FINAL REPORT

EVALUATION OF HEAVY LOAD HANDLING OPERATIONS AT SAN ONOFRE NUCLEAR GENERATING STATION UNITS 2 & 3

RESPONSE TO NUREG-0612

DOCKET NOS. 50-361 & 50-362

SUBMITTED BY:

SCE *Southern California Edison Company*

TERA CORPORATION

CONTROL OF HEAVY LOADS FOR SAN ONOFRE NUCLEAR GENERATING STATION UNITS 2 AND 3

FINAL REPORT

Submitted to:

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1.0 INTRODUCTION

The NRC's letter of December 22, 1980, requested a review of the controls for handling heavy loads at San Onofre Nuclear Generating Station, Units 2 and 3 (SONGS 2/3), the implementation of certain recommendations regarding these controls, and the submittal of information to demonstrate that the recommendations have been implemented.

A report was submitted in July 1981 which addressed the information required in Section 2.1 of Enclosure 3 of the December 22, 1980 letter. This report is responsive to the information required in Sections 2.2, 2.3 and 2.4 of Enclosure 3 of the December 22, 1980 letter. In addition, in Section 4.0 of this report, an evaluation of lift rig designs is provided. This had been identified in the July 1981 report as requiring further evaluation.

Subsequent to our review of cranes used to handle heavy loads at SONGS 2/3, as documented in the July 7, 1981 report, additional cranes have been identified which were either not then in place or not expected to be permanent equipment at that time. These cranes, a side boom extension on the Turbine Gantry Crane and several small jib cranes, will be evaluated and reported upon in a supplemental report.

2.0 IDENTIFIED HANDLING SYSTEMS

The heavy load handling systems and loads required to be addressed in this report were identified in our submittal of July 1981. The handling systems are:

Inside Containment

Polar Crane

Outside Containment

Turbine Gantry Crane
Cask Handling Crane
New Fuel Handling Crane (monorail section)
Auxiliary Feedwater (AFW) Pump Bridge Crane
Component Cooling Water (CCW) Pump Monorail
Safety Injection (SI) Pump Monorails
Side Boom Extension*
Jib Cranes 1, 2, 3 and 4*
Main Steamline Isolation Valve (MSIV) Jib Cranes*

*Identified as permanent cranes after our July 7, 1981 report was issued.

3.0 RESPONSES TO REQUESTS FOR INFORMATION IN SECTIONS 2.2, 2.3, AND 2.4 OF ENCLOSURE 3 OF NRC DECEMBER 22, 1981 LETTER

ITEM 2.2 SPECIFIC REQUIREMENTS FOR OVERHEAD HANDLING SYSTEMS OPERATING IN THE VICINITY OF FUEL STORAGE POOL

NUREG 0612, Section 5.1.2, provides guidelines concerning the design and operation of load-handling systems in the vicinity of stored, spent fuel. Information provided in response to this section should demonstrate that adequate measures have been taken to ensure that, in this area, either the likelihood of a load drop which might damage spent fuel is extremely small or the estimated consequences of such a drop will not exceed the limits set by the evaluation criteria of NUREG 0612, Section 5.1, Criteria I through III.

RESPONSE: As described in our July 1981 report, no heavy loads are lifted over spent fuel in the spent fuel pool. Lifts of the spent fuel cask by the cask handling crane are restricted to an area away from the spent fuel pool, which precludes direct or indirect interactions in the event of a load drop. Lifts of the bulkhead gates at either end of the spent fuel pool are performed by the cask handling crane and the new fuel handling crane. In each case the physical arrangement of the cranes precludes lifting of the gate over the spent fuel pool. While these loads were included in the initial report for completeness, at this time it is not anticipated that lifts of the pool gates would be required on a routine basis. The only requirement for removal of the gates would be for maintenance if problems are experienced with the gate seals. In addition, the load characteristics of the gates, which weigh only 3,500 lb and have dimensions of 3 feet by 18 feet, indicate that they do not represent a significant damage potential in the event of a load drop. The load is only a fraction of each crane's capacity, which further increases the design margins in the cranes by factors of about 3 and 6 for the new fuel handling and cask handling cranes, respectively. Therefore, the resultant safety margins are typically 15:1 and 30:1 for these two cranes, since each has a 5:1 margin to ultimate strength. In consideration of these factors, and that the cranes, lifting devices, and procedures that would be used in the event of a lift have been fully evaluated in accordance with NUREG 0612 guidelines, it is concluded that no further analysis of load drops is necessary.

