi

Therefore,

$$R = 2 \times 65 \times 144 \times 32.2 \times 47 \Big/ \left(26 \times 10^6 / 3600\right)^2$$

$$R = 0.54 \ ft^{-4}.$$

<u>NOTE:</u> At 100% power the flow is fully turbulent with,

$$Re = 123.9 \frac{\rho v d}{\mu}$$

where,

ρ = 47 lb/ft³
v = 87 ft/sec (Based on 26×10^6 lb/hr, flow and 18" pipe diameter)
d = 18"
μ = 0.111 cp

$Re = 8 \times 10^5 \gg 2300$ (Critical Reynolds number)

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REV	BY	DATE	CHECKED	DATE	

At 200°F, $\mu = 0.313$ and with core flow reduced to 1 percent of the value at full power,

$$Re = 8 \times 10^5 \times 0.01 \times \frac{0.111}{0.313} = 2900$$

Still greater than the critical Reynolds number (2300) for pipe flow. Therefore the assumption of turbulent flow during the shutdown with natural circulation is valid.

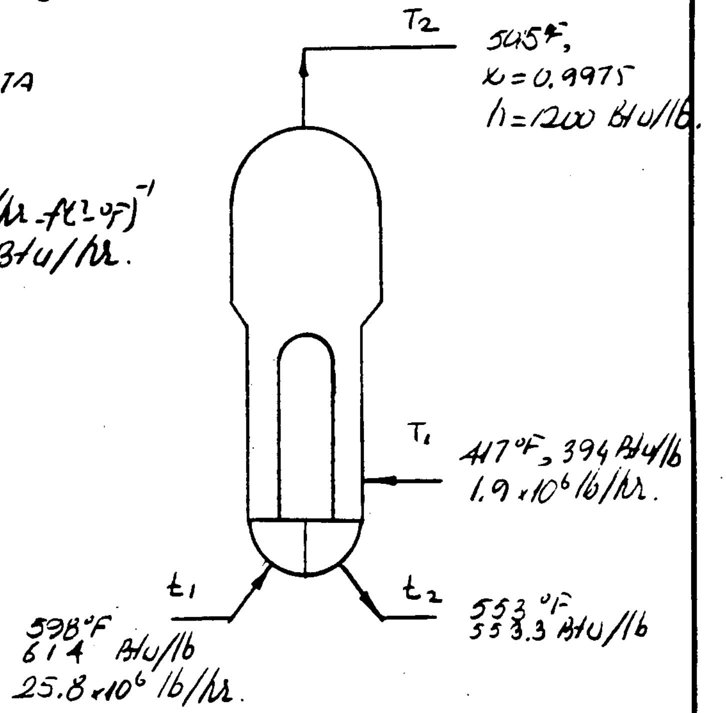
3.7 Steam Generator Capacity

STEAM GENERATOR DATA
(Source: Reference 15)

Heating Surface = 27700 ft^2
Fouling Factor = .0002 $(Btu/hr\text{-}ft^2\text{-}°F)^{-1}$
Heat Transferred = 1532×10^6 Btu/hr.

Operational Limitations:

- 50°F step change on the steam side
- ∓ 100°F/hr on the primary (tube) side



U-tubes:

n = 3794
t = 0.055 in
OD = 0.75 in
Ni Cr Fe alloy

k = 11 Btu/hr-ft-°F

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0	TD	1/16/84	[illegible]	1/23/84

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Overall Heat Transfer Coefficient - Normal operation

$Q = UA\,\Delta T_{LM}\,F$

$U = Q / A\,\Delta T_{LM}\,F$

$\Delta T_{LM} = \left[(598-417) - (553-505)\right] / \ln\left(\frac{598-417}{553-505}\right)$

$= 100°F$

$F = 0.95$ (From Ref. 10 for, $P = (598-553)/(598-417) = .25$
$R = (505-417)/(598-553) = 1.96$

Therefore,

$U = 1532 \times 10^6 / 27700 \times 100 \times 0.95$

$U = 582$ Btu/hr-ft²-°F

Overall Heat Transfer Coefficient - Natural Circulation

$U = \left[\frac{1}{h_o} + \left(r_o + r_i \frac{D_o}{D_i}\right) + \frac{1}{h_i}\cdot\left(\frac{D_o}{D_i}\right) + r_w\right]^{-1}$

$r_w = \frac{D_o}{24k}\left(\ln \frac{D_o}{D_o - 2t}\right)$, $k = 11$ Btu/hr-ft-°F

$= \frac{.75}{24 \times 11} \ln \frac{.75}{.75 - 2 \times .055}$

$= 4.5 \times 10^{-4}$ (Btu/hr-ft²-°F)$^{-1}$

$r_o + r_i \frac{D_o}{D_i} = 2 \times 10^{-4}$

0	TD	1/16/84	[initials]	1/18/84	IMPELL CORPORATION
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CALC NO THI

h_o = 580 Btu/hr-ft²-°F (Minimum from Ref. 11, p:70)
h_i = 450 Btu/hr-ft²-°F (Minimum from Ref. 11, p:70

$$U = \left(\frac{1}{580} + 2\times10^{-4} + 4.5\times10^{-4} + \frac{1}{450} \frac{.75}{.75 - 2\times .055} \right)^{-1}$$

$$= (4.98 \times 10^{-3})^{-1}$$

$$U = 200 \text{ Btu/hr-ft}^2\text{-°F}$$

This value represents the minimum overall heat transfer coefficient at the steam generator for the condition during which it is required to operate. In order to allow uncertainties which are not evaluated in this study (plugged steam generator tubes, tube uncovering, excessive fouling and the approximate nature of the film heat transfer coefficients) the value of "U" is further reduced by a factor of 0.5. Thus,

$$U = 200 \times 0.5$$
$$= 100 \text{ Btu/hr-ft}^2\text{-°F}$$

is used in this calculation

0	TD	1/16/84	[illegible]	1/23/84	IMPELL CORPORATION
REV	BY	DATE	CHECKED	DATE	

JOB NO 0300-027-1373
CALC NO 7H1

Minimum Capacity of the Steam Generator.

with,

$$\dot{q} = U A \Delta T_{LM} F$$

and,

$$U_{min} = 100 \text{ Btu/hr.ft}^2\text{.}^\circ F$$

$$A = 27700 \text{ ft}^2$$

$$\dot{q}_{min} = 27700 \times 100 \times (\Delta T . F)_{min}$$

The minimum ΔT will occur near the cold shutdown conditions, i.e.,

$$t_1 = 195$$

$$t_2 = 195 - 8 = 187^\circ F \quad (8^\circ F \text{ required buoyancy head})$$

$$T_1 = 80^\circ F$$

$$T_2 = 177 \, F \; (10^\circ \text{ TTD assumed})$$

Therefore

$$\Delta T_{LM} = \frac{(195-80) - (187-177)}{\ln (195-80)/(187-177)} = 43^\circ F$$

$$P = (t_2 - t_1)/(T_1 - t_1) = 0.05 \longrightarrow F = 1.$$

$$\dot{q}_{min} = 27700 \times 100 \times 43$$

$$= 119 \times 10^6 \text{ Btu/hr.}$$

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0	TD	1/16/84	GW	1/24/84	IMPELL CORPORATION	JOB NO 0300-027-1373 CALC NO THI	PAGE 59 OF 84

The combined minimum capacity of the steam generators is therefore,

$$q'_{min} = 3 \times 119 \times 10^6$$
$$= 357 \times 10^6 \text{ Btu/hr.}$$

As can be seen this is well above the decay heat and sensible (stored) heat removal rate which is required to achieve the cold shutdown.

REV	BY	DATE	CHECKED	DATE
0	TD	1/16/84	[illegible]	1/24/84

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CALC NO THI

3.8 Auxiliary Feedwater Cooling Capacity

$T_1 = 80°F$, $h_1 = 48.$ Btu/lb

$\rho_1 = 62.2$ lb/ft³

$T_2 = 212°F$, $h_f = 180.2$ Btu/lb

$h_g = 1150.5$ Btu/lb

$\dot{m} = 235 \times (62.2/7.48) \times 60$ *

$= 117250$ lb/hr

Heat Removal Capacity,

A- Steaming Mode

$q'_{SM} = \dot{m} . \Delta h = 117250 \times (1150.5 - 180.2)$

$= 114. \times 10^6$ Btu/hr.

B- Single Phase (liquid) Mode

$q'_{LM} = 117250 \times (180.2 - 48.)$

$= 15.5 \times 10^6$ Btu/hr.

---

* Based on 235 gpm Motor Driven Aux. Fw. Pump Capacity

0	TD	1/16/84	[illegible]	1/23/84
REV	BY	DATE	CHECKED	DATE

IMPELL CORPORATION

JOB NO 0300-027-1373

CALC NO TH1

C. Single Phase Mode - at cold shutdown

Assuming $T_2 = 184\,°F$ (i.e., ~5° TTD)
$h_2 = 152$ Btu/lb.

$q_{SD} = 117250 \times (152 - 48)$
$= 12.2 \times 10^6$ Btu/hr.

These numbers have the following implications

1. At the moment of trip and approximately 12(*) minutes following, the decay heat rate exceeds the cooling capacity of the auxiliary feed water system by a substantial margin. Although there will be a partial compensation for this by steaming at the steam generators, a temperory increase in the primary system temperature is expected during this early period.

2. At the point of transition from the steaming mode to liquid flooded mode the decay heat rate must have reduced to at least 15×10^6 Btu/hr.

---

* See Figure 3-6

3. At the point of cold shutdown the decay heat rate must have reduced to at least 5×10^6 Btu/hr.

It must be realized that these limits are based on the 235 gpm Nominal Pump Capacity. Considering the fact that during this mode of operation the frictional head loss on the secondary side is much smaller than the design frictional head loss the aux feed pump must be capable of delivering more capacity. Assuming that the pump will be operating against 40 percent less head, page 16-25 of Reference 14;

$$H_{NOMINAL} = 2480 \text{ ft} (\sim 1070 \text{ psi})$$
$$H = 2480 \times (1.-0.4)$$
$$= 1480 \text{ ft}$$

which yields,

$$Q = 400 \text{ gpm}$$
$$NPSH_R = 18 \text{ ft.}$$

At this point the available NPSH is (from Ref. 12)

$$NPSH_a = 33.9 + 4.21 - 4.21 \times \left(\frac{400}{235}\right)^2 = 25.9 \text{ ft.}$$

Therefore the available NPSH is adequate.

The cooling capacity of the Aux. Feed loop being directly proportional to the Aux. Feed flow rate, the cooling limits given on the previous pages can be revised as:

Heat Removal Cap. in the Steaming Mode,

$$q'_{SM} = 114 \times 10^6 \times \frac{400}{235}$$

$$= 194 \times 10^6 \ Btu/hr.$$

Heat Removal Cap. in the Single Phase (liquid) Mode

$$q'_{LM} = 15.5 \times 10^6 \times \frac{400}{235}$$

$$= 26.4 \times 10^6 \ Btu/hr$$

Heat Removal Cap. at Cold Shutdown (T_H = 195°F)

$$q'_{SD} = 12.2 \times 10^6 \times \frac{400}{235}$$

$$= 20.8 \times 10^6 \ Btu/hr.$$

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Cooling Water Consumption

The amount of water consumption to achieve and maintain cold shutdown is calculated from the system energy balance.

Phase I - Steaming Mode

Integrated Decay Heat = 2×10^9 Btu (Fig. 3-6)

h_{in} (Cooling wat.) = 48 Btu/lb.

h_{ex} (Sat. Steam at 212°F) = 1150. Btu/lb

$$V_w = \left[2\times10^9/(1150-48)\right] \times \frac{1}{62} \times 7.48$$

= 220 000 Gal.

Phase II - To achieve and maintain cold shutdown at 190°F for up to 1000 hr.

h_{in} = 48 Btu

h_{ex} = 153 Btu (Hot water at 190-5 = 185°F)

Integrated Decay Heat = 13×10^9 Btu

$$V_w = \left[(13\times10^9 - 2\times10^9)/153-48\right] \times \frac{7.48}{62.}$$

$= 12.7 \times 10^6$ Gal

$\simeq$ 13,000,000 Gal.

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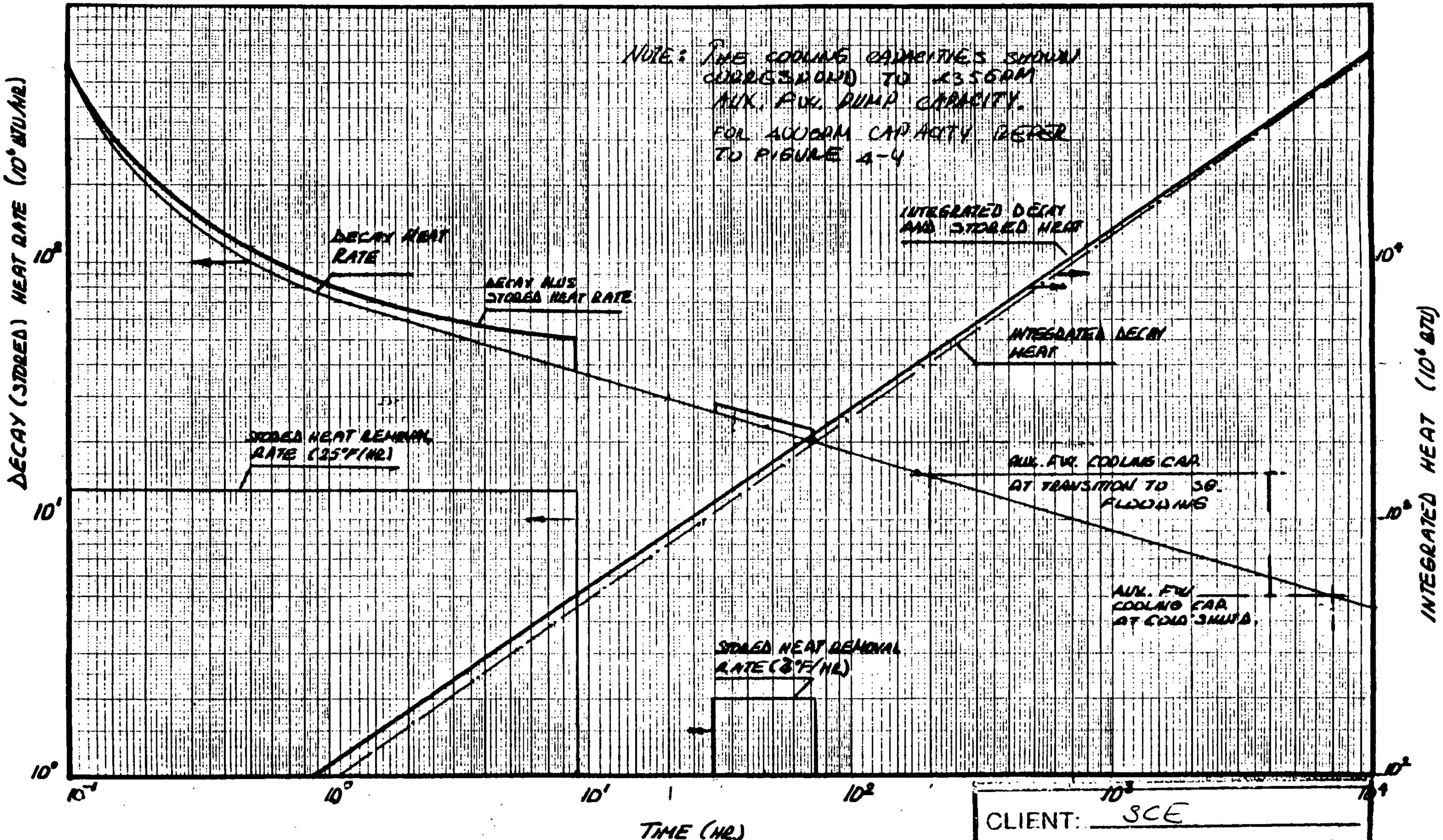

FIGURE 3-6 - PRIMARY SYSTEM HEAT REMOVAL RATE

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3.9 Boron Concentration

Prior to initiation of cold shutdown, the reactor coolant Boron concentration is increased to the shutdown concentration. Figure 2.74 of Reference ?? present Boron Removal/Addition rates after load reduction to zero power. Following values have been read from this figure:

Time After Shutdown (hr.)	0	5	10	15	20	25	30	35	40	45	50	55	60	65
Rate of Change of Boron (PPM/HR)	0	13	22	22	18	16	14	12	9	7	4	2	0	

Assuming that Boron is added in the form of Boric Acid (H_3BO_3) from a 12 percent solution, the required rate of addition is determined from,

$$\frac{d}{dt}(M B) = \dot{m} b \times \left(\frac{12}{100}\right) \times \left(\frac{11}{62}\right)$$

where,

M = Primary System coolant inventory, 300000 lb
B = Primary system Boron concentration
$\dot{m}$ = Coolant addition rate (make up)
b = Concentration of Boric Acid solution in the make up water

Noting that, M = Constant,

$$\dot{m} = 2\ GPM/loop \times 3\ loops \times \frac{1}{7.48} \times 62\ \frac{lb}{ft^3} \times 60\ \frac{min}{hr}$$

$$\cong 3000\ lb/hr.$$

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$$\frac{dB}{dt} = \left(\frac{\dot{m}}{M}\right) \cdot b \times \frac{11}{62} \times \frac{12}{100}$$

from which

$$b = 4700 \frac{dB}{dt}$$

with dB/dt known from the previous page, the concentration of 12% Boric Acid Solution in the make up water is:

Time (Hr.)	5	10	15	20	25	30	35	40	45	50	55	60	65
b (lb/lb)	0.	.06	.11	.11	.09	.08	.07	.06	.04	.03	.02	.01	0.
Rate (lb/hr)*		180	330	330	270	240	210	180	120	90	60	30	0.

By integrating the rate of boric acid addition the amount of Boric Acid solution needed is determined. This is:

Amount of 12% Boric Acid Solution = 10200 lb

≃ 1270 Gal.

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* Rate of addition of 12% Boric Acid Solution to satisfy the required Boron concentration

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If the make-up is supplied from the raw water storage tank (RWST) which contains 3750 ppm Boron (equivalent of 2.1 % Boric acid solution *)

$$M \cdot \frac{dB}{dt} = \dot{m} \times PPM \times 10^{-6}$$

$$\dot{m} = (300000 \times 10^{6} / 3750) \; \frac{dB}{dt}$$
$$\dot{m} = 8 \times 10^{7} \; \frac{dB}{dt}$$

Again, using the dB/dt values given previously

Time (hr)	0	5	10	15	20	25	30	35	40	45	50	55	60	65
$\dot{m}$ (lb/hr)		0	1040	17[illegible]	1760	1440	1280	1120	960	720	560	320	160	0
Galons Pumped			313	1160	2220	3185	4000	4700	5350	5880	6250	6520	6670	6720

By integrating this rate, the amount of 3750 PPM borated water that needs to be supplied from the RWST is:

$$M_{RWST} = 55600 \text{ lb}$$

or

$$\simeq (55600 / 62.4) \times 7.48$$
$$= 6670 \text{ Gal}$$

$$* \quad \% \, H_3BO_3 = (PPM \times 10^{-6} \times \frac{62}{11}) \times 100$$

3.10 Containment Sump Capacity

Based on the assumption that for every two gallon injected into the reactor coolant system one gallon leaks into the containment through the RCS pump third seal,

V_{leak} = 2 (gpm/loop) × 3 loops + 1 gpm (Tech Spec. Req.) = 7 gpm

= 420 gal./hr.

At this rate it will take,

Δt = 295000 Gal / 420 Gal/hr

= 700 hr

to reach the upper limit on the containment water level.

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4.0 RESULTS AND CONCLUSIONS

The study has indicated that the use of the steam generators at SONGS 1 to achieve and maintain cold shutdown is possible. The components that are essential to perform this function are shown in the schematics of Figure 4.1. Primary functions of the system is to:

- Remove the decay heat
- Achieve and maintain cold shutdown at 170°F
- Satisfy reactivity control requirements
- Satisfy primary system pressure control.

Essential elements of the system (excluding the instrumentation) are:

- Reactor vessel
- Steam generators
- Pressurizer
- Coolant reservoirs (Condensate Storage Tank, Auxiliary Feedwater Tank, Reservoir)
- Motor driven auxiliary feedwater pump

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. Charging pump
. Refueling Water Storage Tank
. Emergency Thermal Barrier Pump
. Associated piping and valves

The constraints and the limitations imposed upon the system are discussed below.

Cooldown Rate: The recommended cooldown rate of Reference 1 which is illustrated in Figure 3.2 can be maintained. This cooldown rate consists of 25°F/hr initial cooldown to 350°F, 20 hr. Soak at this point followed by a cooldown rate of 10°F/hr or less to cold shutdown conditions. In this study the final phase of the cooldown is carried out at approximately 5°F/hr so that the decay heat removal requirement at the point of transition to single-phase operation can be matched by the auxiliary feedwater cooling capacity. The cooldown is terminated at 180°F and maintained there for an indefinite period of time.

Primary System Pressure Control: Primary System pressure is limited by primary system subcooling and Nill Ductility Transition Temperature Requirements. These limits are

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indicated by the curves P_A and P_B in Figure 4.4. Also shown in this figure is the primary system pressure as determined by the natural cooldown rate of the pressurizer. Examination of these curves indicates that:

1. The required degree of subcooling to prevent the void formation in the upper head is marginally maintained during the early part of the cooldown (up to the 8th hour). Beyond this point the degree of subcooling is substantially greater than what is required.

2. The nill ductility requirement is maintained up to 35th hour. At this point the primary system pressure exceeds the nill ductility pressure limit and stays above for the rest of the cooldown.

In consideration of the first observation it can be said that pressurization of the primary system through external means (i.e., activating the pressurizer heaters or introducing high pressure nitrogen into the pressurizer) will not be necessary. This statement, however, must be viewed in the light of the assumptions used in this study. Namely the assumption of no mixing at the surge line and the initial water volume of 630 ft^3. If mixing occurs, or if the initial water level is less than the normal, the cool down rate will be somewhat accelerated. These conditions have not been considered in this study, and if examined may indicate a need for external pressurization.

In consideration of the second observation there is an obvious need to accelerate the depressurization after the 35th hour. This timing corresponds to the conditions of this study and may show variations depending on the initial conditions and the shutdown process followed during the early parts. Depressurization can be accelerated by the use of the relief valves and/or the pressurizer spray.

Natural Circulation: The configuration and the hydraulic resistance of the primary system is adequate to establish and maintain a natural circulation so that the decay as well as the stored heat can be transported away. Core circulation and the driving temperature difference are shown in Figure A.3. Near cold shutdown there is enough buoyancy head to maintain 3 percent nominal core flow

Reactivity Control: Following sustained operation at 100% power, approximately 160 lbs. of Boron must be added to the RCS to achieve 5 percent shutdown margin. This amounts to 700 ppm Boron concentration in the primary system and requires:

- 1270 Galons of 12 percent Boric Acid Solution from the Boric Acid Tank, or
- 6000 Galons of 3750 ppm Borated water from the RWST.

The required Boron addition is shown in Figure 3.5. As can be seen this amount can be accomadated by the volume provided by the shrinkage of the RCS due to cooldown.

Auxiliary Feedwater Capacity: The auxiliary Feedwater System has the ability to remove the decay heat and the stored heat from the primary system by way of the steam generators. with the configuration as shown in Figure 4.1, the auxiliary feedwater pump (G-10S) will be operating against a pressure head much less than the design pressure head. As a result the is expected to increase

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from the 235 GPM nominal to 400 GPM. The NPSH available at this point is greater than the required NPSH by approximately 8 ft.

Because of the increased discharge the of the pump, the cooling capacity increases in the same proportion. The cooling capacities provided by the Auxiliary Feedwater System are shown in Figure 4.2 in the steaming as well as the Single Phase Operation Mode. As can be seen from this Figure the cooling capacity provided by the Auxiliary Feedwater pump G-10S is sufficient to achieve shutdown before 72 hrs.

The amount of coolant required is:

At 55 hrs (Point of Transition)	: 200000 Gal
At 72 hrs (Cold Shut down)	: 600000 Gal
At 100 hr	: 1.3×10^6 Gal
At 1000 hr	: 13.4×10^6 Gal

The cooling water consumption is shown in Figure 3.2.