ITEM 2.3 SPECIFIC REQUIREMENTS OF OVERHEAD HANDLING SYSTEMS OPERATING IN THE CONTAINMENT

NUREG 0612, Section 5.1.3, provides guidelines concerning the design and operation of load-handling systems in the vicinity of the reactor core. Information provided in response to this section should be sufficient to demonstrate that adequate measures have been taken to ensure that, in this area, either the likelihood of a load drop which might damage spent fuel is extremely small or the estimated consequences of such a drop will not exceed the limits set by the evaluation criteria of NUREG 0612, Section 5.1, Criteria I through III.

ITEM 2.3-1. Identify by name, type, capacity, and equipment designator any cranes physically capable (i.e., taking no credit for any interlocks or operating procedures) of carrying heavy loads over the reactor vessel.

RESPONSE: The only handling system within containment physically capable of carrying loads over the reactor vessel is the containment polar crane. The crane was designed by PACECO and possesses a 205-ton main hoist and a 30-ton auxiliary hoist. The crane bridge was designed for use in setting the reactor vessel and steam generators, a maximum lift weight of over 600 tons.

ITEM 2.3-2. Justify the exclusion of any cranes in this area from the above category by verifying that they are incapable of carrying heavy loads, or are permanently prevented from the movement of any load either directly over the reactor vessel or to such a location where, in the event of any load-handling-system failure, the load may land in or on the reactor vessel.

RESPONSE: There are no other cranes inside the containment capable of lifting heavy loads as defined in NUREG 0612.

ITEM 2.3-3. Identify any cranes listed in 2.3-1 above which you have evaluated as having sufficient design features to make the likelihood of a load drop extremely small for all loads to be carried and the basis for this evaluation (i.e., complete compliance with NUREG 0612, Section 5.1.6, or partial compliance supplemented by suitable alternative or additional design features). For each crane so evaluated, provide the load-handling-system (i.e., crane-load-combination) information specified in Attachment 1.

RESPONSE: Lifts of the reactor vessel head by the containment polar crane have been analyzed on a probabilistic basis. The study identified and quantitatively analyzed, using fault tree methods, the potential mechanisms for drops of

the reactor vessel head. The study was performed in accordance with the following steps:

- Description of the polar crane system and associated testing, maintenance, inspection, training and lift procedures regarding reactor head removal and installation during refueling

- Event identification and fault tree construction--determination of all the ways the polar crane system could fail

  (1) Structural failure while subjected to normal load conditions

  (2) Structural failure due to excessive load

    i) Two-blocking event

    ii) Load hangup event

  (3) Overspeed event--loss of hoisting or lowering capability coupled with loss of brakes

- Qualitative analysis--find minimal cut sets and establish all single failure events leading to system failure

- Probabilistic analysis

  (1) Find sources of data and determine applicability to San Onofre operations

  (2) Compute probability of the Top Event

  (3) Probabilistically rank basic events and min cut sets (i.e., conduct a sensitivity analysis)

- Conclusions, recommendations and results.

The Top Event for the analysis was defined in terms of two individual events:

- Drop during removal

- Drop during installation

These two events will generate the same load drop scenarios with two exceptions:

- o During installation a two-blocking event would most likely occur above the reactor head laydown area. Hence, this scenario is not considered during installation.

- o A reactor head load hangup event could only occur during removal. Again, this scenario is not considered during installation.

During head removal operations, the head is initially lifted one inch above the reactor vessel flange and carefully inspected. The head remains suspended in that position for 5 minutes before further lifting. To account for these operations, the analysis was segregated into two types of potential load drops:

- o Drop during initial lift

- o Drop after head clears alignment pins.

A drop during initial lift could result from a load hangup event or structural failure. This drop would occur at a height of no more than a few inches above the flange and is of no safety significance. The probability of a structural failure or load hangup following this initial lift is significantly reduced.