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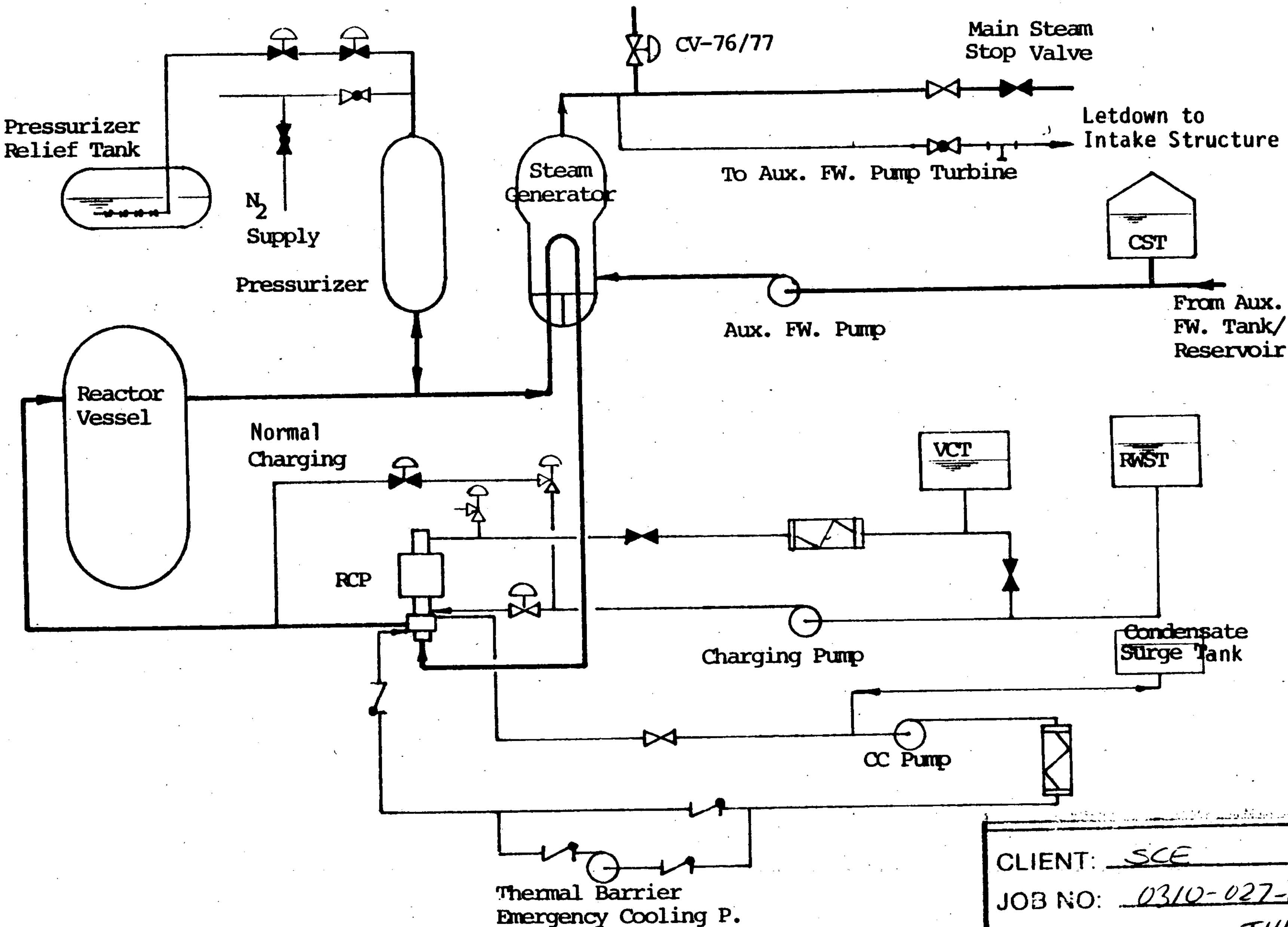

FIGURE 4-1 - SYSTEM SCHEMATIC

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CALC./PROB NO: THI

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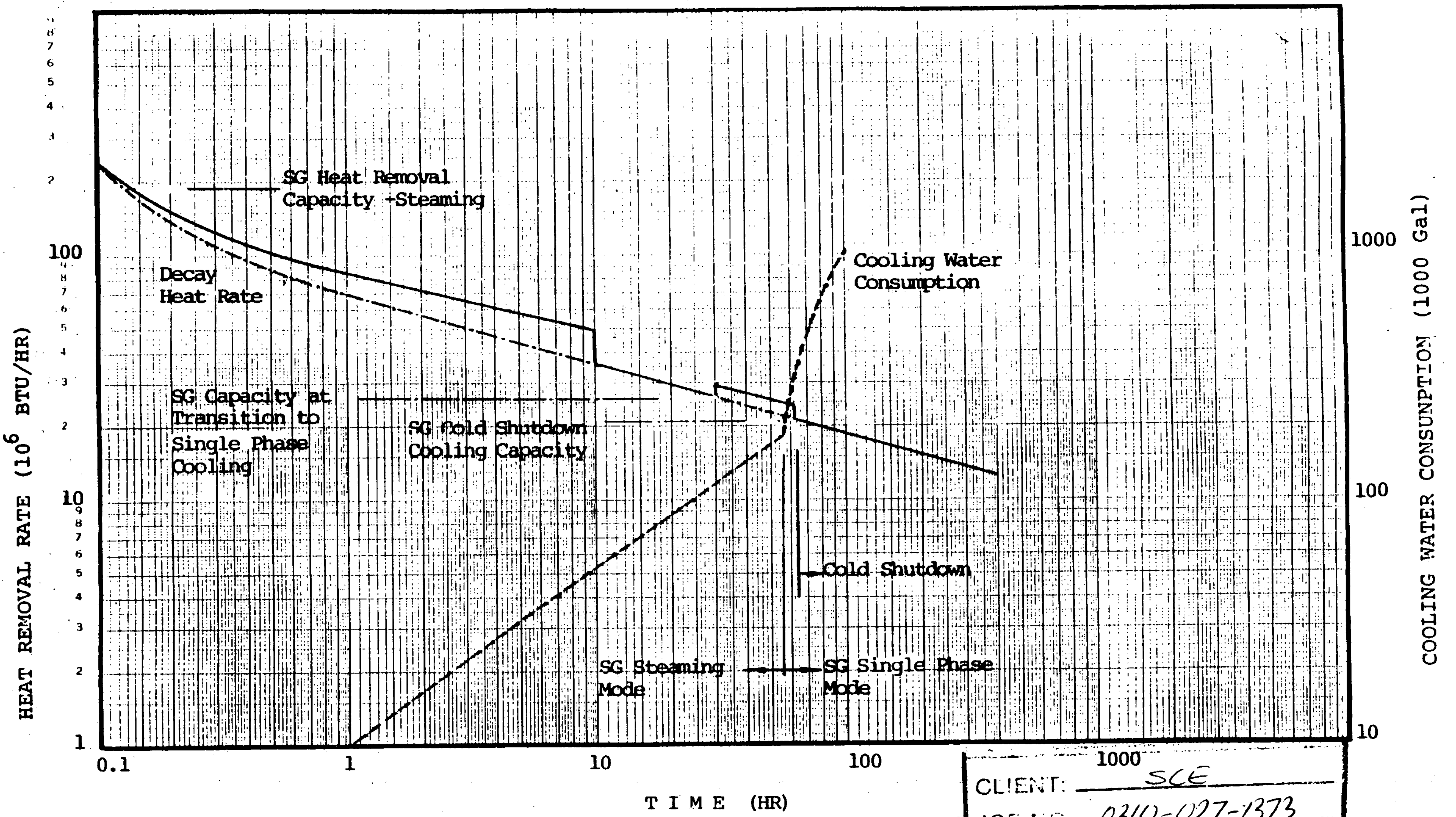

FIGURE 4-2 - PRIMARY SYSTEM COOLING REQUIREMENTS

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JOB NO: 0310-027-1373
CALC/... NO: THI
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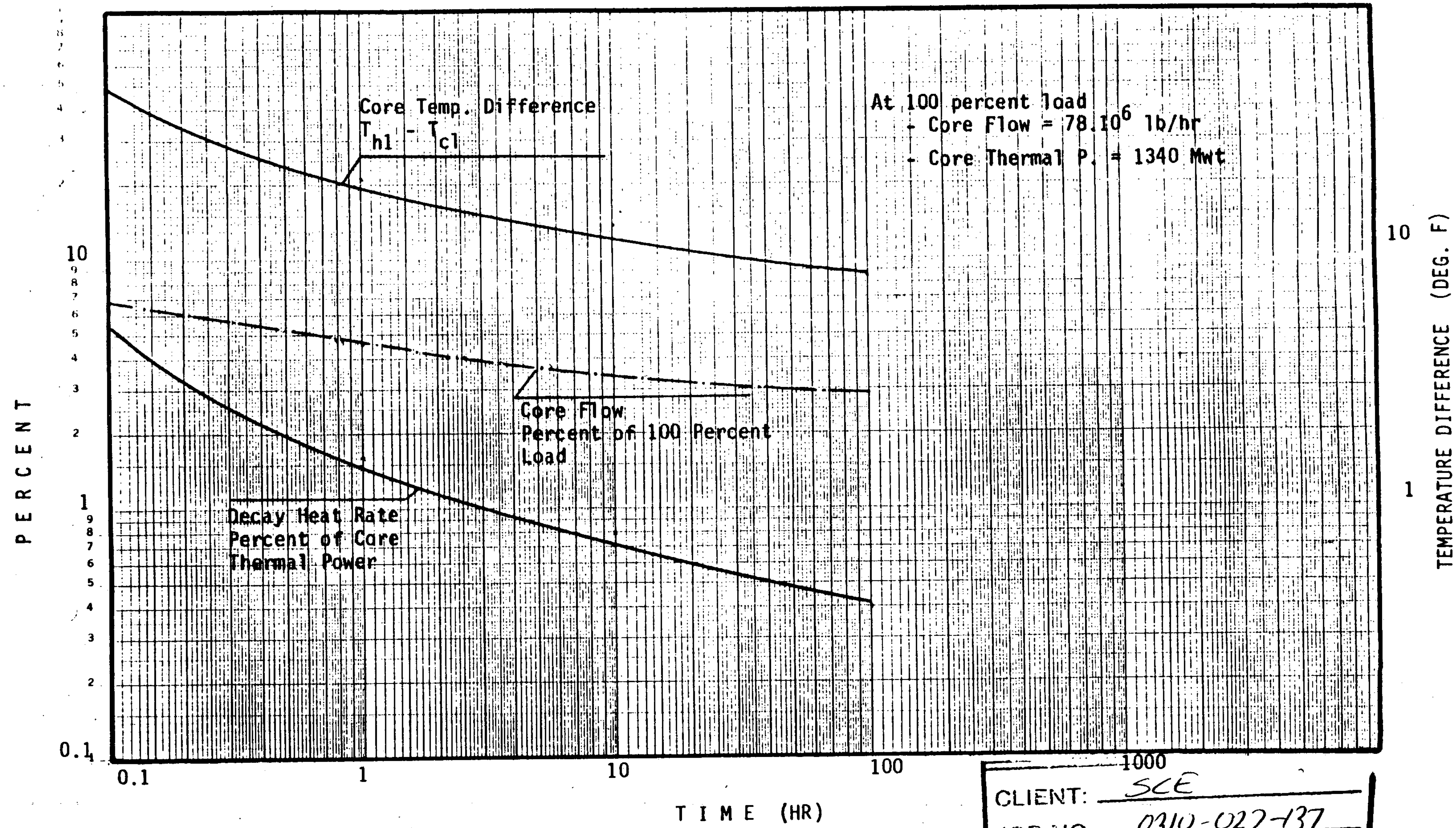

FIGURE 4-3 NATURAL CIRCULATION CORE FLOW RATE AND TEMPERATURE DIFFERENCE

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JOB NO: 0310-022-137
CALC./PROP. NO: THI
BY: TD DATE: 1/16/84
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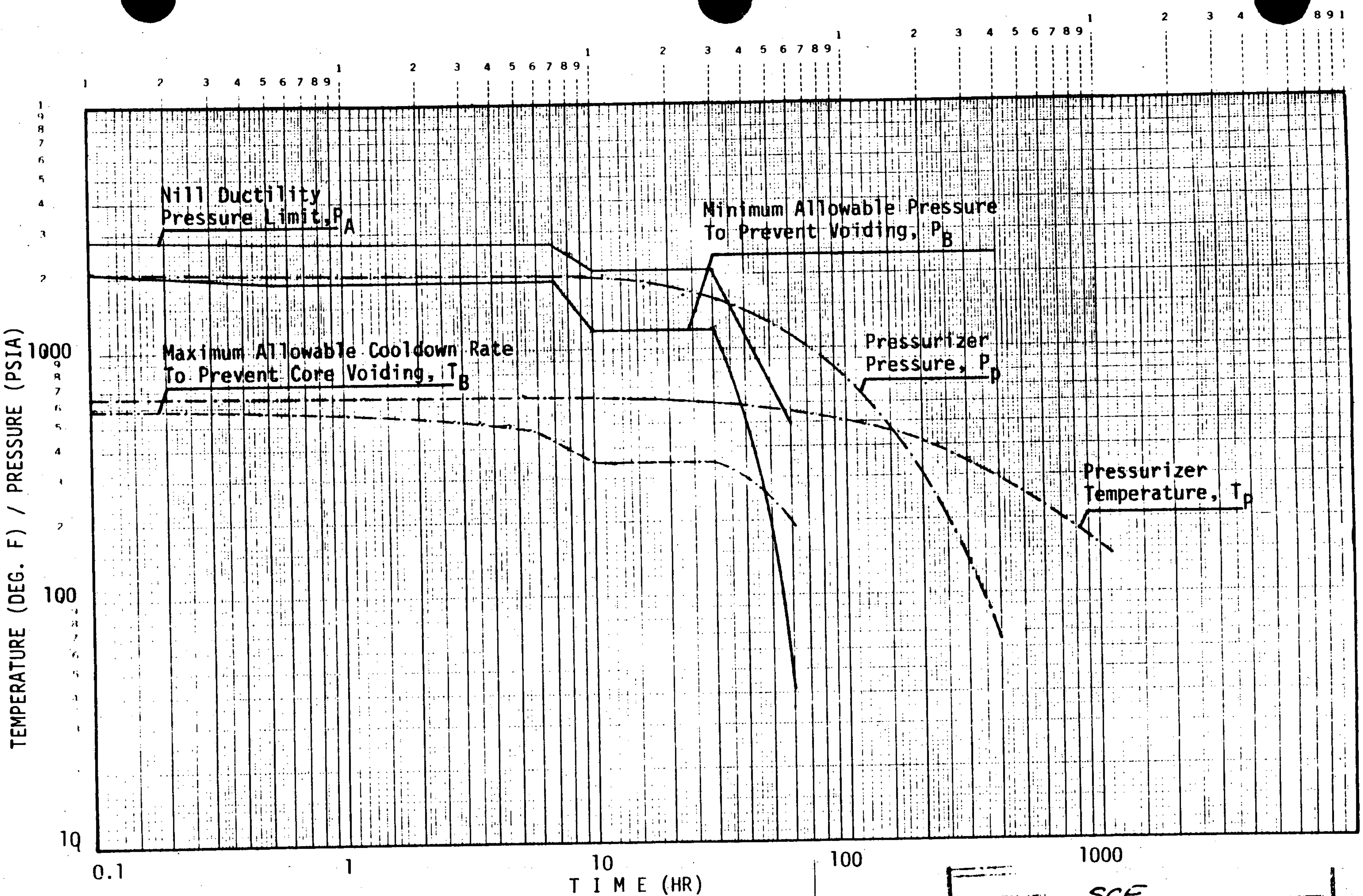

FIGURE 4-4 - PRIMARY SYSTEM COOLDOWN RATE LIMITATIONS

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JOB NO: 0310-027-1373
CALC./PROB. NO: TH1
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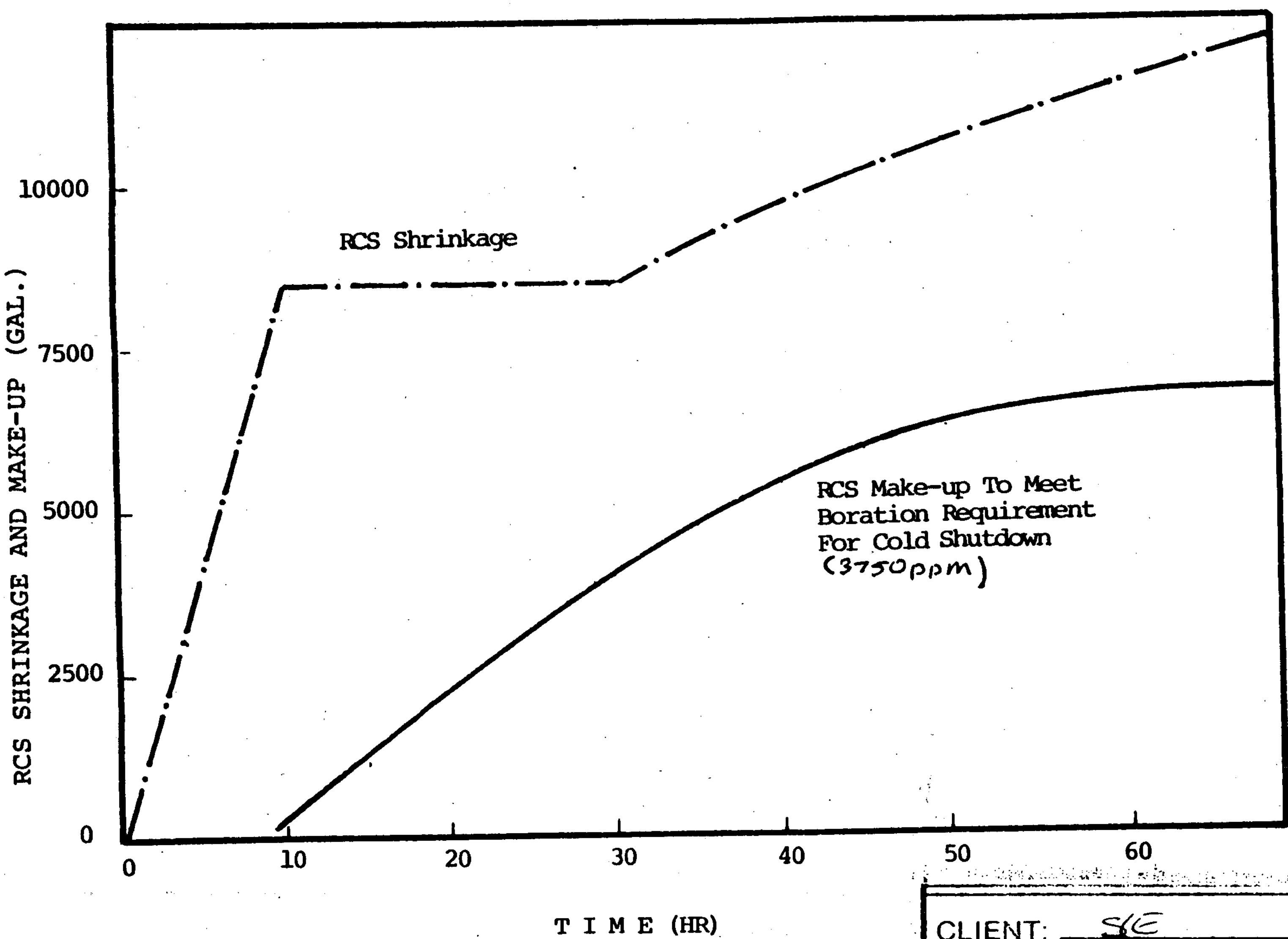

FIGURE 4 -5 - PRIMARY SYSTEM MAKE-UP REQUIREMENTS

CLIENT: S&E
JOB NO: 0310-027-1373
CALC./PROB NO: TMI
BY: TD DATE: 1/16/84
CHKD: gac DATE: 1/24/84

5.0 REFERENCES

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2. "Decay Heat", SCE Calculation No. DC-1354, SONGS1 Project, 3-11-83.

3. "Auxiliary Feedwater Tank Volume Requirement" SCE SONGS1 Project, Calculation No. DC-1365 3-17-83

4. "Condensate Tank Flow Calculation", SCE SONGS1 Project, Calculation No. DC-343, 8-2-78

5. "Loss of Secondary Coolant", Attachment to Westinghouse Electric Corporation Letter No. SC-82-563, dated August 13, 1983

6. Technical Specifications, San Onofre Nuclear Generating Station Unit 1 with change No. 73, 5-20-83.

7. Final Safety Analysis Report, SONGS 1, Southern California Edison Company

8. Design Criteria Manual, SONGS 1, Revision 1, Jan. 1983, Southern California Edison Company

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9. "Dedicated Safe Shutdown System", Record of Conversation from G. Weber (Impell) to R. Ornealy, Dec. 9, 1983

10. "DSSS/Pressurizer Insulation, Heaters", Record of Conversation from T. Dogan (Impell) to J. Pierson and R. Cope (SCE), Jan 13, 84.

11. Technical Manual - Pressurizer Assembly, 1440-C79, F-16 1-5, DWG. NO. 790 D 654.

12. "Aux. Feed Available NPSH", SCE SONGS 1 Project, Calculation No. DC 344, Aug 4, 78.

13. "DSSS/Cold Shutdown Boron Concentration", Record of Conversation from T. Dogan (Impell) to J. Pierson (SCE), Jan 20, 84.

14. "Auxiliary Feedwater Pump, Motor Driven, G-10S Data Sheet, VPS-E32-12156, Rev. 0, pp 16-23/16-25.

15. "Vertical Steam Generator for Southern California Edison San Onofre Nuclear Generating Station", Technical Manual No. 1440-C77, Westinghouse Electric Corp., Dec. 1965

16. "Transient Modeling of Steam Generator Units in Nuclear Power Plants: Computer Code, TRANSG-01," EPRI-NP-1368, Interim Report March 1980.

17. Van Wylen, G.J and R.E Sonntag, Fundamentals of Classical Thermodynamics, 2nd edition, SI version, John Willey

18. Rohsenow and Hartnett, Handbook of Heat Transfer, McGraw-Hill.

19. Technical Manual No: 1440-C79, Pressurizer Assy. San Onofre Nuclear Generating Station, Aug. 1965, (Project Design Input Doc. No: 1)

20. Specifications - Owens/Corning Fiberglass, Insul-Quick Insulation (Project Design Input Doc. No: 2)

21. ROC from D. Wert to R. Ornelas dated March 2, 84.

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Additional Information for NRC Review of SEP Topic II-4.F

Item 1

Justification for separating the settlement of loose fill as seismic-settlement taking place during the seismic event and post-seismic-settlement taking place after the seismic event.

Response

In loose saturated sands, seismically induced volume reductions are restricted from occurring due to the presence of the water. The tendency towards a more compact particle arrangement due to seismic shaking causes the pore water pressure to increase. Any excess residual pore water pressure will eventually dissipate along some drainage path after the earthquake. The sand permeability is not high enough to allow for an instantaneous dissipation of the excess pore water pressure. The rate of dissipation will depend on the drainage characteristics of the soil profile and complete dissipation may take from a few minutes to several hours after the earthquake has ended. See the following references: (1) Lee and Albaisa, "Earthquake Induced Settlements in Saturated Sands," Journal of the Geotechnical Engineering Division, ASCE, v.100, no. GT4, April 1974, (2) Seed, Martin and Lysmer, "The Generation and Dissipation of Pore Water Pressures During Soil Liquefaction," Report No. EERC 75-26, August 1975, and (3) Woodward-Clyde Consultants, "Report on the Results of Analyses Performed on Well 8 at the SONGS Units 2 and 3, San Onofre, California", forwarded by letter from K. P. Baskin (SCE) to R. Baer (NRC) dated August 25, 1978. The dissipation of this excess pore water pressure will be accompanied by volume reductions, and the corresponding settlements at the ground surface.

Two documented cases are discussed below to illustrate the timing of events: 1) the SONGS 2 and 3 Well 8 report; and 2) calculated and observed phenomena at Niigata, Japan in 1964. Case 1 is based on seismic response/pore water dissipation analysis of conditions similar to those prevalent at San Onofre Unit 1, and Case 2 is based on pore water dissipation as well as actual observation of earthquake response.

Case 1: Conditions similar to those existing at the SONGS 1 site are also encountered locally at the SONGS 2 and 3 site at some dewatering well locations (WCC's 1978 Report on the Results of the Analyses Performed on Well 8 at SONGS Units 2 and 3). The finite element model and the ground motion input for that analysis are shown in Figures 1 and 2.

Pore water pressure development and dissipation for the design earthquake (duration = 80 seconds) are shown for times: 12 seconds, 30 seconds, 80 seconds, 3 minutes, 30 minutes, and 60 minutes in Figures 3 through 8, respectively. Increasingly higher pore pressures were obtained at 12, 30, and 80 seconds during earthquake shaking (Figures 3 through 5). At time 3 minutes (about 2 minutes after shaking had ceased) the size of the liquefied zone decreased considerably (Figure 6) due to the dissipation of pore water pressures. At 30 minutes, the dissipation was considerable, with only a small area having r_u slightly higher than 0.5. At 60 minutes, the dissipation was completed. In this case, settlement would only occur in the cavity infill area and only upon dissipation of pore water pressure in this area within about 1 hour after the earthquake.

Case 2: A complete description of the generation and dissipation of pore water pressures at Niigata was presented by Seed, Martin, and Lysmer (1978). A summary of the calculated and observed surface phenomena, showing the dissipation of pore water pressures is presented in Figures 9 through 12 and Table 1. Signs of dissipation of pore water pressure were observed at the surface between 3 minutes and one-half hour after the earthquake, as indicated from actual observations documented in Table 1. This is in agreement with the results of analyses also documented in Table 1. Though the pore water pressures were being generated (Figures 10 through 12) during earthquake shaking, no surface observation (Table 1) of ground cracking, sand boils, or settlement occurred during this time because these phenomena are a result of pore water pressures being dissipated through drainage.

The timing of the settlements was also considered by the consulting board in estimating settlement as shown in Table 2. It was the consensus, considering the foundations are lightly loaded, that settlement of soils below the water table would occur after ground shaking has ceased and upon drainage of excess water pressures caused by liquefaction. It was the consensus of the consultants that the settlements of sand above the water table, however, would occur during seismic shaking because the volume change would not be restricted due to the presence of pore water.

Item 2

Degree of accuracy in estimating the settlement of loose granular fill due to SSE at this site.

Response

Seismically induced settlements at the site were estimated using the procedures presented in Appendix D of the soil conditions report submitted to the NRC by letter dated April 18, 1983. These procedures considered two conditions: 1) soil above the water table; and 2) soil below the water table. The backfill soils below each foundation were conservatively characterized based on the information available and the procedures indicated in Appendix D were applied to calculate settlements. After these calculations were made, the conditions of each foundation (the geometry and density of the backfill, the location of the water table, and the intensity of foundation loading) and the calculated settlements were reviewed with a consulting board comprised of Drs. I. M. Idriss, H. B. Seed, and R. L. McNeill. Each consultant was then asked for his conservative estimate of settlements for each foundation considering the data available. A summary of each consultants estimate for each foundation is presented in Table 2. Also, shown in Table 2 is the settlement documented for the various foundations in Table 5-1 of SCE's September 1, 1983 letter to the NRC. These estimates were considered conservative and accommodate variation expected from computed values. Where uncertainty or variations in subsurface conditions were greater, a more conservative range of values was given.

Item 3

Additional settlement, if any, caused by the footing load on loose granular fill during a SSE event.

Response

In considering the effects of the loading imposed by the various footings in Table 2 in the response to Item 1 above, it was noted that for soils above the water table, the presence of vertical load does not significantly affect settlements for a given induced shear strain (Silver and Seed, "Settlement of Dry Sands During Earthquakes", Journal of the Soil Mechanics and Foundation Division, ASCE, V.98, No. SM4, April 1972). For soils below the water table, the increase in pore water pressure due to liquification by definition accommodates all applied overburden and foundation pressures. Because the resulting settlement is only a function of relative density of the soil and the fact that liquefaction has occurred, the effects of foundation loads are automatically considered.

Item 4

Copy of a table presenting the settlement of structures due to a SSE event, as estimated by members of the review panel (Drs. H. Seed, I. Idriss and R. McNeill).

Response

See the response to Items 1 and 2 above.

Item 5

Plot of low and high bounds of shear modulus as a function of shear strain, used by Bechtel in the SSI analysis.

Response

The variation of soil properties used in soil structure interaction analysis has been discussed with the NRC in meetings on July 28 to 30, 1982 and November 10, 1982. Detailed information was also provided in SCE's letter to the NRC dated September 15, 1982.