The results of the analysis indicate that the dominant failure mechanisms are those related to the occurrence of a load drop during its initial lift and hold from the reactor vessel flange. The mean probability of such an occurrence was determined to be on the order of 10^{-5} per lift. Because the initial lift height is limited to 1 inch above the flange, the consequences of dropping the head at this stage of the lift are considered minimal. The mean probability of failures leading to dropping of the head subsequent to the initial lift and hold was determined to be on the order of 10^{-6} per lift which is sufficiently small such that specific analyses of the consequences of a load drop are not necessary. In addition, to enable immediate detection of load hangups, SCE is installing a more accurate load cell for lifts of the head and upper guide structure, and will use a second operator to monitor crane operations, including specific monitoring to

prevent two blocking at the top of this lift. This will further reduce the likelihood of a load drop. Based on the results of the analysis and the further actions being undertaken, it is concluded that reactor vessel head lifting operations will be conducted safely.

ITEM 2.3-4. For cranes identified in 2.3-1 above not categorized according to 2.3-3, demonstrate that the evaluation criteria of NUREG 0612, Section 5.1, are satisfied. Compliance with Criterion IV will be demonstrated in your response to Section 2.4 of this request. With respect to Criteria I through III, provide a discussion of your evaluation of crane operation in the containment and your determination of compliance. The response should include the following information for each crane:

ITEM 2.3-4-a. Where reliance is placed on the installation and use of electrical interlocks or mechanical stops, indicate the circumstances under which these protective devices can be removed or bypassed and the administrative procedures invoked to ensure proper authorization of such action. Discuss any related or proposed technical specification concerning the bypassing of such interlocks.

RESPONSE: Interlocks governing operations of the polar crane are described on Page 9 of the July 1981 report. The Polar Crane Checkout and Operation Procedure SO23-1-3.22 stipulates that these interlocks can only be bypassed with authorization of the Maintenance Supervisor.

ITEM 2.3-4-b. Where reliance is placed on other, site-specific considerations (e.g., refueling sequencing), provide present or proposed technical specifications and discuss administrative or physical controls provided to ensure the continued validity of such considerations.

RESPONSE: The only such consideration is the physical protection provided by the reactor vessel head when in place or the absence of fuel. Loads lifted only when the reactor vessel head is in place and the unit is in a shutdown mode or the reactor is defueled were not considered as loads that could potentially drop into the core. These are: the CEDM cooling duct, the core support barrel, the CRDM missile shield blocks, the pool seal ring, and the head stud tensioners. Due to its large size and configuration (spanning the refueling cavity) and lifting procedures, the cable support structure cannot fall into the refueling cavity.

ITEM 2.3-4-c. Analyses performed to demonstrate compliance with Criteria I through III should conform with the guidelines of NUREG 0612, Appendix A. Justify any exception taken to these guidelines, and provide the specific information requested in Attachment 2, 3, or 4, as appropriate, for each analysis performed.

RESPONSE: Analyses were performed for a potential drop of the Upper Guide Structure (UGS) onto the reactor vessel (RV). The UGS drop was analyzed to demonstrate that the following consequences would not occur:

- o Drop does not cause failure of the UGS flange and consequent movement of the UGS into the underlying fuel bundles.
- o Drop does not cause failure of the reactor core barrel flange with attendant uncontrolled movement of the reactor core assembly within the reactor vessel.
- o Drop does not cause failure of one or more of the cooling water inlet nozzles, from which the reactor vessel is suspended, resulting in loss of reactor coolant.
- o Drop does not cause yield or buckling of reactor vessel support columns.

During refueling operations when the UGS is removed from the reactor vessel, it is lifted vertically to clear the top of the alignment pins and then transported to its storage location in the refueling cavity. The maximum required lift of the UGS above its in-place position is 13 feet. During this operation the UGS remains entirely below water, although part of its lift rig assembly is above water. In terms of masses, 65 tons of the total 73-ton weight remain under water. For purposes of these calculations it was assumed that the entire drop takes place under water. This assumption is justified on the grounds that the percentage of the total weight that is out of the water is small and because buoyancy effects are minor due to the high density contrast between water and steel.