Item 6

Provide available information regarding soil compaction in the vicinity of the diesel generator building.

Response

Information regarding soil compaction in the vicinity of the diesel generator building is provided in the attached report from Woodward-Clyde Consultants dated July 15, 1977.

Item 7

Provide justification or back-up data for the coefficients of earth pressure for the dynamic conditions used in the seawall analysis.

Response

The earth pressure coefficients were developed by Woodward-Clyde Consultants (WCC) in accordance with the information presented in Appendix B to SCE's letter from K. P. Baskin to D. M. Crutchfield dated September 15, 1982. The actual coefficients used in the seawall analysis were provided in letters from WCC dated November 30, 1981 and June 9, 1982. Copies of these two letters are attached.

Item 8

Perform a new equivalent static analysis by using the peak spectral acceleration multiplied by a factor of "1.5" as input. In addition, evaluate the adequacy of the seawall by modelling the wall as a vertical cantilever beam.

Response

The requested calculation is attached. This calculation concludes that the seawall meets the seismic reevaluation criteria.

Item 9

Provide the actual elevation of the top of seawall, particularly in the vicinity of the seawater intake conduit pipes.

Response

The elevation of the top of the seawall was verified by a field survey on March 16, 1984. The results of this survey are shown on Figure 13. The elevation of the top of the seawall was found in all cases to be above the design elevation of 28.2 feet.

Item 10

For the case of the seawall under tsunami loading, the analysis should include hydrostatic pressure on the sea side of the wall, between the elevations +5.0 ft. and 15.6 ft. Provide calculations to show the new (or revised) factor of safety.

Response

The material below the beach walkway on the ocean side of the seawall was considered to be saturated and the forces associated with this water pressure were accounted for in the analysis of the seawall. This is shown on page 16 of the calculations provided to the NRC at the February 8 and 9 meeting.

Item 11

Provide calculations for soil parameters in the vicinity of the seawall.

Response

Calculations of the soil parameters at the seawall are provided in a letter from Woodward-Clyde Consultants dated April 30, 1984. A copy of this letter is attached.

JLR:1182F

Table 1. Comparison of Computed Rate of Pore Pressure Development and Observations of Surface Phenomena at Niigata

Computed		Observed	
0-50 sec.	Earthquake	0-50 sec.	Earthquake
20-50 sec.	Liquefaction between depths of 15 and 40 ft.	0-50 sec.	Liquefaction at some depth below ground surface
1-4 min.	Development of essentially liquefied condition between depths of 3 and 15 ft.		
≃5 min.	At depth of 3 ft. water pressure becomes equal to overburden pressure. Cracks likely to develop in top 3 ft. of soil with water boiling up through cracks and cavities.	≃3 min.	Ground cracking and some eruptions of water near school building
≃12 min.	Water table rises to ground surface. Water emerges generally from ground surface. Surface becomes 'quick'.	≃8 min.	Sudden upward flow of water in cracked area.
		≃13 min.	Heavy water flow at surface to heights of above 3 ft.
≃17 min.	Pore pressures begin to drop at ground surface--surface begins to stabilize but water continues to flow to surface.	≃14 min.	Several inches of water accumulated on ground surface.
≃60 min.	Pore pressure ratio in all layers has dropped to 0.1 to 0.3. All soils stablized but small flow of water continues at surface.	≃28 min.	Water still flowing at ground surface.

ESTIMATED SETTLEMENT RESPONSE OF FILL UNDER EQUIPMENT FOUNDATIONS AND STRUCTURAL COMPONENTS

Settlement (inches)

Item Number	Description	Table 5-1 Soil Conditions Report: During Seismic Shaking	Table 5-1 Soil Conditions Report: Total	Consultants Evaluation (IMI - I. M. Idriss; HBS - H. B. Seed; RLM - R. L. McNeill) 7 April 1983 Meeting: During Seismic Shaking			After Seismic Shaking			Total			Notes
				IMI	HBS	RLM	IMI	HBS	RLM	IMI	HBS	RLM	
1	Aux. Feedwater Pumps	1	2-3	1	1	1	1-1/2	1-1/2	1	2-3	2	2	
2	Aux. Feedwater Pumps	1/2 - 1	1-1/2	1	1/2	1/2	1-1/2	1	see note	2-3	1-1/2	1/2	Potential tilting toward north
3	E-W Duct Bank, East of Intake Structure	1/2	3-5	<1/2	<1/2	<1/2	3-5	3-5	3-5	3-5	3-5	3-5	
4	Air Compressor	*	*	*	*	*	0	0	0	*	*	*	
5	Air Receivers	*	*	*	*	*	0	0	0	*	*	*	
6	Duct Bank to North Tsunami Gate	1/2	3-5	1/2 - 1	1/2	1/2	3-5	3-5	3-5	3-5	3-5	3-5	
7	Motor Control #3	1-1/2	1-1/2	1	1	1	*	*	*	1	1	1	
8	Conduit Duct Bank	1-1/2	1-1/2	1/2	1/2	1/2	*	*	*	1/2	1/2	1/2	Potential for tilting toward southwest
9	Turbine Coolers	1′	3-5	1	1	1	1-2	2-5	2-5	2-3	3-6	3-5	
10	Intake Culverts	*	3-5	*	*	*	3-4	4-5	3-4	3-4	4-5	3-4	
11	Spent Fuel Pit Pump	1	1	1	1	1		see note		1	1	1	Potential for tilting toward north
12	Refueling Water Pump	1	1	1	1	1		see note		1	1	1	Potential for tilting toward north
13	Pipe Tunnel	1/2	2	1/2	1/2	1/2	1-1/2	1-1/2	1-1/2	2	2	2	
14	480V Switchgear Room	1	2-3	1	1	1	2	1-1/2	1-1/2	2-3	2	2-1/2	
15	Column Footing for Piping Supports	1	2-3	1	1	1	2	1-1/2	1-1/2	3	2-1/2	2-1/2	
16	Column Footing for Piping Supports	1	2-3	1	1	1	2	1-1/2	1-1/2	3	2-1/2	2-1/2	
17	Column Footing for Piping Supports	*	*	*	*	*	*	*	*	*	*	*	
18	Column Footing for Piping Supports	*	*	*	*	*	*	*	*	*	*	*	
19	Column Footing for Piping Supports	*	*	*	*	*	*	*	*	*	*	*	
20	Column Footing for Piping Supports	1	1 - 2-1/2	1	1	1	0 - 1-1/2	0 - 1-1/2	0 - 1-1/2	1 - 2-1/2	1 - 2-1/2	1 - 2-1/2	Potential for tilting north
21	Column Footing for Piping Supports	1/4	1/4	1/4	1/4	1/4	-	-	-	1/4	1/4	1/4	
22	N-S Duct Bank, East of Intake	1/2	2	1/2	1/2	1/2	1-1/2 - 2	1-1/2	1-1/2	2	2	2	
23	Refueling Water Storage Tank	1 1/2	1 1/2	1	1	1	-	-	-	1	1	1	
24	Aux. Feedwater Piping Trench	1/2	3-5	1/2	1/2	1/2	3-4	3-5	3-5	3-4	3-5	3-5	
25	Aux. Feedwater Tank	*	*	*	*	*	*	*	*	*	*	*	
26	Salt Water Cooling Line	*	3-5	*	*	*	4-6	4-5	3-5	4-6	4-5	3-5	
27**	Refueling Water Filter Pump and Refueling Water Filter	1/2	1/2										Potential for tilting north
Vent Building		(see Figure 4-2b)		use 1% of thickness of soil above the water table			use 1-1/2% of thickness of soil below the water table			summation of during and after seismic shaking			
Sea Wall		*	3-6	*	*	*	3-5	4-5	4-5	3-5	4-5	4-5	No impact on seawall because this type of seawall was developed to accommodate differential movements much larger than 3 to 5 inches without structural distress

* negligible < 1/4 inch

** this equipment not considered during 7 April 1983 meeting

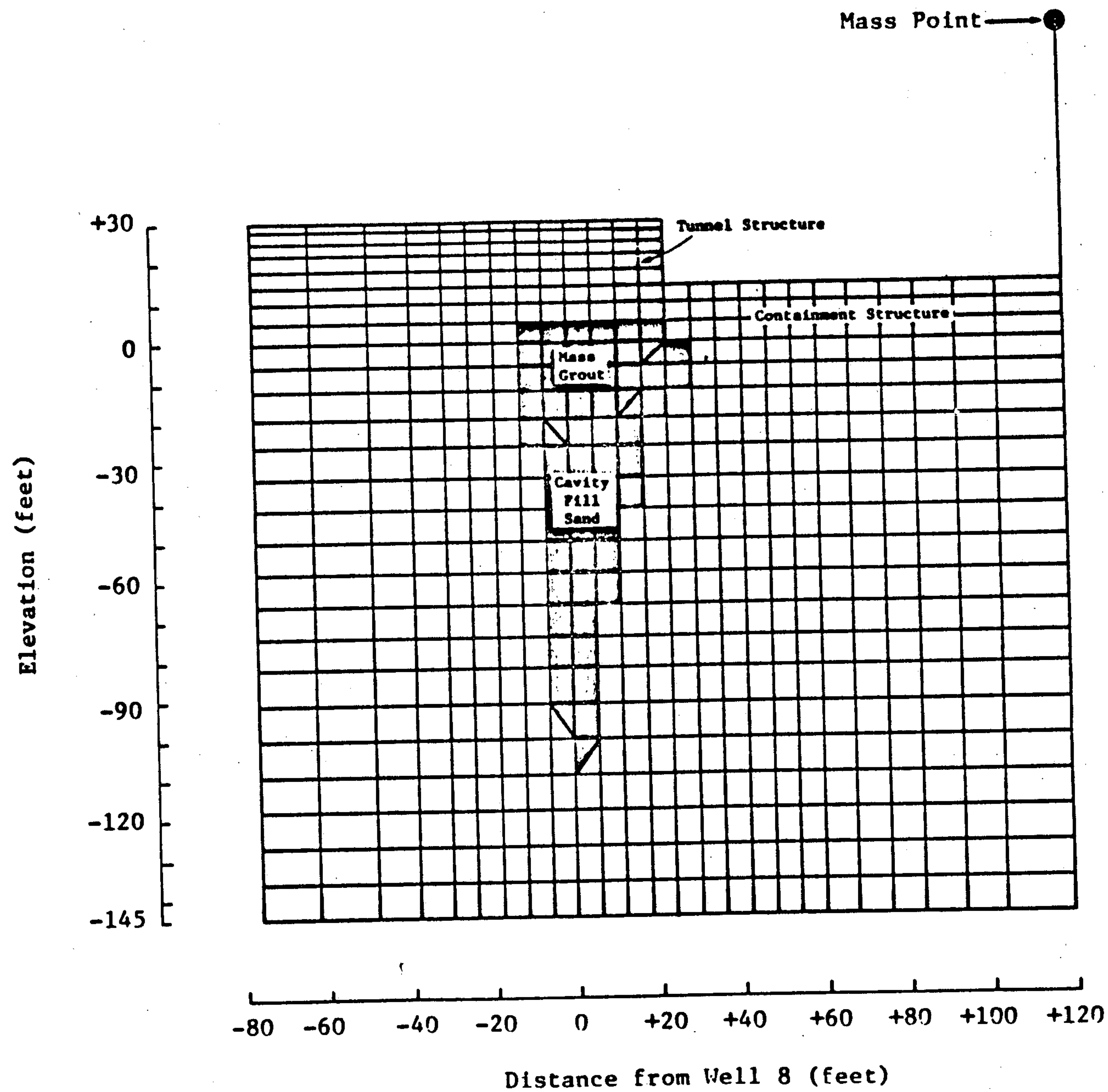


Fig. 1 FINITE ELEMENT MESH USED IN ANALYSIS

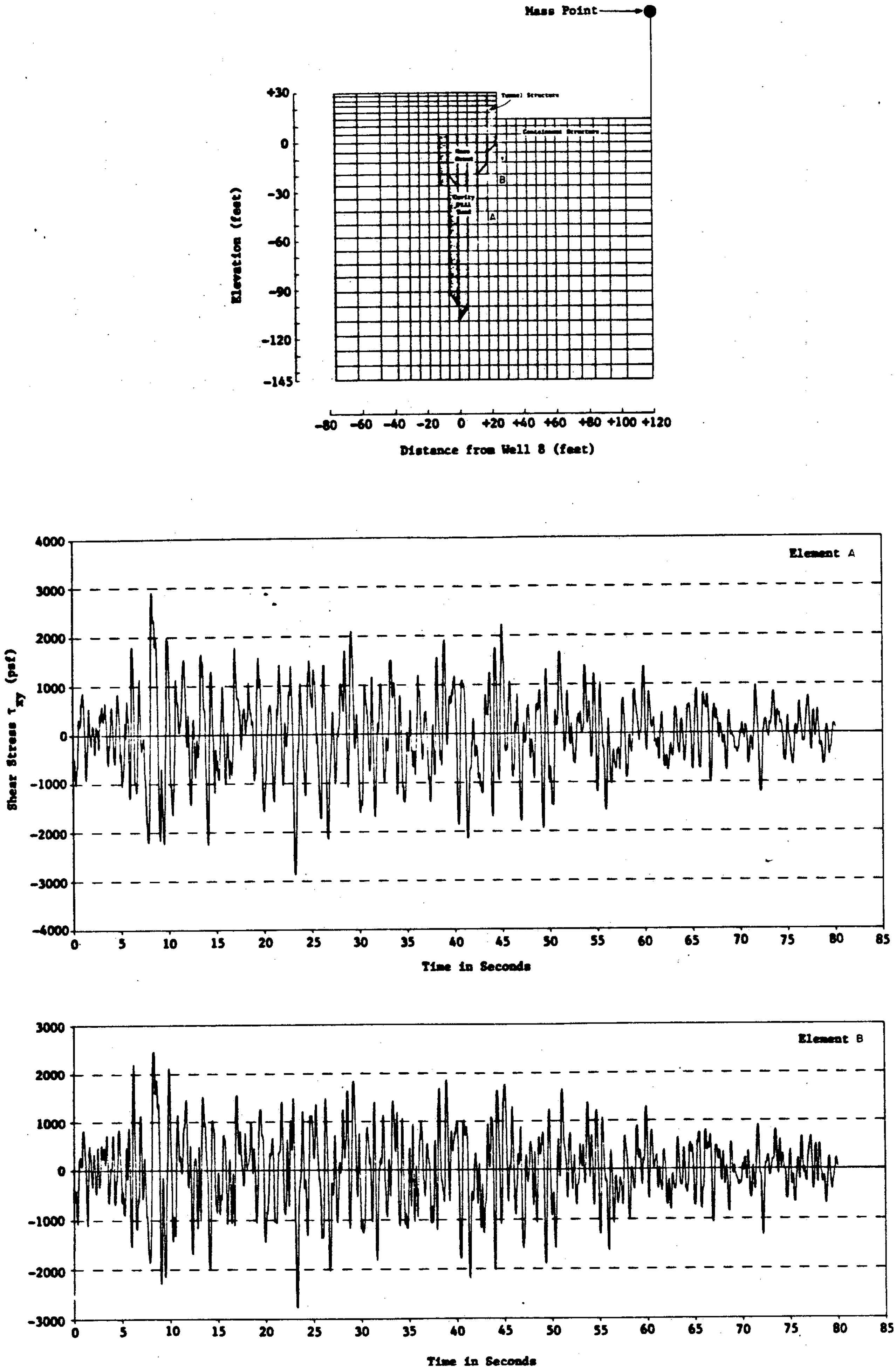


Fig. 2 TYPICAL TIME HISTORIES OF SHEAR STRESSES AT SELECTED ELEMENTS

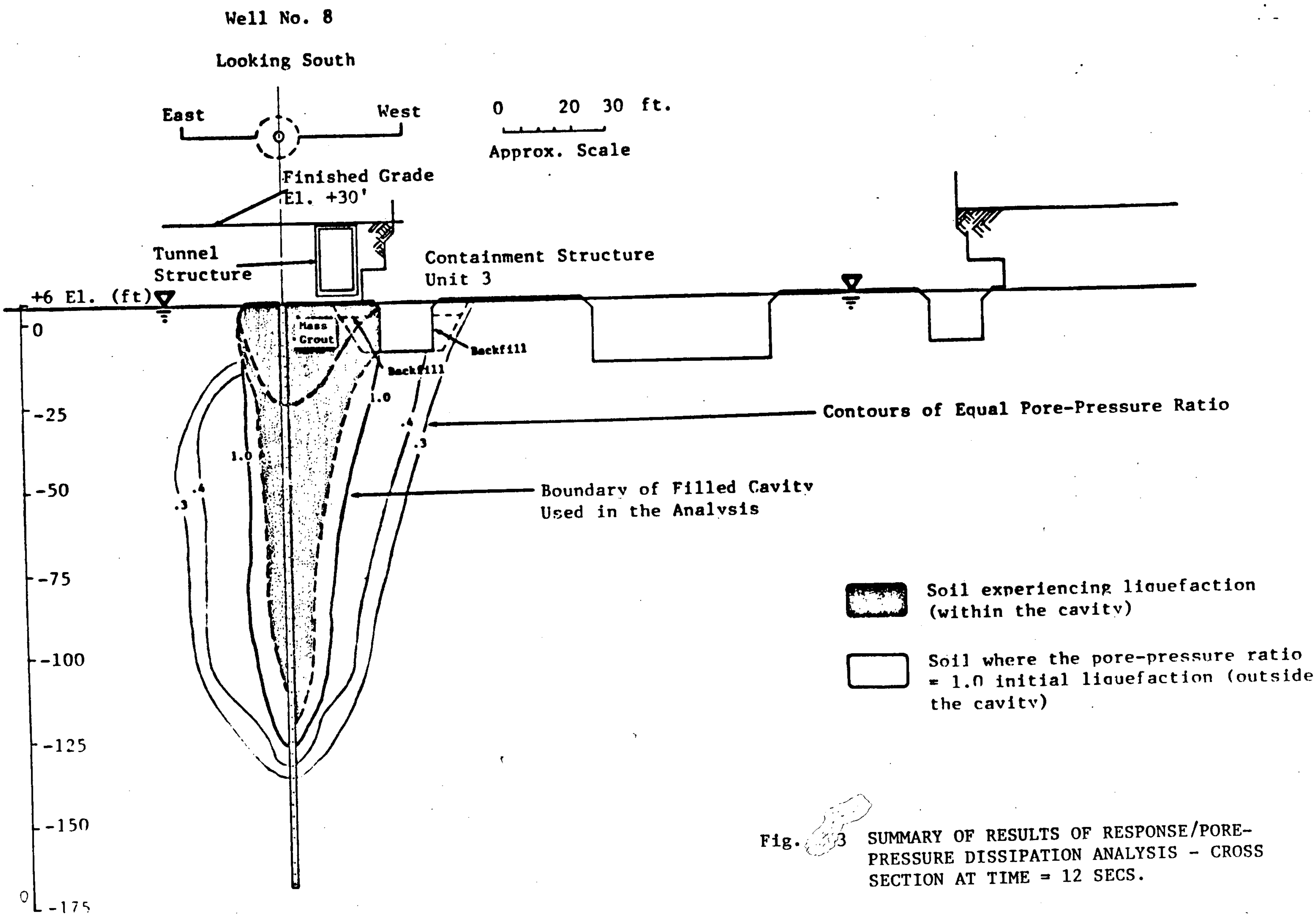


Fig. 3 SUMMARY OF RESULTS OF RESPONSE/PORE-PRESSURE DISSIPATION ANALYSIS - CROSS SECTION AT TIME = 12 SECS.

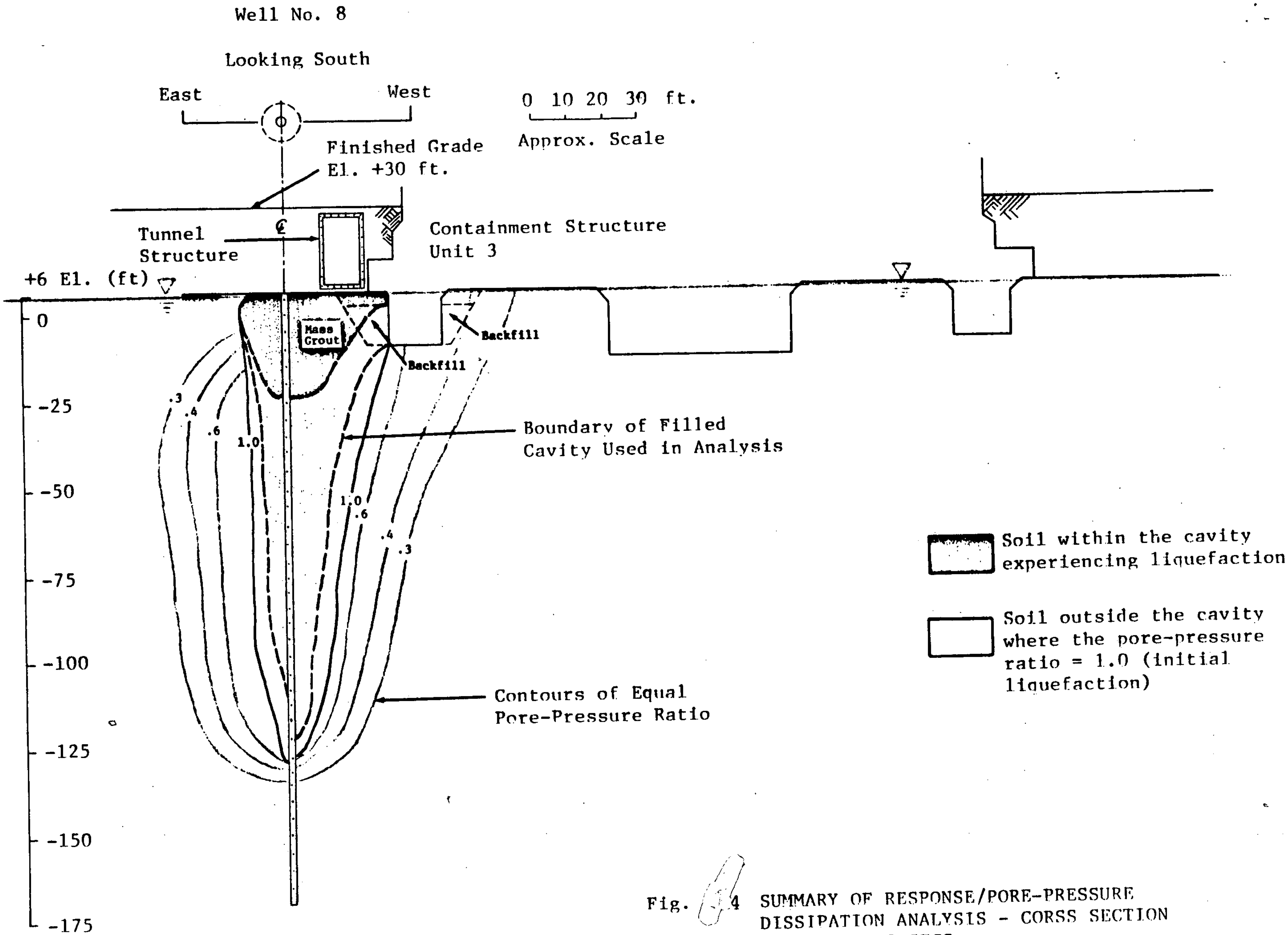


Fig. 4 SUMMARY OF RESPONSE/PORE-PRESSURE DISSIPATION ANALYSIS - CORSS SECTION AT TIME = 30 SECS.

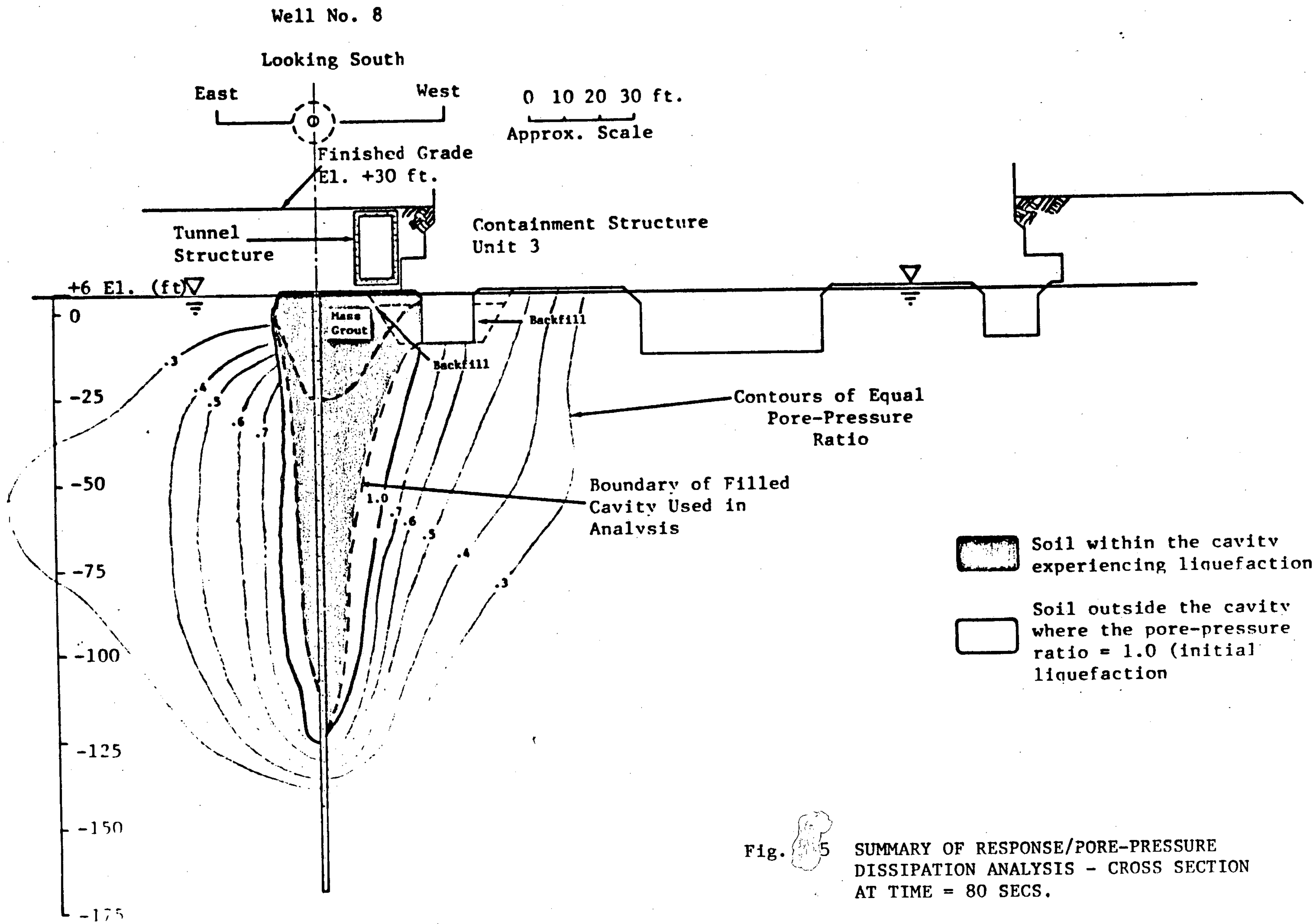


Fig. [illegible]5 SUMMARY OF RESPONSE/PORE-PRESSURE DISSIPATION ANALYSIS - CROSS SECTION AT TIME = 80 SECS.

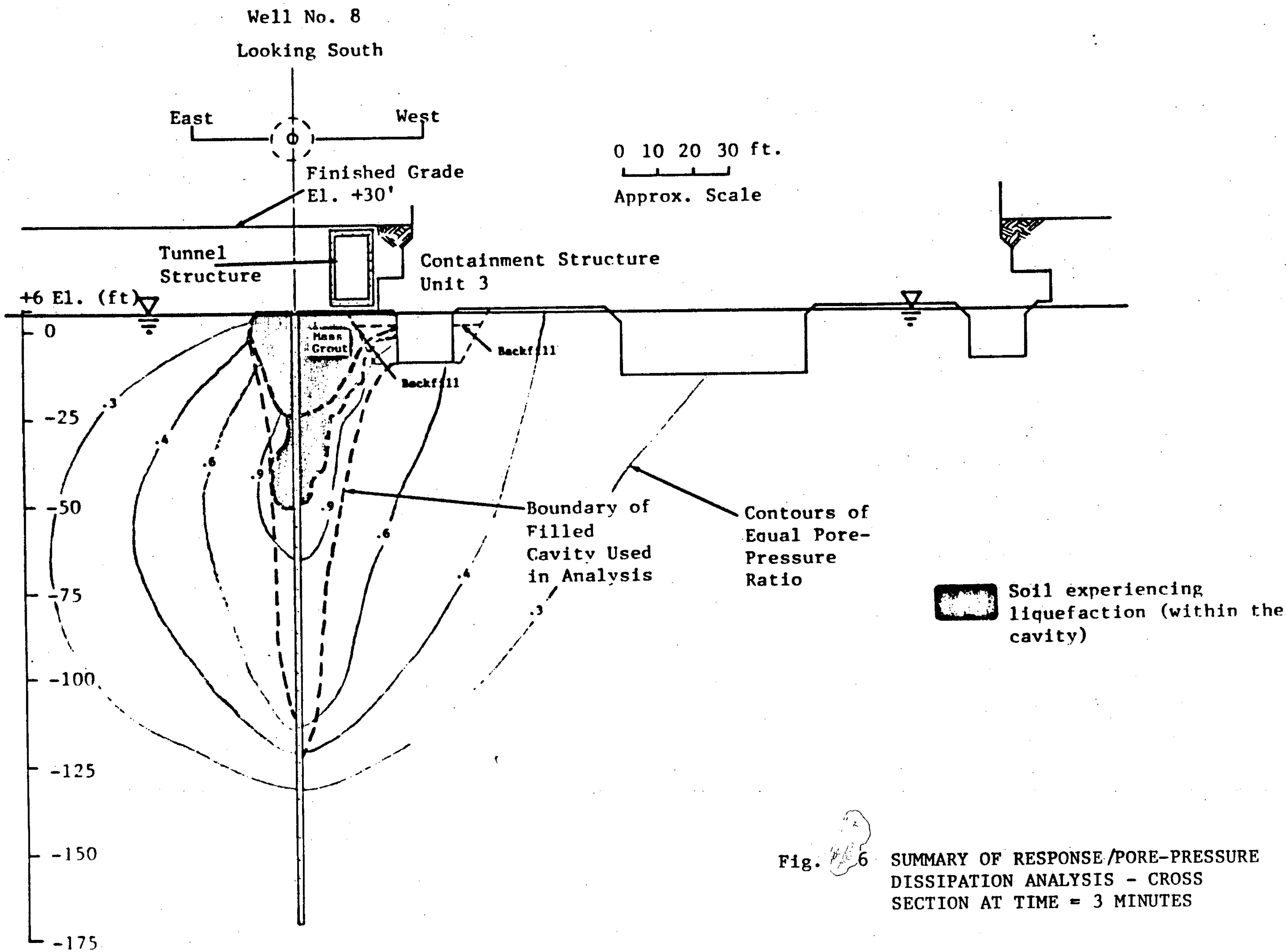


Fig. 6 SUMMARY OF RESPONSE/PORE-PRESSURE DISSIPATION ANALYSIS - CROSS SECTION AT TIME = 3 MINUTES

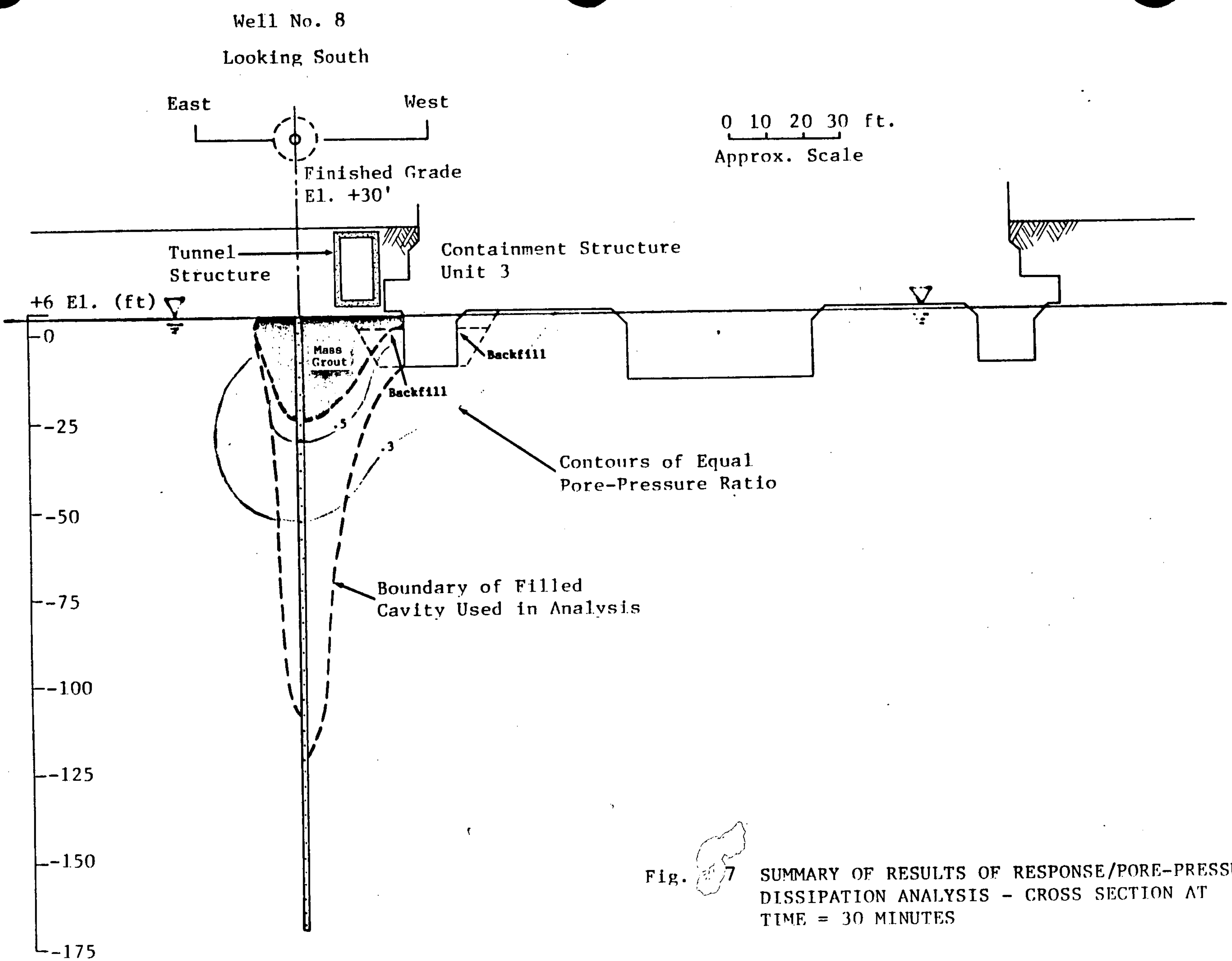


Fig. 7 SUMMARY OF RESULTS OF RESPONSE/PORE-PRESSURE DISSIPATION ANALYSIS - CROSS SECTION AT TIME = 30 MINUTES

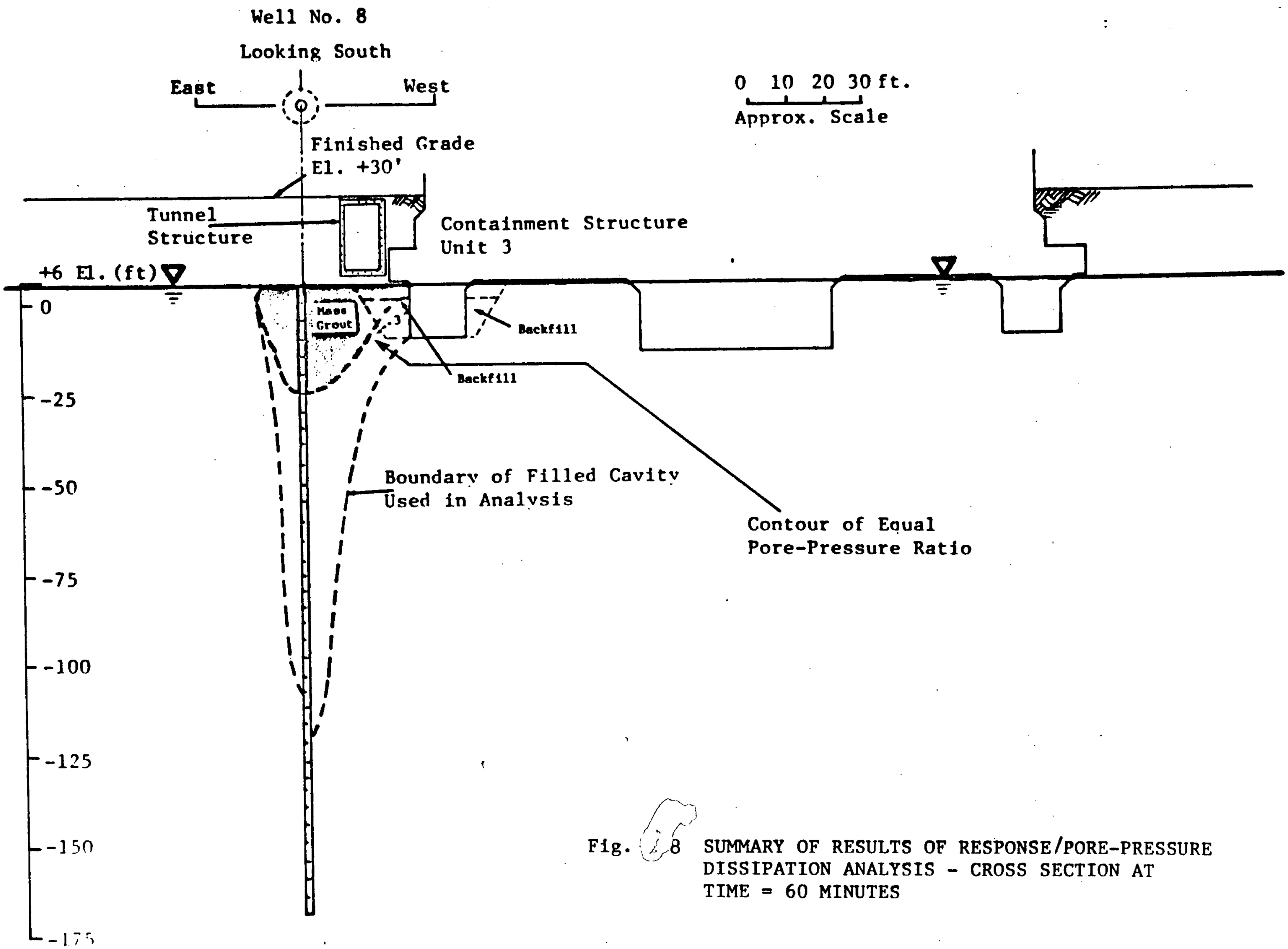


Fig. 8 SUMMARY OF RESULTS OF RESPONSE/PORE-PRESSURE DISSIPATION ANALYSIS - CROSS SECTION AT TIME = 60 MINUTES

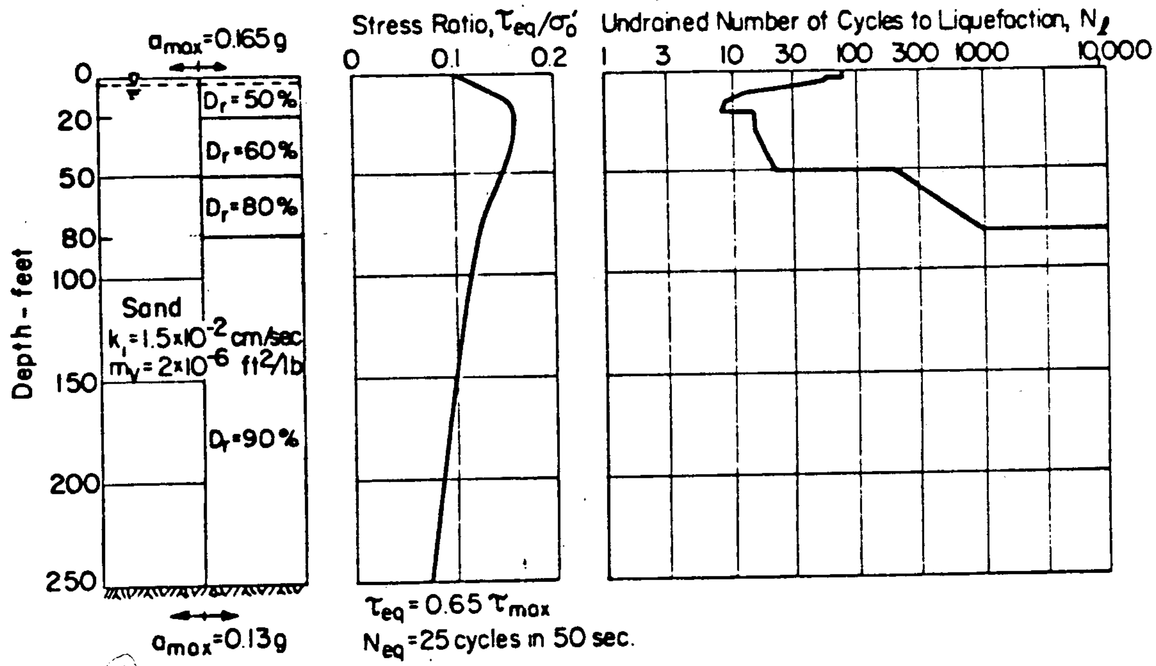


Fig. 9 SOIL PROFILE AND STRESS CONDITIONS USED FOR ANALYSIS.

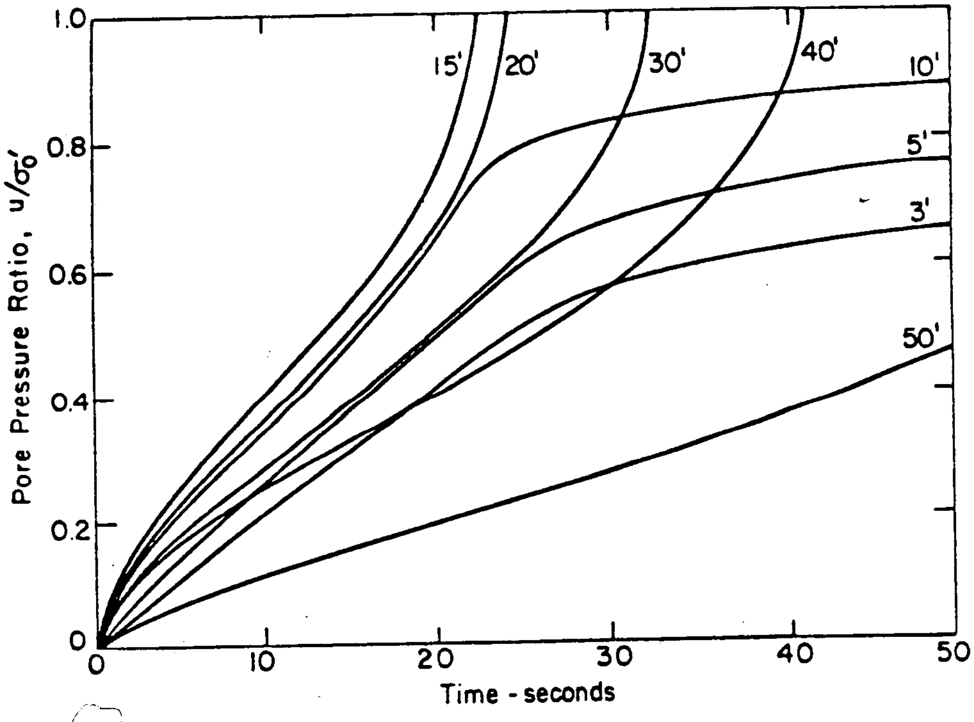


Fig. 10 COMPUTED DEVELOPMENT OF PORE WATER PRESSURES DURING EARTHQUAKE SHAKING FOR SOIL PROFILE SHOWN IN Fig. 9.

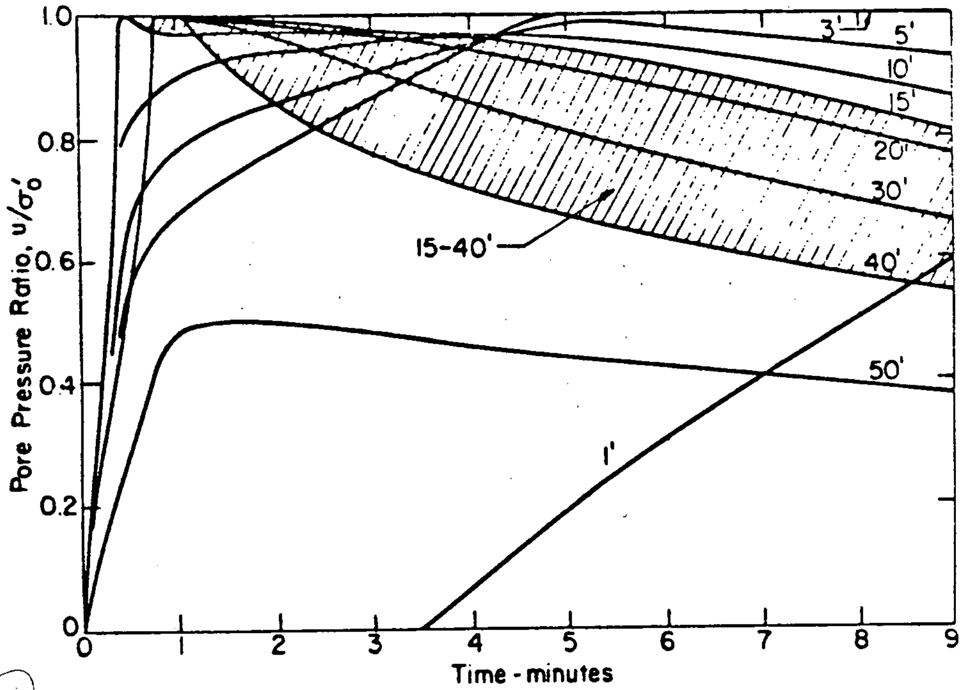


Fig. 11 COMPUTED VARIATION OF PORE WATER PRESSURES IN 8 MINUTE PERIOD FOLLOWING EARTHQUAKE FOR SOIL PROFILE SHOWN IN Fig. 9

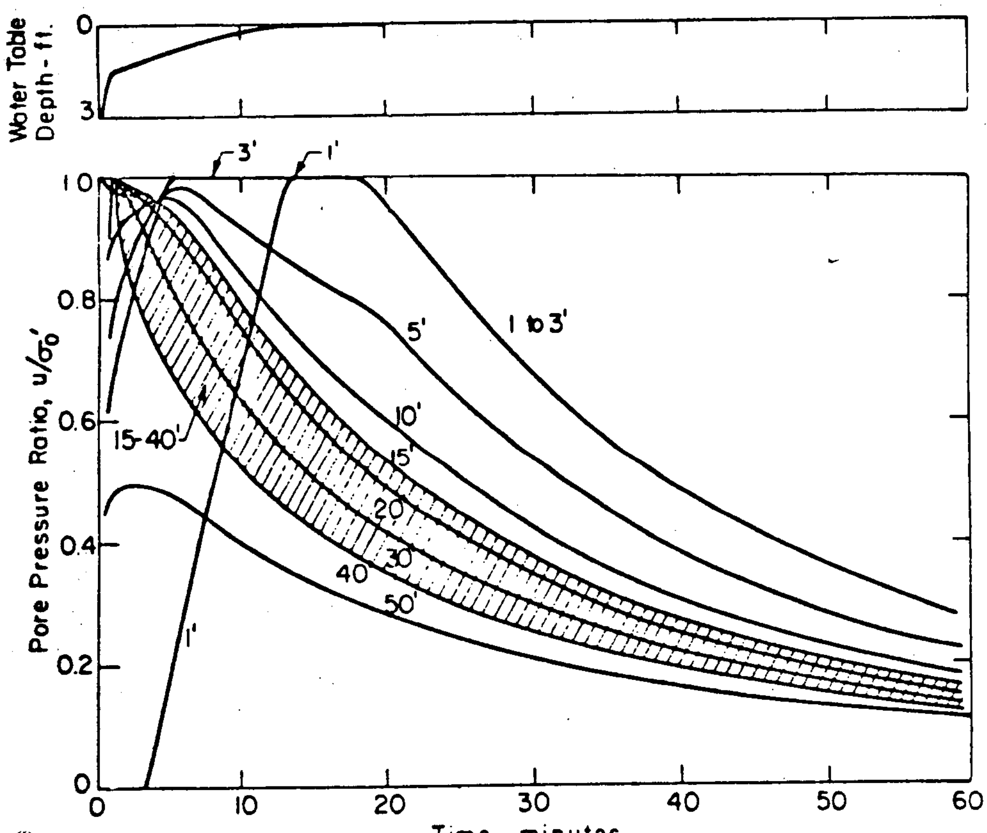


Fig. 12 COMPUTED VARIATION OF PORE WATER PRESSURES IN 60 MINUTE PERIOD FOLLOWING EARTHQUAKE FOR SOIL PROFILE SHOWN IN Fig. 9.

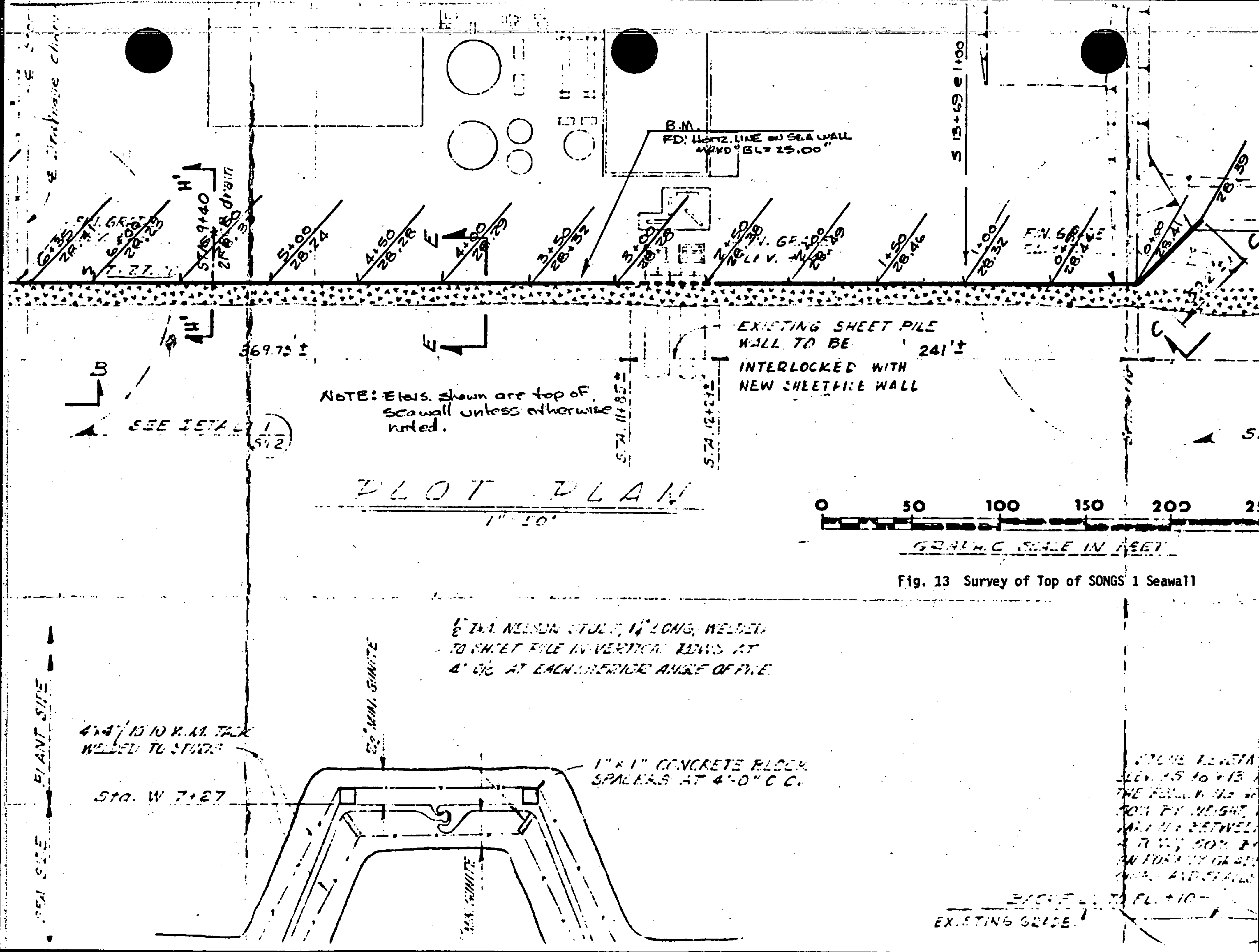


Fig. 13 Survey of Top of SONGS 1 Seawall

Post Office Box 1149
4000 West Chapman Avenue
Orange, California 92668
714-634-4440

Hilton Center
900 Wilshire Boulevard, Suite 404
Los Angeles, California 90017
213-581-7164

Woodward-Clyde Consultants

15 July 1977
B684F

Southern California Edison
P. O. Box 800
Rosemead, California 91770

Attention: Mr. John C. Yen

SUBJECT : SOIL TESTING SERVICES PROVIDED DURING CONSTRUCTION OF SONGS UNIT 1 STANDBY POWER ADDITION SAN ONOFRE, CALIFORNIA

Gentlemen:

As authorized under your Purchase Order No. U0695003, and in accordance with the scope of services presented in our letter of 1 Jan 76, soil testing services have been provided for the subject project. This report presents a description of the soil testing services provided, earthwork performed, test results, and other pertinent data.