In computing the final velocity of the UGS and lift rig assembly after a drop, the drag coefficient, C_D, for the body was taken to be 1.0. This results in a velocity at impact of approximately 24.5 ft/sec. Standard calculational methods were then used to calculate stresses in the impact areas (see references).

A drop of the UGS into the reactor vessel will result in the impact of the UGS flange onto the core support barrel flange. The impact area is approximately 4,775 in^2 and the average compression on the flange surface is less than 6,000 psi. The core support barrel itself rests on a flange area of the reactor vessel of approximately 1,380 in^2. The average compression on this contact surface is less than 21,000 psi. The calculated stresses are below the yield stress of the steel and are therefore acceptable.

The impact load of the UGS drop would be transmitted to the reactor vessel nozzles and support columns. The total area of the nozzles experiencing maximum shear is approximately 5,800 in^2 and the shear stress is less than 6,000 psi. The maximum bending stress is less than 9,000 psi. With respect to the columns supporting the reactor vessel nozzles, the impact load is well within the elastic limit of the columns. Thus both the nozzle stresses and column loads are such that the integrity of the reactor vessel would not be affected. It is also apparent that in the unlikely event that the impact load were sustained unequally by the vessel nozzles, there is substantial margin available to accommodate the loading.

The above evaluations indicate that no gross failure of the UGS or vessel supports will occur. In addition, the probabilistic analysis performed for lifts of the reactor vessel head (see Response to Item 2.3-3) indicating that the probability of a polar crane failure is very small, is also applicable to lifts of the UGS. In fact, the probability of a crane failure during lifting of the UGS, subsequent to a successful lift of the head, is less than the probability for a head drop. Under these circumstances it was not considered to be necessary to evaluate the UGS in any greater detail.

ITEM 2.4 SPECIFIC REQUIREMENTS FOR OVERHEAD HANDLING SYSTEMS OPERATING IN PLANT AREAS CONTAINING EQUIPMENT REQUIRED FOR REACTOR SHUTDOWN, CORE DECAY HEAT REMOVAL, OR SPENT FUEL POOL COOLING

NUREG 0612, Section 5.1.5, provides guidelines concerning the design and operation of load-handling systems in the vicinity of equipment or components required for safe reactor shutdown and decay heat removal. Information provided in response to this section should be sufficient to demonstrate that

adequate measures have been taken to ensure that, in these areas, either the likelihood of a load drop which might prevent safe reactor shutdown or prohibit continued decay heat removal is extremely small, or damage to such equipment from load drops will be limited in order not to result in the loss of these safety-related functions. Cranes which must be evaluated in this section have been previously identified in your response to 2.1-1 and their loads in your response to 2.1-3-c.

ITEM 2.4-1. Identify any cranes listed in 2.1-1 above which you have evaluated as having sufficient design features to make the likelihood of a load drop extremely small for all loads to be carried and the basis for this evaluation (i.e., supplemented by suitable alternative or additional design features). For each crane so evaluated, provide the load-handling-system (i.e., crane-load-combination) information specified in Attachment 1.

RESPONSE: No cranes operating in the referenced plant areas required evaluation against the criteria of Section 5.1.5.

ITEM 2.4-2. For any cranes identified in 2.1-1 which are not designated as single-failure-proof in 2.4-1, a comprehensive hazard evaluation should be provided which includes the following information:

ITEM 2.4-2-a. The presentation in a matrix format of all heavy loads and potential impact areas where damage might occur to safety-related equipment. Heavy loads identification should include designation and weight or cross-reference to information provided in 2.1-3-c. Impact areas should be identified by construction zones and elevations or by some other method such that the impact area can be located on the plant general arrangement drawings. Figure 1 provides a typical matrix.

RESPONSE: The requested information is provided in Tables 3-1 through 3-7. Layout drawings showing the locations of equipment are provided in Figures 3-1 through 3-8 and in those drawings previously provided in the June 1981 report.