Soil Testing Services

1. An experienced soils technician observed and tested backfill placement on an as-required basis, in accordance with the project specifications (82-6220 and S023-210-14). Field work performed by the soils technician was supervised by a project engineer. Observations by these personnel were made of all structural subgrade areas and areas to receive backfill.

2. All soil testing services for safety-related construction were performed in accordance with the Woodward Clyde Consultants (WCC) Soil Testing Services Quality Control Manual for Quality Class II Construction, SONGS Units 2 and 3, Rev. 1, dated 1 May 75 (and all updates as applicable). This manual has been reviewed and approved by SCE Quality Assurance personnel for use on this project.

3. Laboratory tests were performed in support of field testing, as required.

4. Documentation of daily activities was provided by photographs and by preparation of a daily written report which included a description of work in progress, test results and other pertinent data. The photographs and originals of field reports are maintained in our files. Copies of the daily field reports were submitted to Mr. R. Paz of SCE on site during construction.

Earthwork

Soils testing services for this project began on 26 Sep 75 and were completed on 13 May 77. The initial phases of earthwork primarily involved making excavations in native undisturbed San Mateo Sand to provide foundations for structures. All foundation excavations were carefully inspected to verify conditions, and field density tests were made to determine in-situ soil density. These tests indicated 122 to 125 pcf, which represent a relative compaction (ASTM D-1557-70) of 101 to 104%. Test results are included on Table 1.

Other primary excavations included those for underground diesel fuel storage tanks and utility ducts. In each of these areas the invert level was inspected and tested as required.

After placement of structures in each of the areas discussed above, backfill was placed and compacted. Compaction equipment included a vibratory sheepsfoot roller pulled by a bulldozer, and hand compaction equipment (rollers, wackers, powder-puffs). All areas which received backfill were inspected by Bechtel QC personnel who then directed WCC personnel to inspect, probe, and test the backfill. All field test results are summarized on Table 1. An explanation of abbreviations used on Table 1 is given on Table 2. Test locations are given on Fig. 1.

Concrete was placed in lieu of soil as backfill in some locations on the site (to expedite construction). Bechtel QC has recorded the locations of concrete backfill.

It is our understanding that Quality Class 2 backfill placement has been completed for this project. All test results and inspections made indicate this backfill has been compacted to the specified density. We understand there are some surficial non-safety related areas in which backfill has not yet been compacted to the specified density. However, we also understand this compaction will be done under a separate maintenance contract by others.

We have enjoyed working with your staff on this important project. If you have any questions, or require further information, please contact the undersigned at your convenience.

Very truly yours,

John A. Barneich

Andrew M. Worswick

JAB:AMW:ls
Attachments

TABLE 1

Field Data [illegible]eet

Sheet No: 1

Job Name: SONGS DIESEL GENERATOR BUILDING

Job Number: B684F

1975 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Req. %	Drawing No., Spec.	Quality Class.
Sep 26	1			S10+35 W3+00	Storm drain	14	118	10	SC	120	99	95	5149204	2 *2
"	2			S7+40 W2+90	Temp. Access (subg.)	23	118	6	"	"	98	90	"	" *1,2,5
"	3			S8+15 W3+00	" " "	20	117	10	"	"	98	"	"	" *1,2,5
"	4			S8+60 W3+60	" " "	17	115	9	"	"	96	"	"	" *1,2,5
"	5			S8+30 W2+00	Temp. Ramp	23	116	10	"	"	97	95	"	" *1,2,5
"	6			S8+80 W2+25	" "	20	118	8	"	"	98	"	"	" *1,2,5
Sep 30	7			S10+00 W2+90	O.G.	19	124	2	"	"	103	--	"	O.G.
Oct 01	8			S9+60 W3+60	"	19	122	3	"	"	101	--	"	O.G.
Oct 08	9			S9+50 W3+22	Bldg. Pad	16	119	8	"	"	99	95	"	2 *2
"	10			S10+02 W3+74	" "	16	122	8	"	"	102	"	"	" *2
"	11			S9+13 W3+63	" "	17	121	9	"	"	101	"	"	" *2
Oct 09	12			S9+23 W3+16	" "	18	121	9	"	"	101	"	"	" *2
Oct 10	13	14		S9+13 W2+40	Site Area	17	113	9	"	"	94	"	"	" *2
"	14		13	S9+13 W2+40	" "	17	117	9	"	"	97	"	"	" *2
Oct 14	15			S9+85 W3+00	Bldg. Pad	19	120	8	"	"	100	"	"	" *2
"	16			S9+18 W3+00	" "	19	126	8	"	"	105	"	"	" *2
Oct 15	17			S10+25 W2+90	Front Admin. Bldg.	19	117	6	"	"	97	"	"	" *2
"	18	19		S11+10 W3+10	Storm Drain	19	111	7	"	"	93	"	"	" *2
Oct 16	19		18	S11+10 W3+10	" "	19	125	9	"	"	103	"	"	" *2
"	20			S8+35 W2+65	Near Guard Gate	22	124	8	"	"	104	"	"	" *2
"	21			S11+40 W3+10	Storm Drain	19	122	9	"	"	102	"	"	" *2

Remarks: *1 Temporary backfill *2 Test requested by SCE *5 Area tested as directed by SCE

O.G. Original Ground

Class 1 & 2 Reviewed By: ____________

Class 3 & 4 Reviewed By: ____________

TABLE 1 ([illegible]'d)

Field Dat[illegible]eet

Sheet No: 2

Job Name: SONGS DIESEL GENERATOR BUILDING

Job Number: B684F

1975 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Reg. %	Drawing No., Spec.	Quality Class.
Nov 04	22			S9+85 W3+70	F.P. Trench	17	120	6	SC	120	100	95	5149204	2 *2
Nov 05	23			S9+50 W2+78	" "	19	114	5	"	"	95	90	"	" *2
Nov 10	24			S10+25 W3+40	Fire hydrant area	19	114	5	"	"	95	95	"	" *2
Nov 12	25			S10+20 W3+30	O.G.	13	125	4	"	"	104	D.V.	"	O.G.
Nov 13	26	27		S8+50 W2+60	Fire Protection Sys.	19	110	3	"	"	92	95	"	2 *2
"	27	28	26	S8+50 W2+60	" " "	19	112	6	"	"	94	"	"	" *2
Nov 14	28		27	S8+50 W2+60	" " "	19	124	7	"	"	103	"	"	" *2
"	29			S8+80 W3+45	Fire hydrant area	19	115	6	"	"	96	"	"	" *2
"	30			S10+30 W2+70	Fire Protection Sys.	19	119	9	"	"	99	"	"	" *2
Nov 17	31			S10+45 W3+75	Steam Line	17	119	5	"	"	99	"	"	" *2
"	32			S8+25 W2+85	Fire Protection Sys.	18	115	5	"	"	96	"	"	" *2
Nov 18	33			S8+80 W2+45	" " "	19	120	6	"	"	100	"	"	" *2
Nov 24	34			S9+10 W3+20	Sump Excavation	3	123	11	"	"	103	"	"	" *2
Dec 16	35			S9+00 W2+96	" "	6	120	9	"	"	100	"	"	" *2
"	36			S9+10 W3+25	" "	8	118	4	"	"	98	"	"	" *2
Dec 17	37	38		S9+10 W3+15	Sump Tank	10	109	7	"	"	91	"	"	" *2
"	38		37	S9+10 W3+15	" "	10	116	8	"	"	96	"	"	" *2
Dec 18	39	40		S8+92 W3+05	" "	12	111	7	"	"	93	"	"	" *2
"	40		39	S8+92 W3+05	" "	12	125	9	"	"	104	"	"	" *2
Dec 24	41			S9+00 W3+20	" "	14	114	9	"	"	95	"	"	" *2
Dec 30	42			S10+30 W3+30	Manhole 715 & 707	11	118	8	"	"	99	"	"	" *2

Remarks: *2 Test requested by SCE O.G. Original Ground

Class 1 & 2 Reviewed By: ______

Class 3 & 4 Reviewed By: ______

TABLE 1 (Cont'd)

Field Data Sheet

Sheet No: 3

Job Name: SONGS DIESEL GENERATOR BUILDING

Job Number: B684F

1975 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Reg. %	Drawing No., Spec.	Quality Class.
Dec 31	43			S10+05 W3+20	Manhole 705 & 706	13	125	9	SC	120	104	95	5149204	2 *2
"	44			S9+95 W3+08	" " "	15	123	7	"	"	102	"	"	" *2
1976 Jan 02	45			S9+95 W3+20	" " "	17	125	11	"	"	104	"	"	" *2
Jan 05	46			S10+27 W3+25	Manhole 707 & 715	19	126	9	"	"	105	"	"	" *2
Jan 09	47			S9+50 W3+85	Manhole 701	13	127	9	"	"	105	"	"	" *2
"	48			S9+20 W3+90	Manhole 702	13	125	8	"	"	104	"	"	" *2
Jan 12	49			S9+15 W3+90	" "	15	126	7	"	"	105	"	"	" *2
"	50			S9+45 W3+90	Manhole 701	15	125	6	"	"	104	"	"	" *2
Jan 13	51			S10+25 W3+25	Manhole 707 & 715	13	120	6	"	"	100	"	"	" *2
Jan 14	52			S9+00 W3+10	Sump Fill	16	125	6	"	"	104	"	"	" *2
"	53			S10+40 W3+30	Manhole 715	15	123	6	"	"	102	"	"	" *2
Jan 15	54			S9+20 W3+10	Sump Fill	15	126	5	"	"	105	"	"	" *2
"	55			S10+40 W3+25	Manhole 715	17	114	6	"	"	95	"	"	" *2
Jan 19	56			S10+10 W3+90	Manhole 703	12	130	8	"	"	108	"	"	" *2
Jan 22	57			S9+00 W3+00	Sump Fill	16	121	9	"	"	101	"	"	" *2
Feb 03	58			S10+04 W3+76	Manhole 714	13	115	6	"	"	96	"	"	" *2
Feb 04	59			S9+50 W2+95	East footing	14	111	7	"	"	92	"	"	" *2
Feb 05	60			S10+05 W3+77	Manhole 714	15	126	7	"	"	105	"	"	" *2
"	61			S9+70 W3+82	Electrical trench	16	120	8	"	"	100	"	"	" *2
Feb 06	62			S9+50 W3+86	Manhole 701	15	118	9	"	"	98	"	"	" *2
Feb 09	63			S10+30 W3+81	Electrical trench	20	121	7	"	"	101	"	"	" *2

Remarks: *2 Test requested by SCE

Class 1 & 2 Reviewed By:

Class 3 & 4 Reviewed By:

TABLE 1 (Cont'd)

Field Data Sheet

Sheet No: 4

Job Name: SONGS DIESEL GENERATOR BUILDING

Job Number: B684F

1976 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Req. %	Drawing No., Spec.	Quality Class.
Feb 11	64			S9+50 W2+95	East footing	14	122	10	SC	120	101	95	5149204	2 *2
"	65			S10+25 W3+80	Manhole 703	18	124	7	"	"	103	"	"	" *2
Feb 13	66			S9+65 W3+90	East footing	16	124	8	"	"	103	"	"	" *2
"	67			S9+35 W3+80	Electrical trench	19	126	7	"	"	105	"	"	" *2
Feb 17	68			S9+60 W2+90	East footing	18	117	5	"	"	98	"	"	" *2
Feb 18	69			S9+20 W3+85	Manhole 702	18	127	8	"	"	105	"	"	" *2
Feb 24	70			S9+85 W3+20	Manhole 705	18	121	8	"	"	101	"	"	" *2
Mar 02	71			S10+15 W3+45	South footing	17	122	8	"	"	101	"	"	" *2
Mar 03	72			S10+20 W3+75	" "	18	120	7	"	"	100	"	"	" *2
"	73			S9+00 W3+73	North footing	18	121	9	"	"	101	"	"	" *2
Mar 04	74			S8+80 W3+70	" "	19	121	9	"	"	100	"	"	" *2
Mar 10	75			S11+64 W3+37	Manhole 708 & 709	11	124	5	"	"	103	"	"	" *6
"	76			S11+66 W3+38	" " "	13	114	6	"	"	95	"	"	" *6
Mar 12	77			S11+65 W3+37	" " "	15	125	6	"	"	104	"	"	" *6
Mar 15	78			S11+67 W3+36	" " "	17	126	9	"	"	105	"	"	" *6
Mar 29	79	81		S12+20 W3+80	Manhole 711	7	104	4	"	"	87	"	"	" *6
"	80			S12+15 W3+80	" "	8	117	4	"	"	97	"	"	" *6
Apr 05	81		79	S12+20 W3+80	" "	7	115	7	"	"	96	"	"	" *6
"	82			S10+68 W3+35	Electrical trench	19	117	7	"	"	97	"	"	" *6
"	83			S12+15 W3+80	Manhole 711	9	119	9	"	"	99	"	"	" *6
"	84			S10+48 W3+27	Electrical trench	19	117	5	"	"	98	"	"	" *6

Remarks: *2 Test requested by SCE *6 Test requested by SCE QC

Class 1 & 2 Reviewed By: ____________

Class 3 & 4 Reviewed By: ____________

TABLE 1 (Cont'd)

WOODWARD-CLYDE CONSULTANTS

Field Data Sheet

Sheet No: 5

Job Name: SONGS DIESEL GENERATOR BUILDING

Job Number: B684F

1976 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Req. %	Drawing No., Spec.	Quality Class.
Apr 05	85			S9+75 W2+94	East footing	17	120	7	SC	120	100	95	5149204	2 *2
Apr 06	86			S9+12 W3+00	Manhole 708 & 709	17	114	6	"	"	95	"	"	" *6
Apr 08	87			S19+12 W3+00	North footing	17	123	7	"	"	102	"	"	" *2
Apr 19	88			S11+70 W3+65	Electrical trench	17	119	4	"	"	99	"	"	" *6
Apr 21	89			S12+15 W3+86	Manhole 711	11	114	5	"	"	95	"	"	" *6
"	90			S12+27 W3+80	" "	13	116	8	"	"	96	"	"	" *6
Apr 23	91			S12+25 W3+85	" "	15	124	8	"	"	103	"	"	" *6
"	92			S12+20 W3+92	" "	17	117	10	"	"	97	"	"	" *6
Apr 26	93			S12+24 W3+88	" "	19	120	6	"	"	100	"	"	" *6
Apr 27	94			S11+68 W3+77	Electrical trench	19	122	5	"	"	102	"	"	" *6
Apr 28	95			S9+35 W3+73	Fire line trench	17	114	6	"	"	95	"	"	" *2
"	96			S12+16 W3+75	Manhole 710	9	117	10	"	"	97	"	"	" *6
Apr 29	97			S9+83 W3+75	Fire line trench	17	121	10	"	"	101	"	"	" *2
May 06	98	99		S14+20 W5+57	Waste line trench	14	112	6	"	"	93	"	"	3 & 4 *6
"	99	100	98	S14+20 W5+57	" " "	14	110	5	"	"	92	"	"	" *6
"	100		99	S14+20 W5+57	" " "	14	116	8	"	"	97	"	"	" *6
May 07	101			S14+09 W5+60	" " "	16	116	8	"	"	96	"	"	" *6
"	102	103		S14+20 W5+10	" " "	16	112	5	"	"	93	"	"	" *6
May 10	103		102	S14+20 W5+10	" " "	16	115	4	"	"	96	"	"	" *6
"	104			S14+20 W5+13	" " "	18	119	9	"	"	99	"	"	" *6
"	105			S9+65 W3+73	Fire Protection Line	19	120	5	"	"	100	"	"	2

Remarks: *2 Test requested by SCE *6 Test requested by SCE QC

Class 1 & 2 Reviewed By: ____________

Class 3 & 4 Reviewed By: ____________

TABLE 1 (Cont'd)

Field Data Sheet

Job Name: SONGS DIESEL GENERATOR BUILDING

Sheet No: 6

Job Number: B684F

1976 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Reg. %	Drawing No., Spec.	Quality Class.
May 11	106			S12+18 W3+17	Manhole 712	11	114	7	SC	120	95	95	5149204	2 *6
May 12	107	108		S12+10 W3+24	" "	13	110	5	"	"	92	"	"	" *6
"	108		107	S12+10 W3+24	" "	13	122	7	"	"	102	"	"	" *6
May 13	109			S12+07 W3+20	" "	15	114	7	"	"	95	"	"	" *6
"	110			S13+48 W5+60	Waste line trench	15	121	8	"	"	101	"	"	" *6
May 14	111			S14+20 W4+90	" " "	17	120	9	"	"	100	"	"	3 & 4 *6
"	112			S14+20 W4+99	" " "	19	121	9	"	"	101	"	"	" *6
May 18	113			S12+16 W3+70	Manhole 710	11	114	5	"	"	95	"	"	" *6
May 19	114	115		S12+07 W3+81	" "	13	108	5	"	"	90	"	"	2 *6
"	115		114	S12+07 W3+81	" "	13	123	7	"	"	102	"	"	" *6
May 20	116			S12+18 W3+77	" "	15	118	9	"	"	98	"	"	" *6
May 21	117			S12+12 W3+80	" "	17	122	8	"	"	101	"	"	" *6
"	118			S12+07 W3+75	" "	19	120	9	"	"	100	"	"	" *6
May 24	119			S11+50 W3+15	Electrical trench	19	123	5	"	"	102	"	"	" *6
Jun 03	120			S12+12 W3+60	" "	14	113	4	"	"	95	"	"	" *6
Jun 08	121			S12+11 W3+56	" "	18	117	3	"	"	98	"	"	" *6
Jun 16	122			S9+90 W2+57	Fuel tank (south)	5	121	8	"	"	101	100	"	" *6
"	123			S10+13 W3+00	" " "	5	120	5	"	"	100	"	"	" *2
Jun 17	124			S9+80 W2+70	" " "	7	123	8	"	"	103	95	"	" *2
"	125			S10+20 W2+84	" " "	7	119	9	"	"	99	"	"	" *2
"	126			S19+80 W2+55	" " "	9	117	9	"	"	98	"	"	" *2

Remarks: *2 Test requested by SCE *6 Test requested by SCE QC

Class 1 & 2 Reviewed By: ____

Class 3 & 4 Reviewed By: ____

TABLE 1 (Co d) Field Data S et Sheet No:

Job Name: SONGS DIESEL GENERATOR BUILDING Job Number: B684F

1976 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Req. %	Drawing No., Spec.	Quality Class.
Jun 17	127			S10+25 W3+05	Fuel tank (south)	9	120	9	SC	120	100	95	5149204	2 *2
Jun 18	128			S9+95 W2+85	" " "	11	119	8	"	"	99	"	"	" *2
"	129			S10+10 W2+72	" " "	11	124	8	"	"	103	"	"	" *2
"	130			S10+15 W2+90	" " "	13	121	9	"	"	101	"	"	" *2
"	131			S9+80 W2+60	" " "	13	120	9	"	"	100	"	"	" *2
Jun 21	132			S10+38 W2+97	" " "	15	115	7	"	"	96	"	"	" *2
"	133	134		S9+74 W2+66	" " "	15	111	7	"	"	92	"	"	" *2
"	134		133	S9+74 W2+66	" " "	15	115	9	"	"	96	"	"	" *2
Jun 22	135			S10+04 W2+92	" " "	17	111	7	"	"	97	"	"	" *2
"	136			S9+94 W2+75	" " "	19	121	12	"	"	100	"	"	" *2
Jun 23	137			S9+95 W2+85	Oil sump trench	16	119	8	"	"	99	"	"	" *2
Jun 24	138			S12+23 W3+12	EMH #713	11	125	8	"	"	104	"	"	" *6
"	139			S12+18 W3+05	" "	13	120	9	"	"	100	"	"	" *6
"	140			S12+15 W3+13	" "	15	115	9	"	"	96	"	"	" *6
Jun 28	141			S12+20 W3+03	" "	17	121	8	"	"	101	"	"	" *6
Jul 12	142			S11+74 W3+09	Electrical trench	17	118	8	"	"	98	"	"	" *6
Jul 19	143			S12+20 W3+37	" "	17	115	5	"	"	96	"	"	" *6
Jul 21	144			S8+75 W3+03	Fuel tank (north)	5	123	7	"	"	102	100	"	" *2
"	145			S9+20 W2+68	" " "	5	124	7	"	"	103	"	"	" *2
"	146			S8+95 W2+70	" " "	7	124	11	"	"	103	95	"	" *2
"	147			S9+00 W2+90	" " "	7	127	11	"	"	106	"	"	" *2

Remarks: *2 Test requested by SCE *6 Test requested by SCE QC

Class 1 & 2 Reviewed By:

Class 3 & 4 Reviewed By:

TABLE 1 (C[illegible]'d)

Field Data Sheet

Sheet No: 8

Job Name: SONGS DIESEL GENERATOR BUILDING

Job Number: B684F

1976 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Req. %	Drawing No., Spec.	Quality Class.
Jul 21	148			S9+80 W2+57	Fuel tank (north)	9	121	7	SC	120	101	95	5149204	2 *2
"	149			S8+89 W3+02	" " "	9	121	7	"	"	101	"	"	" *2
Jul 22	150			S8+87 W2+75	" " "	11	120	6	"	"	100	"	"	" *2
"	151			S9+11 W2+81	" " "	11	114	8	"	"	95	"	"	" *2
"	152			S9+10 W2+50	" " "	13	121	11	"	"	100	"	"	" *2
"	153			S8+90 W2+90	" " "	13	122	11	"	"	102	"	"	" *2
Jul 23	154			S8+93 W3+02	" " "	15	123	8	"	"	102	"	"	" *2
"	155			S9+10 W2+49	" " "	17	115	2	"	"	96	"	"	" *2
Jul 26	156			S9+82 W2+57	Fuel pipe trench	16	119	8	"	"	99	"	"	" *2
"	157			S9+04 W2+96	Fuel water riser	17	120	9	"	"	100	"	"	" *2
"	158			S9+01 W2+63	Fuel tank (north)	19	119	8	"	"	99	"	"	" *2
Jul 28	159			S9+88 W2+73	Fuel pipe trench	18	121	10	"	"	101	"	"	" *2
Aug 02	160			S9+90 W3+68	West footing	19	126	8	"	"	105	"	"	" *2
"	161			S9+45 W2+62	Anode wire trench	19	125	9	"	"	104	"	"	" *2
Aug 09	162			S13+65 W3+10	Electrical trench	17	120	7	"	"	100	"	"	3 & 4 *2
Aug 13	163			S13+70 W3+15	" "	19	125	7	"	"	104	"	"	" *2
Aug 14	164	165		S11+28 W4+06	Manhole 716 & 717	3	113	5	"	"	95	100	"	2 *2
Aug 15	165		164	S11+28 W4+06	" " "	3	120	4	"	"	100	"	"	" *2
Aug 17	166			S10+22 W2+97	Air vent	16	124	7	"	"	103	95	"	" *2
"	167			S9+18 W2+63	Fuel line	15	125	8	"	"	104	"	"	" *2
"	168			S9+06 W2+73	" "	17	118	7	"	"	98	"	"	" *2

Remarks: *2 Test requested by SCE

Class 1 & 2 Reviewed By: ____________

Class 3 & 4 Reviewed By: ____________

TABLE 1 (Cont'd) Field Data Sheet Sheet No: 9

Job Name: SONGS DIESEL GENERATOR BUILDING Job Number: B684F

1976 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Reg. %	Drawing No., Spec.	Quality Class.
Aug 18	169			S9+24 W2+86	Fuel line	17	117	6	SC	120	97	95	5149204	2 *2
Aug 20	170			S10+16 W2+93	Air vent	18	123	8	"	"	102	"	"	" *2
Aug 25	171			S14+04 W2+93	Waste line trench	17	120	10	"	"	100	"	"	3 & 4 *2
"	172			S13+37 W2+93	" " "	17	117	8	"	"	98	"	"	" *2
Aug 26	173	175		S11+07 W2+93	" " "	17	108	5	"	"	90	"	"	" *2
"	174			S13+42 W3+11	Manhole 105	15	114	7	"	"	95	"	"	" *2
"	175		173	S11+07 W2+93	Waste line trench	17	118	8	"	"	98	"	"	" *2
Aug 27	176			S11+50 W2+93	" " "	19	120	7	"	"	100	"	"	" *2
"	177			S13+56 W2+93	" " "	19	115	6	"	"	95	"	"	" *2
"	178			S13+70 W3+19	Manhole 105	17	115	6	"	"	96	"	"	" *2
"	179			S12+78 W2+93	Waste line trench	16	101	7	"	"	84	"	"	" *2*7
Aug 30	180			S12+92 W3+15	Electrical trench	17	114	7	"	"	95	"	"	" *2
"	181			S12+59 W3+18	" "	17	118	6	"	"	98	"	"	" *2
"	182			S8+77 W2+97	Air vent	16	118	8	"	"	98	"	"	2 *2
"	183			S8+84 W2+92	" "	18	124	9	"	"	103	"	"	" *2
Aug 31	184			S14+06 W3+82	Waste line trench	16	115	9	"	"	96	"	"	3 & 4 *2
"	185			S12+37 W2+93	" " "	17	120	8	"	"	100	"	"	" *2
"	186			S11+89 W2+93	" " "	19	119	5	"	"	100	"	"	" *2
Sep 02	187			S13+03 W2+93	" " "	17	120	8	"	"	100	"	"	" *2
"	188			S14+00 W2+93	" " "	17	119	11	"	"	99	"	"	" *2
Sep 03	189			S11+42 W3+77	4KV trench	10	122	8	"	"	102	"	"	2 *2

Remarks: *2 Test requested by SCE *7 Soil removed

Class 1 & 2 Reviewed By: ______

Class 3 & 4 Reviewed By: ______

TABLE 1 (Cont'd)

Field Data Sheet

Sheet No: 10

Job Name: SONGS DIESEL GENERATOR BUILDING

Job Number: B684F

1976 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Reg. %	Drawing No., Spec.	Quality Class.
Sep 04	190	191		S11+25 W4+20	Manhole 716 & 717	5	111	5	SC	120	93	100	5149204	2 *2
"	191		190	S11+25 W4+20	" " "	5	122	5	"	"	102	"	"	" *2
"	192			S11+28 W4+10	" " "	7	114	8	"	"	95	95	"	" *2
"	193			S11+19 W3+76	4KV trench	12	120	6	"	"	100	"	"	" *2
"	194			S11+28 W4+20	Manhole 716 & 717	9	123	9	"	"	103	"	"	" *2
"	195			S11+00 W3+78	4KV trench	10	119	11	"	"	99	"	"	" *2
Sep 07	196			S11+11 W3+77	" "	12	115	12	"	"	96	"	"	" *2
Sep 11	197			S12+29 W3+88	UPS trench	12	108	5	"	"	90	"	"	" *2*7
Sep 13	198			S12+31 W3+88	" "	14	120	9	"	"	100	"	"	" *2
Sep 16	199			S10+29 W2+84	Waste line trench	17	119	7	"	"	99	"	"	" *2
Sep 21	200			S9+11 W4+77	Balcony footing	19	116	5	"	"	97	"	"	" *2
Sep 22	201			S11+16 W4+09	Manhole 716 & 717	7	118	8	"	"	98	"	"	" *2
Sep 23	202			S11+17 W4+07	" " "	9	122	7	"	"	102	"	"	" *2
Sep 25	203			S10+74 W4+40	UPS trench	11	124	9	"	"	103	"	"	" *2
Sep 27	204			S12+41 W3+92	" "	15	118	7	"	"	98	"	"	" *2
Sep 30	205			S13+63 W5+65	Fire line trench	13	122	8	"	"	102	"	"	" *2
Oct 01	206			S14+49 W5+57	" " "	19	120	8	"	"	100	"	"	" *2
"	207			S14+84 W5+97	" " "	26	117	8	"	"	97	"	"	" *2
"	208			S14+73 W5+53	" " "	19	114	11	"	"	95	"	"	" *2
Oct 02	209			S14+77 W5+52	" " "	21	114	6	"	"	95	"	"	" *2
Oct 04	210			S14+75 W5+53	" " "	23	124	9	"	"	103	"	"	" *2

Remarks: *2 Test requested by SCE *7 Soil removed

Class 1 & 2 Reviewed By: ____________

Class 3 & 4 Reviewed By: ____________

TABLE 1 (Cont'd)

Field Data Sheet

Sheet No: 11

Job Name: SONGS DIESEL GENERATOR BUILDING

Job Number: B684F

1976 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Reg. %	Drawing No., Spec.	Quality Class.
Oct 04	211			S13+70 W5+64	Fire line trench	15	120	6	SC	120	100	95	5149204	2 *2
"	212			S14+82 W5+54	" " "	25	117	9	"	"	98	"	"	" *2
"	213			S14+79 W5+53	" " "	27	120	7	"	"	100	"	"	" *2
"	214			S14+84 W5+56	" " "	29	114	8	"	"	95	"	"	" *2
Oct 07	215			S11+30 W3+90	UPS trench	13	114	8	"	"	95	"	"	" *2
"	216			S11+27 W4+36	" "	7	120	9	"	"	100	"	"	" *2
Oct 11	217			S13+75 W3+14	Manhole 105	19	119	8	"	"	99	"	"	3 & 4 *2
Oct 12	218			S11+21 W3+97	UPS trench	13	121	7	"	"	101	"	"	2 *2
Oct 18	219			S11+28 W4+36	" "	10	121	7	"	"	101	"	"	" *2
Oct 20	220			S11+27 W4+19	" "	12	117	9	"	"	98	"	"	" *2
"	221			S12+68 W5+68	Waste line trench	13	118	4	"	"	98	"	"	3 & 4 *2
Oct 22	222			S11+00 W4+40	UPS trench	13	120	8	"	"	100	"	"	2 *2
Oct 28	223			S11+55 W5+33	Feed water footing	11	124	3	"	"	103	"	"	" *2
"	224			S11+58 W5+36	" " "	12	121	10	"	"	101	"	"	" *2
Dec 16	225			S13+73 W5+60	Oil sump trench	13	123	9	"	"	102	"	"	3 & 4 *2
1977 Jan 05	226			S9+00 W3+15	Electrical trench	19	122	9	"	"	101	"	"	2 *2
Jan 11	227	228		S12+12 W3+34	Root drain	18	108	6	"	"	90	"	"	" *2
Jan 12	228		227	S12+12 W3+34	" "	18	121	9	"	"	100	"	"	" *2
Jan 18	229			S8+82 W2+99	Cathodic protection	18	124	10	"	"	103	"	"	" *2
Jan 20	230			S9+19 W2+63	" "	19	124	5	"	"	103	"	"	" *2
Jan 21	231			S9+62 W2+92	" "	17	121	8	"	"	100	"	"	" *2

Remarks: *2 Test requested by SCE

Class 1 & 2 Reviewed By: ____________

Class 3 & 4 Reviewed By: ____________

TABLE 1 (Cont'd)

Field Data Sheet

Sheet No: 13

Job Name: SONGS DIESEL GENERATOR BUILDING

Job Number: B684F

1977 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Req. %	Drawing No., Spec.	Quality Class.
Mar 03	253			S8+83 W2+95	Valve box	16	124	12	SC	120	103	95	5149204	2 *2
Mar 04	254			S8+82 W2+95	" "	18	124	5	"	"	103	"	"	" *2
Mar 14	255			S8+66 W2+61	Ramp area	23	126	8	"	"	105	"	"	" *2
Mar 24	256			S10+57 W2+93	Oil sump line	18	124	6	"	"	103	"	"	" *2
Apr 05	257	258		S9+07 W2+83	Fuel tank valve	19	112	5	"	"	93	"	"	" *2
Apr 06	258		257	S9+07 W2+83	" " "	19	119	6	"	"	99	"	"	" *2
Apr 12	259			S9+55 W3+97	Catch basin	19	125	5	"	"	104	"	"	" *2
"	260			S8+95 W4+77	Drain line	19	120	4	"	"	100	"	"	" *2
May 13	261			S14+06 W3+96	Oil sump line	17	115	8	"	"	95	"	"	3 & 4 *2

Remarks: *2 Test requested by SCE

Class 1 & 2 Reviewed By: ______

Class 3 & 4 Reviewed By: ______

TABLE 2

EXPLANATION OF ABBREVIATIONS USED ON TABLE 1

Location

D.V. - Design Verification in O.G.
O.G. - Original Ground
EMH# - Electrical Manhole

Method (Type of Density Test)

S.C. - Sand Cone (D1556-64-ASTM)

Grid Number

S - South
W - West

Coordinate keyed to SCE grid system

Footnotes

*1 Temporary backfill
*2 Test requested by SCE
*3 Specification requirement (%) as stated by SCE
*4 Test Method - U.S. Bureau of Reclamation E-24
*5 Area tested as directed by SCE Construction
*6 Test requested by SCE QC
*7 Soil removed

203 North Golden Circle Drive
Santa Ana, California 92705
(714) 835-6886
(213) 581-7164
Telex 68-3420

Woodward-Clyde Consultants

30 November 1981
Project No. 41352I-0001

Southern California Edison
P. O. Box 800
Rosemead, California 91770

Attention: Mr. C. M. Knarr

SUBJECT: SOIL PARAMETERS FOR SEAWALL ANALYSIS
BOPS - SEISMIC REEVALUATION PROGRAM
SONGS UNIT 1
SAN ONOFRE, CALIFORNIA

Gentlemen:

As requested in your letter of November 18, 1981, we have reviewed the soil parameters for seawall analysis presented in the attachment to that letter. We concur with the parameters presented except for the effective unit weight of backfill below water table on the sea side, for Load Case 1-Seismic Conditions. As recommended in our letter of 3 August 1981, the total unit weight of the backfill below water on sea side of the wall should be 125 psf or the effective unit weight of that backfill should be 61 pcf in place of 46 pcf indicated in your letter.

If you have any questions, please call.

Very truly yours,

Jagdish N. Mathur

Jagdish N. Mathur

JNM/ea

Southern California Edison Company

P.O. BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

November 18, 1981

Mr. Jagdish N. Mathur
Woodward-Clyde Consultants
203 North Golden Circle Drive
Santa Ana, California 92705

Dear Mr. Mathur:

Subject: Soil Parameters for Seawall Analysis
BOPS - Seismic Reevaluation Program
SONGS - Unit 1

The attachment to this letter summarizes our October 29th, 1981 discussion on the soil parameters to be used for the subject analysis. We will be completing the analysis using these parameters in November, 1981.

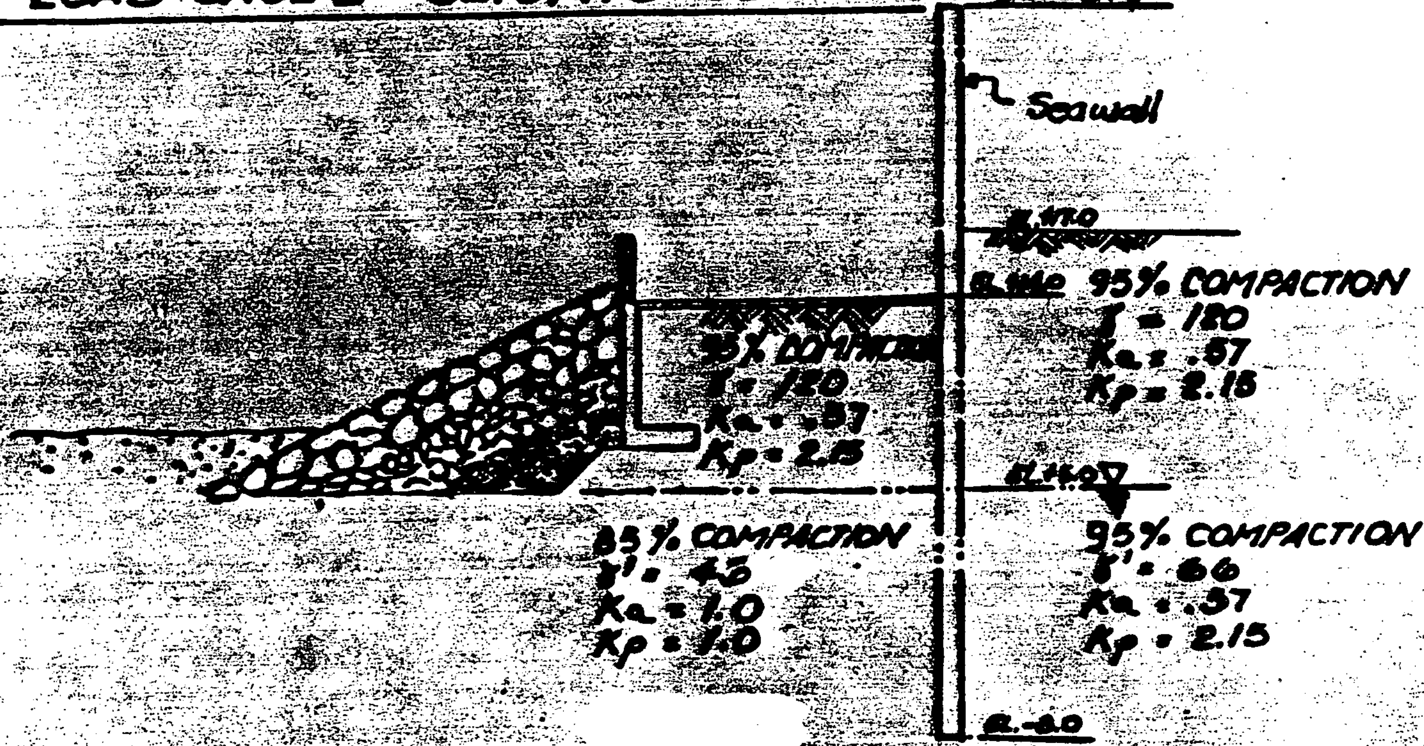
If you have questions or comments, please reply by November 30, 1981.

Sincerely,

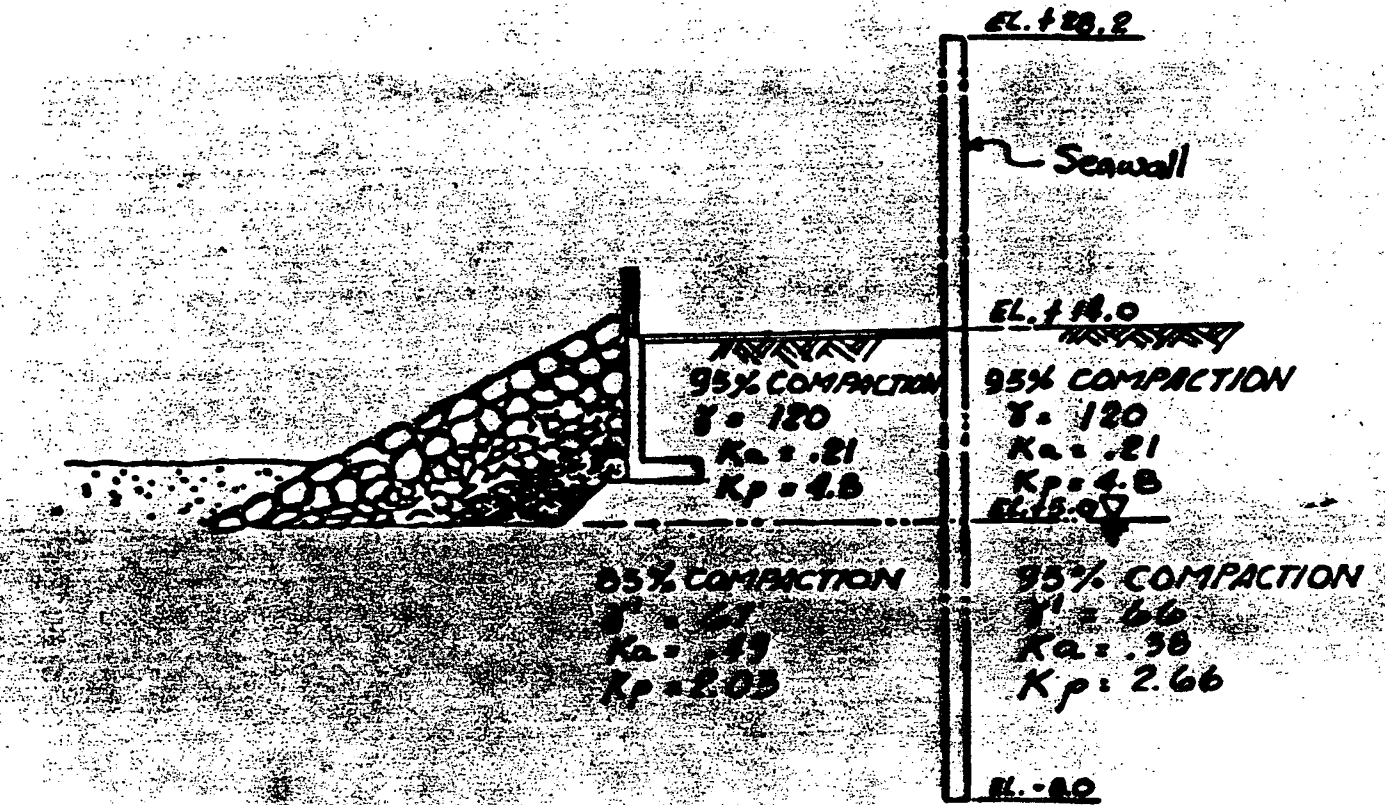
C. M. Knarr

Enclosure

LOAD CASE I - SEISMIC CONDITION



LOAD CASE II - POST SEISMIC CONDITION



203 North Golden Circle Drive
Santa Ana, California 92705
(714) 835-6886
(213) 581-7164
Telex 68-3420

Woodward-Clyde Consultants

9 June 1982
Project No. 41352I-001A

Southern California Edison
P. O. Box 800
Rosemead, California 91770

Attention: Mr. C. M. Knarr

SUBJECT: SOIL PARAMETERS FOR SEAWALL ANALYSIS
BOPS - SEISMIC REEVALUATION PROGRAM
SONGS UNIT 1
SAN ONOFRE, CALIFORNIA

Gentlemen:

As requested in your letter of 1 June 1982, we have reviewed the soil parameters to calculate lateral pressures on the seawall for seismic and post-seismic conditions. Our review indicates that the parameters for the seismic conditions are appropriate. For post seismic condition, the parameters for the below-water soil on plant-side are appropriate for conditions immediately after the seismic event when the soil may be in a condition of initial liquefaction. As time elapses after the seismic event, the excess pore-water pressures in the soil would dissipate and the coefficient of active pressure, k_a, would decrease and that of passive resistance, k_p, would increase. Thus, the parameters presented in your letter of 1 June 1982, for soil below water on plant site are, in our opinion, conservative for post-seismic condition.

We trust that the information in this letter meets project needs at present. If you have any questions, please call.

Very truly yours,

John A. Barneich
Project Manager

Jagdish N. Mathur
Sr. Project Engineer

JAB:JNM/ea

Southern California Edison Company

P. O. BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

June 1, 1982

Mr. John A. Barneich
Woodward-Clyde Consultants
203 North Golden Circle Drive
Santa Ana, CA 92705

Dear Mr. Barneich:

SUBJECT: Soil Parameters for Seawall Analysis
BOPS-Seismic Reevaluation Program
SONGS - Unit 1

Reference: Letter, same subject, dated November 18, 1981,
to Mr. J. Mathur from C. M. Knarr

We are presently reevaluating the seawall as part of the subject program for the in-situ soil conditions at the site. A summary of our review will be included in Bechtel's report reconciling the in-situ soil conditions. In order to complete our reevaluation, we need your review of the in-situ soil conditions adjacent to the plant side of the seawall. This would be done in conjunction with the other work you are doing presently for Bechtel on in-situ soil conditions at the site.

In order to expedite your review, we have prepared the attached sketch similar to that presented in the above-referenced letter showing soil parameters for both the seismic and post-seismic conditions. These values have been taken from your previous work for the subject program. Please let us know if you concur with these values by June 4, 1982.

If you have questions, please call me at (213) 572-3291.

Yours very truly,

C. M. Knarr

Encl.

ENGINEERING DEPARTMENT

CALCULATION SHEET

SUBJECT: SONGS 1 SEAWALL DESIGN CALCULATION NO. DC ______ - ______

J.O. NO. ______ MADE BY P Mo DATE 5-4-84 CHK. BY [signature] DATE 5/4-84

LOAD CASE I - DBE LOAD

THE FOLLOWING CALCULATION WAS PERFORMED TO EXAMINE THE EFFECTS OF SEISMIC LOAD ON THE SEAWALL :

1. FOR THE DBE SEISMIC LOADING AND THE WORST CASE SOIL CONDITION . THE FACTOR OF SAFETY FOR STABILITY WAS FOUND TO BE 1.34, HIGHER THAN THE 1.10 MINIMUM REQUIRED IN THE BOPS SEISMIC REEVALUATION CRITERIA, AND THE BENDING STRESS IN THE STEEL SHEET PILE FOUND TO BE 5.86 KSi, LESS THAN 1.6 X 25 Ksi = 40 Ksi, WHERE 25 KSi IS THE MAXIMUM BENDING STRESS ALLOWED IN THE U.S. STEEL SHEET PILING DESIGN MANUAL AND 1.6 IS THE ALLOWABLE STRESS INCREASE FACTOR FOR THE DBE LOAD CASE.

2. THE PARTICIPATION FROM MODES HIGHER THAN THE FUNDAMENTAL MODE WAS FOUND TO BE LESS THAN 10% AND THEREFORE, THEIR EFFECT WAS IGNORED IN THE STABILITY ANALYSIS.

3. IT IS CONCLUDED THAT THE SONGS ONE SEAWALL MEETS THE SEISMIC REEVALUATION CRITERIA FOR THE DBE LOAD CASE.

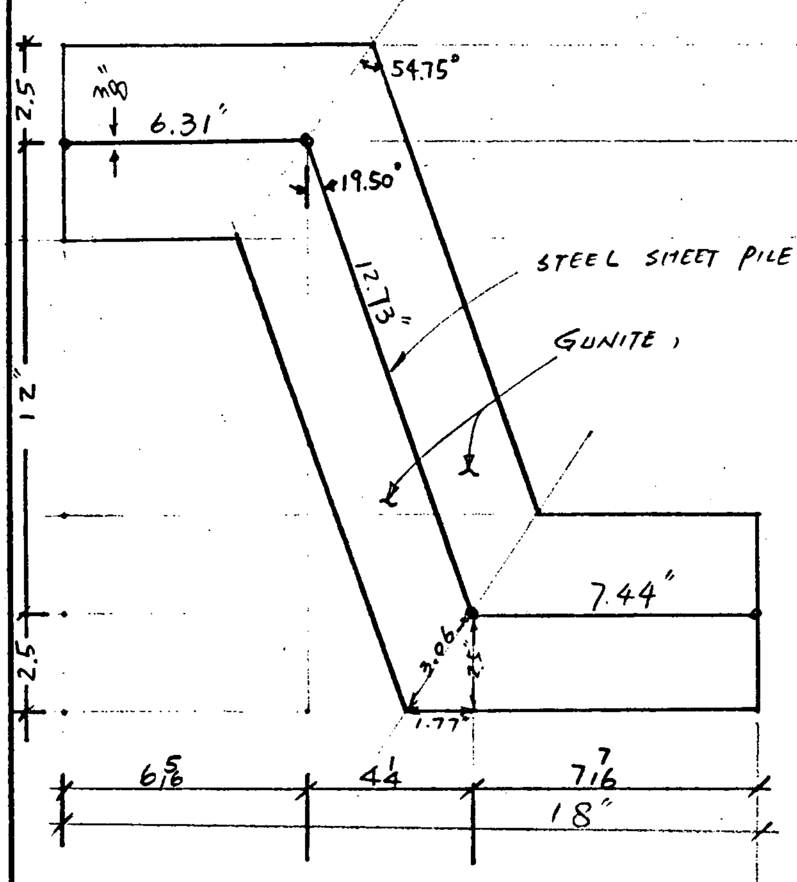
DWG. NO.

ENGINEERING DEPARTMENT

CALCULATION SHEET

SUBJECT: SONGS 1, SEAWALL DESIGN CALCULATION NO. DC ___ - ___

J.O. NO. ___ MADE BY PMo DATE 5-1-84 CHK. BY [signature] DATE 5/4/84



SEAWALL PROPERTIES

USS SHEET PILE MZ 27

W_s = 40.5 #/FT. VERT./PILE × 12"/18" = 27 #/□' PROJ. AREA

S = 30.2 IN³/' = 45.3 IN³/PILE

I = 184.2 IN⁴/' = 276.3 IN⁴/PILE

LINEAR LENGTH PER FT:

(6.31" + 12.73" + 7.44") × 12"/18"

= 17.65" = 1.471'/'

WT. OF SHEET PILE:

27 #/PSF PROJ AREA X 1' WIDE VERT STRIP

= 27 #/FT. VERT. / 1' VERT. STRIP

WT. OF GUNITE: (140 PCF)

140 × 2.5"/12 = 29.17 #/□'

WT. = 29.17 × 1.471 = 42.9 #/□' PROJ AREA/SIDE X 1' = 42.9 #/FT. VERT / 1' VERT. STRIP / SIDE

- STEEL SHEET + ONE SIDE GUNITE:
  WT = 27.0 + 42.9 = 69.9 #/FT. VERT / 1' VERT. STRIP

- STEEL SHEET + BOTH SIDES GUNITE:
  WT = 69.9 + 42.9 = 112.8 #/FT. VERT / 1' VERT. STRIP = 9.4 #/"

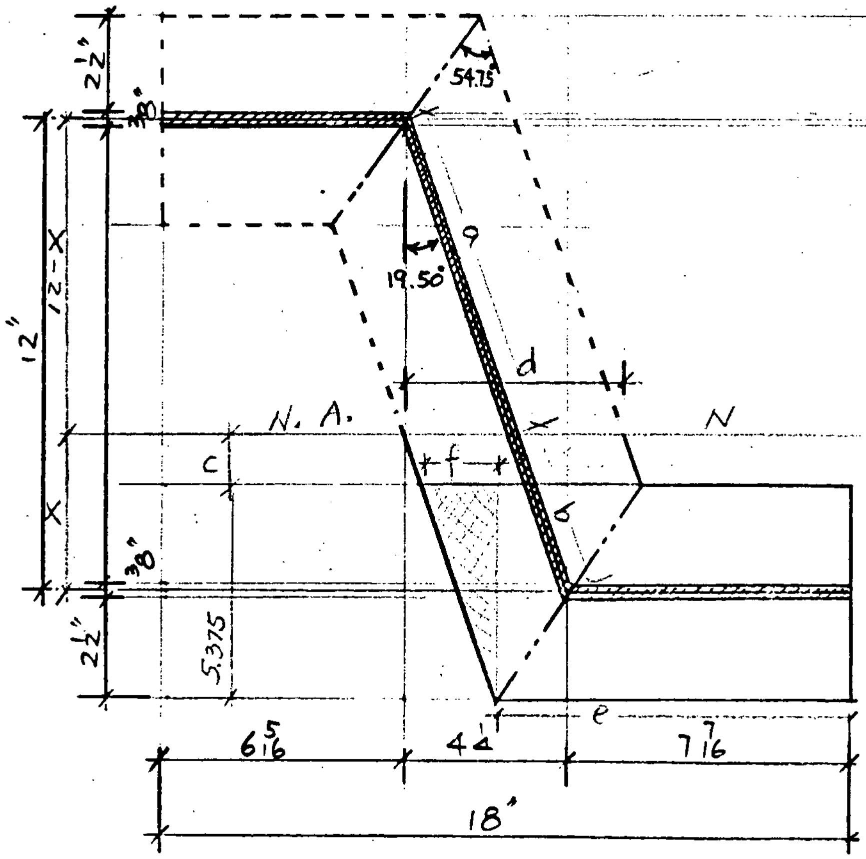
DWG. NO.

ENGINEERING DEPARTMENT
CALCULATION SHEET

SUBJECT: SONGS 1 SEAWALL — DESIGN CALCULATION NO. DC —

J.O. NO. ____ MADE BY PMo DATE 5-2-84 CHK. BY [signature] DATE 5/4/84

ASSUME N.A. AS SHOWN
(CRACKED SECTION)



$a = (12-x)/\cos 19.50°$

$b = x/\cos 19.50°$

$c = x - 2.6875$

$d = 5.375/\cos 19.50°$

$e = \frac{2.6875}{\tan 54.75°} + 7.4375$

$f = 5.375 \tan 19.50°$

$E_s = 30 \times 10^6$ psi

$E_c = 3 \times 10^6$ psi

FOR STEEL SHEET ALONE: EQUIV. GUNITE AREA $= E_s/E_c = 10 \times A_{steel}$

FOR STEEL IN GUNITING COVERS: ADDITIONAL EQUIV. GUNITE AREA $= 10 - 1 = 9 \times A_{steel}$

Σ(AREA x DISTANCE) ABOVE N.A.

$10[(6.3125)(.375)(12-x) + (a)(.375)(12-x)/2] = \cdots = 570.5 - 71.41x + 1.989x$

ΣAd BELOW N.A.

STEEL:

$9[(b)(.375)(x)/2 + (7.4375)(.375)(x)] = \cdots = 25.10x + 1.790x^2$

GUNITE

$(c)(d)(c)/2 + (5.375)(f/2)(c + 5.375/3) + (5.375)(e)(x) = \cdots$

$= 16.01 + 39.98x + 2.851x^2$

$\Sigma \text{BELOW} = 16.27 + 65.08x + 4.641x^2 = \Sigma \text{ABOVE} = 570.5 - 71.41x + 1.989x^2$

$\therefore x^2 + 51.47x - 209.1 = 0$

$x = 3.784 > 2.6875"$ OK

DWG. NO.

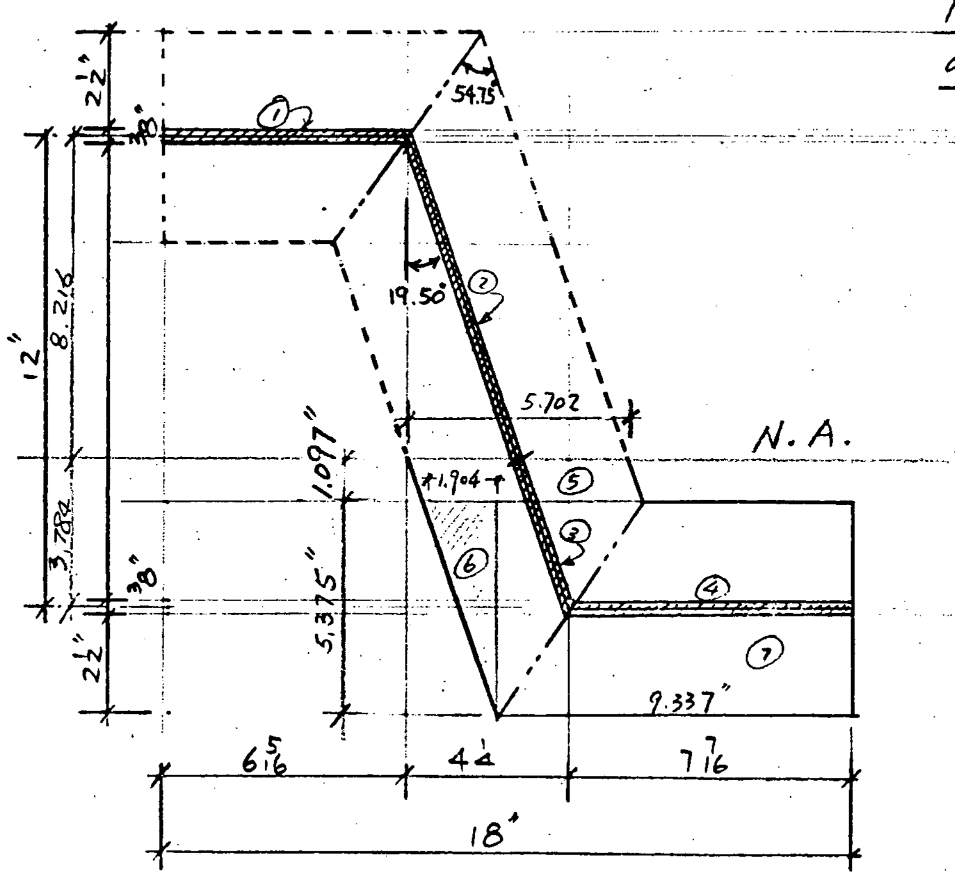
ENGINEERING DEPARTMENT

CALCULATION SHEET

SUBJECT: SONGS 1 SEAWALL   DESIGN CALCULATION NO. DC ______ – ______

J.O. NO. ______ MADE BY PMo DATE 5-2-84 CHK. BY [signature] DATE 5/4/84

MOMENT OF INERTIA OF EQUIVALENT CONCRETE ARE[A] TO N. A. (CRACKED SECTION)



ITEM	A	Y	AY²	I	AY² + I
①	(6.3125)(.375)(10) = 23.67	8.216	1598	(6.3125)(.375³/12)(10) = 0	1598
②	(.375 / cos 19.50°)(8.216)(10) = 32.69	4.108	551	(.375 / cos 19.50°)(8.216³/12)(10) = 184	735
③	(.375 / cos 19.50°)(3.784)(9) = 13.55	1.891	48	(.375 / cos 19.50°)(3.784³/12)(9) = 16	65
④	(7.4375)(.375)(9) = 25.10	3.784	359	(7.4375)(.375³/12)(9) = 0	359
⑤	(5.702)(1.097) = 6.26	0.549	2	(5.702)(1.097³)/12 = 1	3
⑥	(5.375)(1.906)/2 = 5.12	2.889	43	(1.904)(5.375³)/36 = 8	51
⑦	(9.337)(5.375) = 50.19	3.784	718	(9.337)(5.375³)/12 = 121	839
					3650

$$\Sigma I_{N.A.} = 3650 \text{ IN}^4$$

DWG. NO.

ENGINEERING DEPARTMENT

CALCULATION SHEET

SUBJECT: SONGS 1, SEAWALL DESIGN CALCULATION NO. DC ______ - ______

J.O. NO. ______ MADE BY P Mo DATE 5-2-84 CHK. BY [signature] DATE 5/4/84

FREQUENCY & ACCELERATION

$f_{1st\ mode} = \frac{3.52}{2\pi l^2}\sqrt{\frac{EIg}{w}}$ (Roark's 5th, Tab. 36, Case 3b) For Uniform mass cantilever beam

$w = 9.40$ #/"

$E_c = 3 \times 10^6$ psi

*$l = 16' = 192"$

$I = 3650$ IN^4

∴ $f = 10.20$ cps , $T = 0.098$ sec

PER RESPONSE SPECTRA SK-C-067 OF DESIGN CRITERIA REV. 3 (2-84):

DBE, H = 0.698 g

HORIZ. ACCEL. = 0.698 g

* The ground surface adjacent to the sheet piling in the vicinity of the C.W.S. intake & discharge conduits is @ EL. +14. There is AC pavement on both sides of the pile underlain by compacted backfill of 95% on the sea side (for beach walkway) and 85+% on the plant side. Calculation of the pile's natural frequency is based on the assumption of a free standing cantilever pile from EL. +12 (or 2' below top of AC pavement) and ignored the resistance from the soil and AC pavement to the pile above EL. +12'.

DWG. NO.

ENGINEERING DEPARTMENT

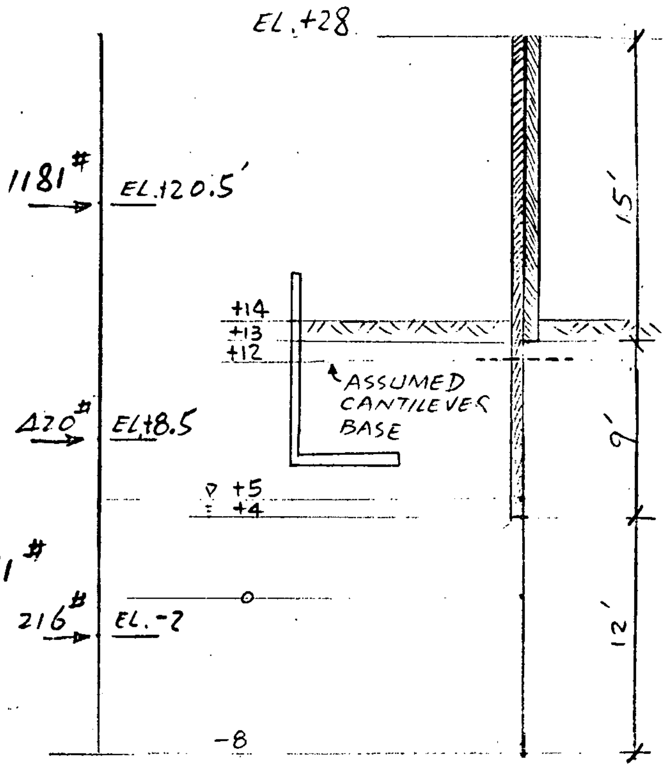
CALCULATION SHEET

SUBJECT: SONGS 1, SEAWALL — DESIGN CALCULATION NO. DC ____ – ____

J.O. NO. ____ MADE BY PNlo DATE 5-2-84 CHK. BY [signature] DATE 5/4/84

SEISMIC LOAD:

- HORIZ. ACCEL = 0.698 g
  FOR PORTION ABOVE GROUND
- HORIZ. ACCEL = 0.667 g (ZPA)
  FOR PORTION EMBEDDED UNDERGROUND



SEISMIC LOAD:

- BTWN. EL. +13 & +28 : (15')

  112.8 x .698 x 15' = 78.7 PLF x 15 = 1181#

- BTWN. EL. +4 & +13 (9')

  69.9 x .667 x 9' = 46.6 PLF x 9' = 420#

- BTWN. EL -8 & +4 (12')

  27.0 x .667 x 12' = 18.0 PLF x 12' = 216#

DWG. NO.

ENGINEERING DEPARTMENT

CALCULATION SHEET

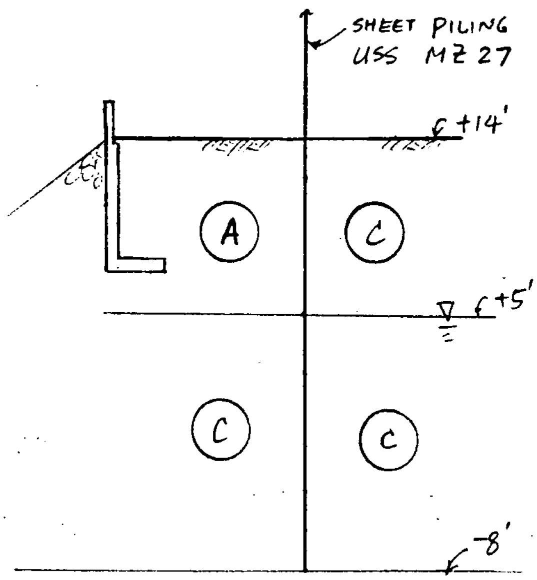
SUBJECT: SONGS 1 - SEAWALL   DESIGN CALCULATION NO. DC ______ - ______

J.O. NO. 6307   MADE BY T. Wang   DATE 6/9/82   CHK. BY HYW   DATE 6-29-82

LOAD CASE I - SEISMIC LOADING

SEISMIC FORCE 1720# AT EL. +15' (Calculation by C. Wang, 8/12/81)

SOIL PARAMETERS (LETTER DATED 6/9/82 FROM J.N. MATHUR OF WOODWARD-CLYDE CO. TO C.M. KNAR- LOAD CASE I)



Type Ⓐ equiv. to 95% compaction

unit wt. $\gamma = 120\ \#/ft^3$

$K_a = 0.57$, $K_p = 2.15$

Type Ⓒ equiv. to 85% compaction

unit wt. $\gamma = 110\ \#/ft^3$ above water table

$\gamma' = 61\ \#/ft^3$ below " "

$K_a = 1.0$, $K_p = 1.0$

SOIL PRESSURE

	SEA SIDE	PLANT SIDE
EL. +5'	$P_{a_s} = 0.57 \times 120 \times 9 = 616$	$P_{a_p} = 1 \times 110 \times 9 = 990$
	$P_{p_s} = 2.15 \times 120 \times 9 = 2322$	$P_{p_p} = 1 \times 110 \times 9 = 990$
	$P_{p_s} - P_{a_p} = 2322 - 990 = 1332$,	$P_{p_p} - P_{a_s} = 990 - 616 = 374$
EL. -8'	$P_{a_s} = 616 + 1 \times 61 \times 13 = 1409$	$P_{a_p} = 990 + 1 \times 61 \times 13 = 1783$
	$P_{p_s} = 2322 + 1 \times 61 \times 13 = 3115$	$P_{p_p} = 990 + 1 \times 61 \times 13 = 1783$
	$P_{p_s} - P_{a_p} = 3115 - 1783 = 1332$,	$P_{p_p} - P_{a_s} = 1783 - 1409 = 374$

DWG. NO.

ENGINEERING DEPARTMENT

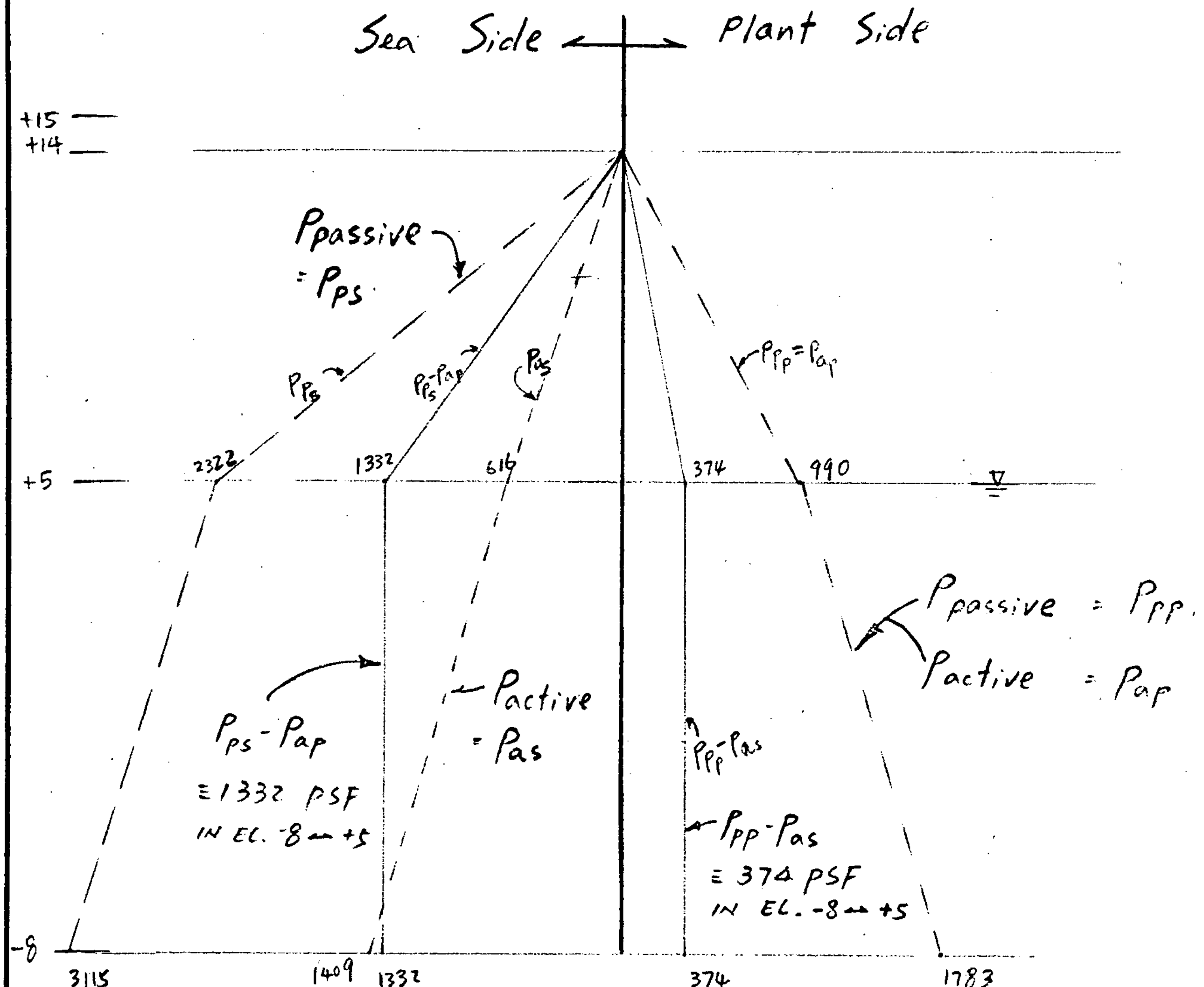
CALCULATION SHEET

SUBJECT: SONGS I — SEAWALL DESIGN CALCULATION NO. DC ______ – ______

J.O. NO. 6307 MADE BY T. Wang DATE 6/10/82 CHK. BY HMW DATE 6/29/82

LOAD CASE I — SEISMIC LOADING

SOIL PRESSURE DISTRIBUTION



DWG. NO.

ENGINEERING DEPARTMENT

CALCULATION SHEET

SUBJECT: SONGS 1 SEAWALL — DESIGN CALCULATION NO. DC ____ - ____

J.O. NO. ____ MADE BY PMo DATE 5-3-84 CHK. BY [signature] DATE 5/4/84

$\Sigma F = 0$

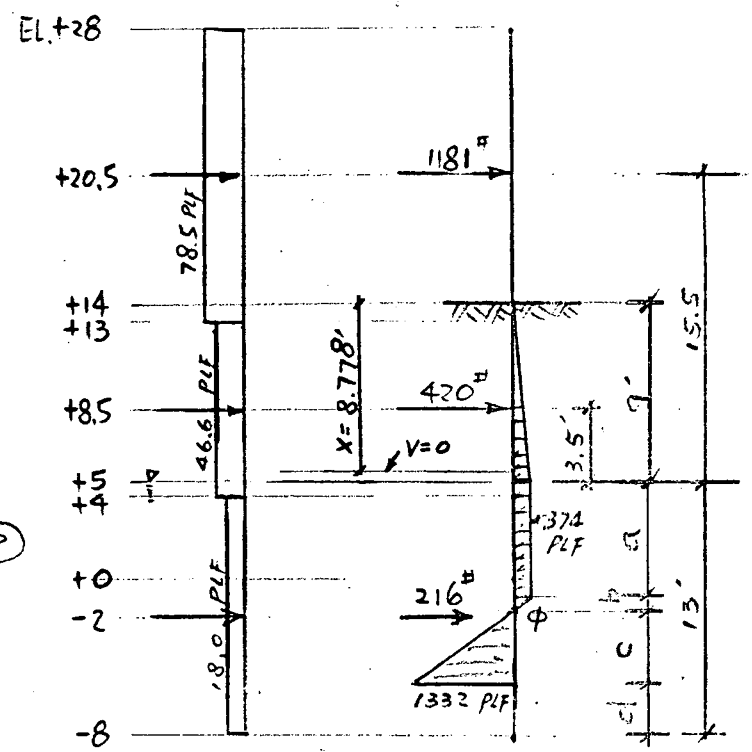
$1181 + 420 + 216 + 1332\left(\frac{c}{2}\right)$
$= (9 + 2a + b)(374/2)$ —— ①

$\Sigma M_\phi = 0$

$1181(15.5 + a + b) + 420(3.5 + a + b)$
$+ 216(a + b - 7)$
$= (374)\left(\frac{9}{2}\right)\left(\frac{9}{3} + a + b\right) + (374)(a)\left(\frac{a}{2} + b\right)$
$+ (374)\left(\frac{b}{2}\right)\left(\frac{2}{3}b\right) + (1332)\left(\frac{c}{2}\right)\left(\frac{2}{3}c\right)$ — ②

SIMILAR TRIANGLE:

$\frac{c}{b} : \frac{1332}{374}$ —— ③



FROM ③ : $c = 3.561\,b$

FROM ① : $1817 + 666c = 1683 + 374a + 187b$ — ④

SUBSTITUTE c INTO ④ : $134 - 374a + 2185b = 0$

$\therefore\ a = 0.358 + 5.842\,b$

FROM ② : $18264 + 1817a + 1817b = 5049 + 1683a + 1683b + 187a^2 + 374ab + 124.67b^2 + 444$

$\Rightarrow 13215 + 134a + 134b = 187a^2 + 374ab + 124.67b^2 + 444c^2$ —— ⑤

SUBSTITUTE a & c INTO ⑤

$13239 = 14324\,b^2$

$b = 0.9614$

$a = 5.9747$

$c = 3.4239$

$\Sigma\ 10.3600'$

$d = 13 - 10.360 = 2.640'$

TOTAL REQ'D PILE DEPTH
$= 9' + 10.360' = 19.360'$

DWG. NO.

ENGINEERING DEPARTMENT

CALCULATION SHEET

SUBJECT: SONGS 1 SEAWALL DESIGN CALCULATION NO. DC ____ – ____

J.O. NO. ____ MADE BY PM. DATE 5-3-84 CHK. BY [signature] DATE 5/4/84

CHECK STRESS :

M_{max} @ $V=0$

SHEAR @ EL +5 : $1181 + 420 - 374(\frac{9}{2}) = -82^{\#} < 0$

∴ ZERO SHEAR SECTION IS ABOVE EL. +5

LET X = DEPTH OF ZERO SHEAR SECTION FROM GRADE (EL. +14'):

$1181 + 420 = (\frac{374}{9})(x)(\frac{x}{2})$ ∴ $X = 8.778'$ OR EL. $14 - 8.778 = $ EL. +5.2…

AT THIS DEPTH, SOIL PRESSURE $= (\frac{374}{9})(8.778) = 364.8$ PLF

$M_{max} = M_{EL.+5.222'} = 1181(20.5-5.222) + 420(8.5-5.222) - (364.8)(\frac{8.778}{2})(\frac{8.778}{3})$

$= 14735^{\#-'}$ $S = 30.2\ IN^3$ (STEEL ONLY)

$f_b = 14735 \times 12 / 30.2 = 5,855$ PSI $= 5.86$ KSI ← LOW, OK.

CHECK SAFETY FACTOR

REQ'D DEPTH = 19.360'
PROVIDED DEPTH = 22' > $22/19.360' = 113.64\%$

OR 13.64% EXCEED THE REQ'D.

PER USS "STEEL SHEET PILE DESIGN MANUAL" Pg. 21

F.S. = 1.5 IF 20% DEPTH INCREASE

2.0 IF 40% DEPTH INCREASE.

∴ $F.S. = 1.5 + \left(\frac{2.0-1.5}{40\% - 20\%}\right)(13.64\% - 20\%) = 1.34$

F.S. = 1.34 > 1.10 REQ'D. OK

DWG. NO.

ENGINEERING DEPARTMENT

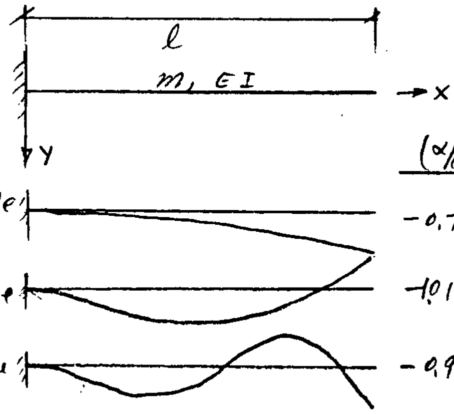
CALCULATION SHEET

SUBJECT: SEAWALL - SONGS 1 | DESIGN CALCULATION NO. DC ___ - ___

J.O. NO. 6733 | MADE BY T. Wang | DATE 2/27/84 | CHK. BY [signature] | DATE 3-1-84

MODE PARTICIPATION STUDY

(Ref. "Introduction to Structural Dynamics, by Biggs)



(Table 4.1)

$$\frac{\Sigma M_r \phi_{rn}}{\Sigma M_r \phi_{rn}^2} = \frac{\int_0^l M_r \phi_{rn}(x)\,dx}{\int_0^l M_r \phi_{rn}^2(x)\,dx} = \Gamma_n$$

	$(\alpha/\beta)_n$	$\int_0^l \phi(x)dx$	$\int_0^l [\phi(x)]^2 dx$	Γ_n	Γ_{n+1}/Γ_n
1st Mode	-0.7341	0.7830 l	l	0.7830	
2nd Mode	-1.0184	0.4340 l	l	0.4340	0.554
3rd Mode	-0.9994	0.2544 l	l	0.2544	0.325

PER 1 ft of sheet pile,

$$f_1 = \frac{(0.597\pi)^2}{2\pi l^2}\sqrt{\frac{EI}{m}} = \frac{3.5176}{2\pi(192)^2}\sqrt{\frac{30\times10^6(184.2)(386.4)}{9.355}} = 7.26 \text{ cps}$$

$$f_n \cong \frac{(n-\frac{1}{2})^2\pi^2}{2\pi l^2}\sqrt{\frac{EI}{m}},\ n>1$$

$$f_2 = \frac{22.2}{2\pi(192)^2}\sqrt{\frac{30\times10^6(184.2)(386.4)}{9.355}} = 45.82 \text{ cps}$$

$$f_3 = \frac{61.68}{2\pi(192)^2}\sqrt{\frac{30\times10^6(184.2)(386.4)}{9.355}} = 127.3 \text{ cps}$$

NODAL DISPLACEMENT AND RELATIVE ACCELERATION

$$\ddot{Y}_{in} = \Gamma_n A_n \phi_{in}$$

$$Y_{in} = \frac{\ddot{Y}_{in}}{\omega_n^2}$$

$$\phi_{ny}(x) = \left(\frac{\alpha}{\beta}\right)_n(\sinh a_n x - \sin a_n x) + \cosh a_n x - \cos a_n x,\quad a_n = \sqrt[4]{\frac{m\omega_n^2}{EI}}$$

cf. "Formulas for Natural Frequency and Mode shape", by R.D. Blevins

at $x = l$, (ϕ_{ny} from Table 8-2(6) cf.; A_n from Resp. Curve; $\ddot{Y}_n$ relative accel.)

Mode	$\phi_{ny}^{(l)}$	$f^{(cps)}$	ω_n	$A_n^{(g)}$	Γ_{ny}	$\ddot{Y}_n^{(g)}$	$Y_n^{(g)}$ (x386.4) =	$Y_n^{(in)}$	$\frac{Y_n}{\Sigma Y_n}$ %
1	2	7.26	45.6	0.75	0.7830	1.1745	0.0005648	0.218	98.7
2	-2	45.82	287.9	0.67	0.4340	0.5816	0.00000702	0.00271	1.2
3	2	127.3	799.8	0.67	0.2544	0.3409	0.000000533	0.000206	0.10
					Σ SRSS	1.354 g		0.2180	
					Σ ABSOLUTE			0.2209	100%

DWG. NO.

ENGINEERING DEPARTMENT
CALCULATION SHEET

SUBJECT: SEAWALL-SONGS 1 DESIGN CALCULATION NO. DC ___ - ___

J.O. NO. 6733 MADE BY T. Wang DATE 2/29/84 CHK. BY [signature] DATE 3/1/84

MODE PARTICIPATION STUDY

at $x = \frac{l}{2}$,

Mode	$\phi_{ny}^{(l/2)}$	$f^{(cps)}$	w_n	A_n	Γ_{ny}	$\ddot{Y}_n^{(g)}$	$Y_n^{(g)}$ (X 386.4) =	$Y_n^{(in)}$	$= \frac{Y_n}{\Sigma Y_n}$ %
1	0.679	7.26	45.6	0.75	0.7830	0.399	0.000192	0.0741	97.46
2	1.427	45.82	287.9	0.67	0.4340	0.415	0.5×10^{-4}	0.00193	2.54
3	0.039	127.3	799.8	0.67	0.1544	0.00665	0.103×10^{-6}	0.000004	≈ 0
							Σ	0.0760	

at $x = \frac{l}{4}$,

Mode	ϕ_{ny}	f	w_n	A_n	Γ_{ny}	$\ddot{Y}_n^{(g)}$	$Y_n^{(g)}$	$Y_n^{(in)}$	%
1	0.195	(SAME)				0.1145	0.0000551	0.02129	94.53
2	0.80					0.2326	0.281×10^{-4}	0.001085	4.82
3	1.44					0.2454	0.3836×10^{-5}	0.000148	0.65
							Σ	0.022523	

i.e. The fundamental mode is the dominating mode for model displacement. The higher modes are not significant in displacement participation.

DWG. NO.

ENGINEERING DEPARTMENT

CALCULATION SHEET

SUBJECT: SEAWALL – SONGS 1 DESIGN CALCULATION NO. DC ______ – ______

J.O. NO. 6733 MADE BY T. Wang DATE 2/28/84 CHK. BY [signature] DATE 3/1/84

MODE PARTICIPATION STUDY

FROM THE OUTPUT OF SAP 5.2 FOR LUMPED MASS MODEL,

AT NODE 10 (TOP POINT),

$$\ddot{Y}_{in} = \Gamma_n A_n \phi_{in}$$

$$Y_{in} = \frac{\ddot{Y}_{in}}{\omega_n^2}$$

Mode	$\phi_{ny}^{(\ell)}$	$f^{(cps)}$	ω_n	$A_n^{(g)}$	Γ_{ny}	$\ddot{Y}_n$	$Y_n^{(g)}$	(x 386.4) $Y_n^{(in)}$	$\frac{Y_n}{\Sigma Y_n}$ %
1	-0.763	7.16	44.99	0.75	-2.033	1.163	0.0005746	0.222	98.6
2	-0.728	43.16	271.2	0.67	1.14	0.556	0.00000756	0.00292	1.3
3	-0.672	115.0	722.5	0.67	-0.67	0.302	0.000000578	0.000223	0.1
					Σ SRSS	1.324		0.2220	
					Σ ABSOLUTE			0.2251	100%

DWG. NO.

ENGINEERING DEPARTMENT

CALCULATION SHEET

SUBJECT: SEAWALL – SONGS 1 DESIGN CALCULATION NO. DC ______ – ______

J.O. NO. 6733 MADE BY T. Wang DATE 2/29/84 CHK. BY [signature] DATE 3/1/84

MODE PARTICIPATION STUDY

FROM SAP 5.2,

	Mode	ϕ_{ny}	$f^{(cp)}$	w_n	$A_n^{(g)}$	Γ_{ny}	$\ddot{Y}_n$	$Y_n^{(g)}$ (x 386.4)	$Y_n^{(in)}$	$\frac{Y_n}{\Sigma Y_n}$ %
NODE 5, ½ SPAN, z=96"	1	−0.260	7.16	44.99	0.75	−2.033	0.396	0.000196	0.0757	97.2
	2	−0.541	43.16	271.2	0.67	1.14	0.413	0.00000562	0.00217	2.8
	3	−0.0319	115.0	722.5	0.67	−0.67	0.0143	0.274×10^{7}	0.0000106	≈0
						Σ SRSS			0.0757	
						Σ ABSOLUTE			0.0779	
NODE 7, ¾ SPAN, z=144"	1	−0.502	(SAME)				0.765	0.000378	0.146	99.58
	2	0.1165					0.0890	0.00000121	0.000467	0.32
	3	−0.447					0.201	0.000003843	0.000149	0.10
						Σ SRSS				
						Σ ABSOLUTE			0.146616	
NODE 3, ¼ SPAN, z=48"	1	−0.0750					0.114	0.0000563	0.02176	93.67
	2	0.321					0.245	0.3331×10^{-4}	0.001287	5.54
	3	−0.552					0.248	0.475×10^{-5}	0.000184	0.79
						Σ ABSOLUTE			0.023231	

i.e. The fundamental mode is the dominating mode for model displacement.
The higher modes are not significant in displacement participation.

DWG. NO.

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Woodward-Clyde Consultants

30 April 1984

Mr. C. Michael Knarr
Southern California Edison
P. O. Box 800
Rosemead, California 91770

SUBJECT: SEA WALL ANALYSIS PARAMETERS
SONGS UNIT 1
SAN ONOFRE, CALIFORNIA

Dear Mr. Knarr:

The seismic lateral pressure parameters used in the SONGS 1 sea wall analysis presented in Table 1 were developed based on a pseudo static procedure similar to Coulomb's wedge analysis. This method has been used by Mononobe et al. (1929) and described and used by Seed and Whitman (1970). The procedure is a force-equilibrium analysis where the critical angle of slope of the base of the wedge is determined to obtain the maximum pressure on the wall and considers an earth pressure coefficient of 1.0 as a practical maximum for the active case and minimum for the passive case. The basic steps involved in this analysis are presented in Appendix A. The supporting calculations to develop the lateral pressure coefficients are presented in Appendix B.

We trust that this letter meets your current needs. If you have any questions, please call.

Very truly yours,

John A. Barneich

John A. Barneich
Vice President

JAB/ea
Enclosures

TABLE 1

Summary of Earth Pressure Coefficients

DBE EARTHQUAKE LOADING	φ DEGREES	K_A (Active) Due to K_v[2] ↑	K_A (Active) Due to K_v ↓	K_p (Passive) Due to K_v ↑	K_p (Passive) Due to K_v ↓	MATERIAL[3]
	41.5	0.57	0.56	2.15	5.3	A
K_h = 0.47g [1]	35	0.84	0.70	1.23	3.83	B
K_v = 0.31g	30	1.0	0.84	1.0	3.0	C

NOTE: As rest coefficient assumed minimum for fixed structure wall; for static condition use K_A = 0.34 and 0.43 for materials A and B, respectively; K_p = 4.93 and 3.0 for materials A and C, respectively.

1 2/3 peak values are used as high average for equivalent uniform pseudo-static parameters.

K_h = seismic coefficient in horizontal direction.
K_v = seismic coefficient in vertical direction.

2 Arrow shows direction of K_v, upward or downward.

3 A = San Mateo Sand in native state or at 95% compaction.
B = San Mateo Sand at 90% compaction.
C = Beach Sand or loose to medium dense fill.

REFERENCES

1. Mononobe, N. and Matsuo, H. 1929, "On the Determination of Earth Pressures During Earthquakes", Proceedings of the Second World Conference on Earthquake Engineering, Tokyo, Japan.

2. Seed, H. B. and Whitman, R. V., 1970, "Design of Earth Retaining Structures for Dynamic Loads - ASCE Speciality Conference - Lateral Stresses in the Ground and Design of Earth Retaining Structures".

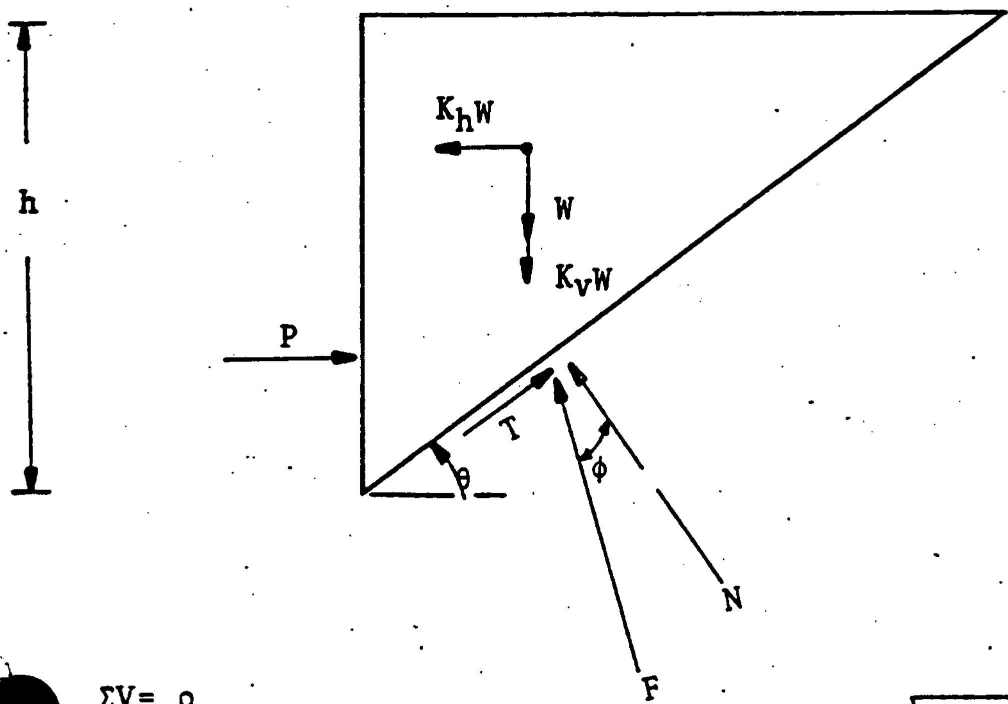
APPENDIX A

Wedge Analysis -- Active & Passive Earthpressures due to Earthquake Loading.

ACTIVE PRESSURE --

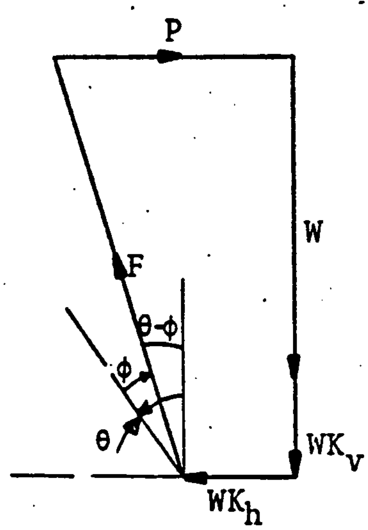
Horizontal Acceleration $= K_h g$

Vertical Acceleration $= K_v g$



$\Sigma V = 0$

$\Sigma H = 0$



(1) $W + W K_v = F \cos(\theta - \phi)$

$$F = \frac{W(1+K_v)}{\cos(\theta-\phi)}$$

(2) $P = WK_h + F \sin(\theta - \phi)$

$$= WK_h + \frac{W(1+K_v)\sin(\theta-\phi)}{\cos(\theta-\phi)}$$

$$= W\left[K_h + (1+K_v)\tan(\theta-\phi)\right]$$

$$= \tfrac{1}{2}\gamma h^2 \cot\theta \left[K_h + (1+K_v)\tan(\theta-\phi)\right]$$

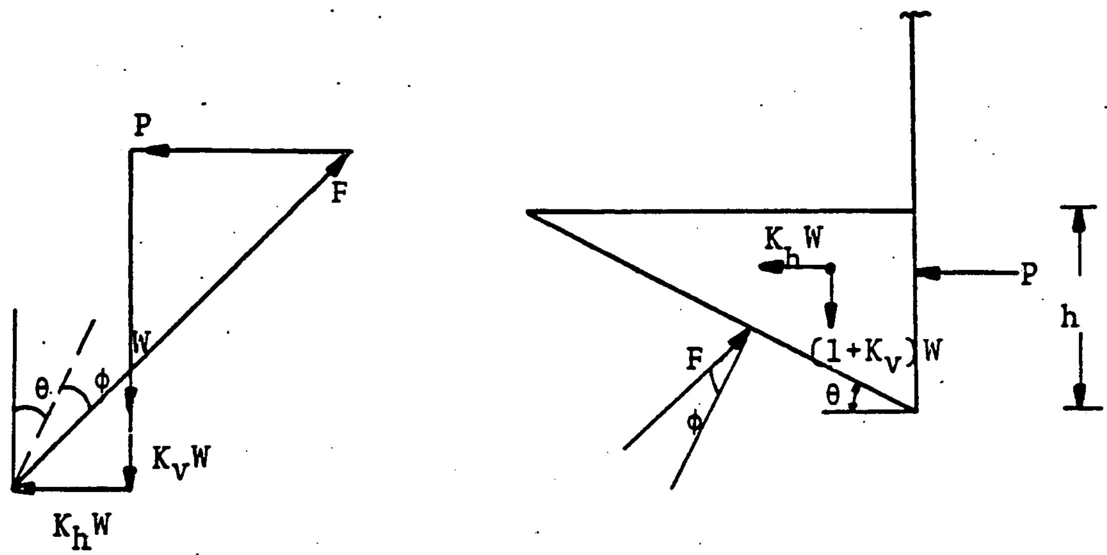
$$P = 1/2\ \gamma h^2\ K$$

Where, $K = \cot\theta \left[K_h + (1+K_v)\tan(\theta-\phi)\right]$

K_{AE} is the maximum value at $\theta = \theta_{critical}$

$$K_{AE} = \cot\theta_{cr}\left[K_h+(1+K_v)\tan(\theta_{cr}-\phi)\right] \qquad (1)$$

PASSIVE PRESSURE--



$\Sigma V = o$ so, $(1+K_v) = F\cos(\theta+\phi)$

or $F = W(1+K_v)/\cos(\theta+\phi)$

and $\Sigma H = o$, so $P+K_hW = F\sin(\theta+\phi)$

or $P + W(1+K_v)\tan(\theta+\phi) - K_hW$

$= W\left[(1+K_v)\tan(\theta+\phi) - K_h\right]$

For the critical value of θ, the lateral pressure P should be minimum.

$$P_{min} = \frac{\gamma h^2}{2} \cot \theta_{cr} \left[(1+K_v) \tan (\theta_{cr} + \phi) - K_h \right]$$

$$= \frac{\gamma h^2}{2} K_{PE}$$

Where $K_{PE} = \left[(1+K_v) \tan (\theta_{cr} + \phi) - K_h \right] \cot\theta_{cr}$ (2)

θ_{cr} can be found numerically so as to give minimum value K_{PE}.

Using the above equations (1) and (2), computed values K_{AE} and K_{PE}, along with values of $\theta_{critical}$ for the two earthquake loadings and different angles of friction are shown in Table A-1. The calculations to support these values are attached in Appendix B.

TABLE A-1

SUMMARY OF RESULTS

		KA and Θcr				Kp and Θcr			
		Kv (↑)		Kv (↓)		Kv (↑)		Kv (↓)	
DBE eqk	ϕ degrees	Ka	Θcr (degree)	Ka	Θcr (degree)	Kp	Θcr (degree)	Kp	Θcr (degree)
Kh=0.47g	41.5	0.57	27.5	0.56	49.5	2.15	15	5.3	20.5
Kv=0.31g	35	0.84	8.5	0.702	43.5	1.23	7	3.83	22
	30	1.0	*	0.84	37.5	1.0	*	3.0	22

* Indeterminate, used K_A and Kp = 1.0 as practical maximum and minimum values.

APPENDIX B

SUPPORT CALCULATIONS

Appendix B
Support Calculations

minimize the passive pressure:

$$K_{PE} = ((1+k_v)\tan(\theta_{cr}+\phi) - K_h)\cot\theta_{cr}.$$

$$\frac{\partial K_{PE}}{\partial \theta_{cr}} = \left((1+k_v)\tan(\theta_{cr}+\phi) - K_h\right)(-\csc^2\theta_{cr}) + \cot\theta_{cr}(1+k_v)\sec^2(\theta_{cr}+\phi)$$

$$= 0.$$

$$\Rightarrow \quad \frac{(1+k_v)\tan(\theta_{cr}+\phi) - K_h}{-\sin^2\theta_{cr}} + \frac{(\cos\theta_{cr})(1+k_v)}{\sin\theta_{cr}\cos^2(\theta_{cr}+\phi)} = 0.$$

$$((1+k_v)\tan(\theta_{cr}+\phi) - K_h) - \frac{\sin\theta_{cr}\cos\theta_{cr}(1+k_v)}{\cos^2(\theta_{cr}+\phi)} = 0.$$

$$(1+k_v)\sin(\theta_{cr}+\phi)\cos(\theta_{cr}+\phi) - K_h\cos^2(\theta_{cr}+\phi) - \sin\theta_{cr}\cos\theta_{cr}(1+k_v) = 0$$

$$\frac{1+k_v}{2}\sin 2(\theta_{cr}+\phi) - K_h\left(\frac{1+\cos 2(\theta_{cr}+\phi)}{2}\right) - \frac{1+k_v}{2}\sin 2\theta_{cr} = 0$$

$$(1+k_v)\underbrace{\frac{\sin 2(\theta_{cr}+\phi)}{1+\cos 2(\theta_{cr}+\phi)}} - K_h - (1+k_v)\frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}+\phi)} = 0$$

$$\tan(\theta_{cr}+\phi) - \frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}+\phi)} = \frac{k_h}{1+k_v}$$

For $k_h = 0.47$ & $k_v = 0.31\ (\downarrow)$, $\frac{k_h}{1+k_v} = \frac{0.47}{1+0.31} = 0.359.$

At $\phi = 41.5°$, $\tan(\theta_{cr}+41.5°) - \frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}+41.5°)} = 0.359.$

for $\theta_{cr} = 15°$, left side $= 0.69$; $\theta_{cr} = 25°$, left side $= 0.11$;

& for $\theta_{cr} = 20°$, left side $= 0.43$;

& for $\theta_{cr} = 22°$, left side $= 0.26$; for $\theta_{cr} = 21°$, left side $= 0.352$ ✻.

$\theta_{cr} = 20° \sim 21°$ ✻
say 20.5°

$$K_{PE} = ((1+0.31)\tan(20.5°+41.5) - 0.47)\cot 20.5°$$

$$= 5.3$$

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At $\phi = 35^\circ$,

$$\tan(\theta_{cr} + 35^\circ) - \frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}+35^\circ)} = 0.359$$

For $\theta_{cr} = 15^\circ$, left side = 0.587,

$\theta_{cr} = 20^\circ$, left side = 0.451 ←

$\theta_{cr} = 25^\circ$, left side = 0.200.

$\theta_{cr} = 22^\circ$, left side = 0.369 *

$$K_{PE} = [(1+.31)\tan(22^\circ+35^\circ) - 0.47]\cot 22^\circ$$

$$= 3.83 *$$

At $\phi = 30^\circ$,

$$\tan(\theta_{cr} + 30^\circ) - \frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}+30^\circ)} = 0.359.$$

For $\theta_{cr} = 20^\circ$, left side = 0.414;

$\theta_{cr} = 10^\circ$, left side = 0.548;

$\theta_{cr} = 30^\circ$, left side = 0; $\theta_{cr} = 25^\circ$, left side = 0.264

$\theta_{cr} = 23^\circ$, left side = 0.334; $\theta_{cr} = 21^\circ$, left side = 0.390.

Using $\theta_{cr} = 22^\circ$

$$K_{PE} = ((1+.31)\tan(22^\circ+30^\circ) - 0.47)\cot 22^\circ$$

$$= 2.987 \approx 3.0.$$

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For $K_h = 0.47$ & $K_v = 0.31 (\uparrow)$,

$$\frac{K_h}{1+K_v} = \frac{0.47}{1-0.31} = 0.681.$$

~~For~~

At $\phi = 41.5°$,

$$\tan(\theta_{cr} + 41.5°) - \frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}+41.5°)} = 0.681.$$

for $\theta_{cr} = 15°$, left side $= 0.69$ *

$$K_{PE} = ((1-0.31)\tan(15° + 41.5°) - 0.47) \cdot \cot 15°.$$

$= 2.15$ *

At $\phi = 35°$,

$$\tan(\theta_{cr} + 35°) - \frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}+35°)} = 0.681.$$

For $\theta_{cr} = 10°$, left side $= 0.658$.

$\theta_{cr} = 8°$, left side $= 0.675$.

$\theta_{cr} = \underline{7°}$, left side $= 0.681$ *

$$K_{PE} = ((1-.31)\tan(7° + 35°) - 0.47)\cot 7°.$$

$= 1.23$ *

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4/7 [illegible]

At $\phi = 30°$.

$$\tan(\theta_{cr} + 30°) - \frac{\sin 2\theta_{cr}}{1 + \cos 2(\theta_{cr} + 30°)} = 0.681$$

$\theta_{cr} = 10°$, left side = 0.548.

$\theta_{cr} = 5°$, left side = 0.571.

$\theta_{cr} = 2°$, left side = 0.576.

$\theta_{cr} = 0°$, left side = 0.577. ~~under~~ undetermined

$$K_{PE} = ((1 - .31)\tan(\theta_{cr} + 30°) - 0.47)\cot\theta_{cr}$$

$= 0.15$. for $\theta_{cr} = 5°$,

$= -1.112$ for $\theta_{cr} = 2°$,

$= -\infty$ for $\theta_{cr} = 0°$

indeterminate ∴ use 1.0 as practical minimum

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JGB

maximize the active pressure :

$$K_{AE} = \cot\theta_{cr} \left[K_h + (1+K_v) \tan(\theta_{cr}-\phi) \right]$$

$$\frac{\partial K_{AE}}{\partial \theta_{cr}} = 0 ,$$

$$\frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}-\phi)} - \tan(\theta_{cr}-\phi) = \frac{K_h}{1+K_v}$$

For $K_h = 0.47$ & $K_v = 0.31 (\downarrow)$,

$$\frac{K_h}{1+K_v} = 0.359 *$$

at $\phi = 41.5°$, $\frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}-41.5°)} - \tan(\theta_{cr}-41.5°) = 0.359$.

for $\theta_{cr} = 49°$, left side = 0.372

$\theta_{cr} = 50°$, left side = 0.354 ←

For $\theta_{cr} = 49.5°$,

$K_{AE} = \cot 49.5° [0.47 + (1.31) \tan(49.5° - 41.5°)]$

$= 0.56 *$

at $\phi = 35°$, $\frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}-35°)} - \tan(\theta_{cr}-35°) = 0.359$,

for $\theta_{cr} = 45°$, left side = 0.339 ,

$\theta_{cr} = 44°$, left side = 0.354 , ←

$\theta_{cr} = 43°$, left side = 0.368

Using $\theta_{cr} = 43.5°$, $K_{AE} = \cot 43.5° [0.47 + 1.31 \tan(43.5° - 35°)]$

$= 0.70 *$

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JWB

at $\phi = 30°$, $\frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}-30°)} - \tan(\theta_{cr} - 30°) = 0.359$.

for $\theta_{cr} = 30°$, left side = 0.433. ←

$\theta_{cr} = 40°$, left side = 0.331 ←

$\theta_{cr} = 35°$, left side = 0.386

$\theta_{cr} = 37°$, left side = 0.365 ←

$\theta_{cr} = 38°$, left side = 0.354 ※

Using $\theta_{cr} = 37.5°$,

$K_{AE} = \cot 37.5° [0.47 + (1.31) \tan(37.5° - 30°)]$

$= 0.84$ ※

For $k_h = 0.47$ & $k_v = 0.31$ (↑)

$\frac{k_h}{1+k_v} = 0.681$.

at $\phi = 41.5°$,

$\frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}-41.5°)} - \tan(\theta_{cr} - 41.5°) = 0.681$.

for $\theta_{cr} = 27°$, left side = 0.690.

$\theta_{cr} = 26°$, left side = 0.702.

$\theta_{cr} = 28°$, left side = 0.678

Using $\theta_{cr} = 27.5°$, $K_{AE} = \cot 27.5° [0.47 + 0.69 (\tan(27.5 - 41.5))] = 0.57$ ※

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1/1/84

At $\phi = 35°$,

$$\frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}-35°)} - \tan(\theta_{cr}-35°) = 0.681$$

for $\theta_{cr} = 18°$, left side = 0.627,

$\theta_{cr} = 17°$, left side = 0.634.

$\theta_{cr} = 8°$, left side = 0.683 ※ ←

$\theta_{cr} = 9°$, left side = 0.679

Using $\theta_{cr} = 8.5°$,

$$K_{AE} = \cot 8.5° [0.47 + 0.69 \tan(8.5° - 35°)]$$

$$= 0.84 \text{ ※}$$

At $\phi = 30°$,

$$\frac{\sin 2\theta_{cr}}{1+\cos 2(\theta_{cr}-30°)} - \tan(\theta_{cr}-30°) = 0.681$$

for $\theta_{cr} = 30°$, left side = 0.433.

$\theta_{cr} = 6°$, left side = 0.570.

$\theta_{cr} = 2°$, left side = 0.576.

$\theta_{cr} = 0°$, left side = 0.577.

$\theta_{cr} = -2°$, left side = 0.576

$$K_{AE} = \cot \theta_{cr} [0.47 + 0.69 \tan(\theta_{cr} - 30°)]$$

$= \infty$ for $\theta_{cr} = 0°$.

$= 2.953$ for $\theta_{cr} = 2°$.

$= 1.549$ for $\theta_{cr} = 6°$.

indeterminate ∴ use 1.0 as practical maximum