ITEM 2.4-2-b. For each interaction identified, indicate which of the load and impact area combinations can be eliminated because of separation and redundancy of safety-related equipment, mechanical stops and/or electrical interlocks, or other site-specific considerations. Elimination on the basis of the aforementioned considerations should be supplemented per items 2.4-2-b(1), (2), and (3) as follows.

RESPONSE: This information is provided in Tables 3-1 through 3-7.

ITEM 2.4-2-b(1): For load/target combinations eliminated because of separation and redundancy of safety-related equipment, discuss the basis for determining that load drops will not affect continued system operation (i.e., the ability of the system to perform its safety-related function).

RESPONSE: Two cases were identified where separation and redundancy of safety-related equipment provided the basis for elimination of load/target combinations. These involved movement of loads by the CCW pump monorail and the SI pump monorails.

CCW Pump Monorail

As described in the July 7, 1981 report, each CCW pump is located in a separate compartment. Equipment located in each compartment was reviewed to determine the existence of any potential interactions where a load drop in one compartment could affect the functioning of redundant equipment in another compartment. This review indicated that the consequences of a potential drop would be limited to a single compartment where the CCW pump was being maintained. Therefore, component cooling requirements could be met by the remaining operable CCW pumps.

SI Pump Monorail

As described in the July 7, 1981 report, two Low Pressure Safety Injection (LPSI) and three High Pressure Safety Injection (HPSI) pumps and other safety-related equipment are located in three separate compartments. Equipment located in each compartment was reviewed to determine the existence of any potential interactions in the event of a load drop in one compartment. With the exception of the shutdown cooling line, discussed below, no interactions were identified that would preclude minimum functioning of safety equipment.

Shutdown Cooling Line

Review of the equipment located in Room 005 indicated that a branch of the shutdown cooling line (SCL), including its isolation valve, was located adjacent to LPSI Pump #1. The shutdown cooling line is the path for cooling water to the reactor vessel during shutdown. Pumping capacity is provided by either of the two LPSI pumps. Maintenance of the LPSI pumps could require lifting and removal of the motor by the overhead monorail. A postulated drop of the motor and impact of SCL and valve could result in a non-isolatable leak path from the main run of the shutdown cooling line. The layout of the LPSI pump and SCL is shown on Figures 3-1 through 3-3.

An evaluation was performed to determine the likelihood of interaction of the SCL and isolation valve in the event of a load drop involving the LPSI pump motor. The LPSI pump motor is lifted using a chain hoist positioned on a spur of the monorail located over the pump. After the vertical lift, the hoist trolley is moved along the curved monorail spur to the main section of monorail. During this travel, the motor rotates relative to its initial, in-place position. At no time is the motor lifted partially or directly above the shutdown cooling line or isolation valve. The motor would have to be deflected during its drop to interact with the SCL or valve.

Upon vertical drop of the motor when it is positioned closest to the LPSI pump discharge check valve, there is slight encroachment that may result in impact of motor against valve. Therefore, rotational displacement of the dropping motor due to uneven impact on one edge of the motor is possible, but the shutdown cooling line and isolation valve are not exposed to impact.

Figure 3-2 illustrates the path of the motor if it were to impact the check valve.

The path clears the shutdown cooling line and isolation valve (SCL & V) by 1 ft; therefore, impact against the SCL & V could only result if the motor body underwent a net horizontal translation in addition to the rotation. Such

translation, derived from the rotational impulse originated by vertical impact on one edge, would result only under an elastic type of impact with associated "rebound" along the horizontal direction oriented precisely toward the SCL & V.

Elastic impact means no losses by strain energy and full conservation of momentum, which implies rigid bodies impacting elastically without any crushing. For the case under consideration, the only exposed offset target upon vertical drop of the lifted motor is the LPSI discharge check valve. The structural characteristics and the in-line support of this valve render it as a crushable, energy-absorbing body, incapable of reacting elastically to impact from the much heavier rigid body of the dropping motor. Therefore, the type of impact necessary to result in tilting and horizontal translation of motor to reach the SCL & V is not possible.

ITEM 2.4-2-b(2). Where mechanical stops or electrical interlocks are to be provided, present details showing the areas where crane travel will be prohibited. Additionally, provide a discussion concerning the procedures that are to be used for authorizing the bypassing of interlocks or removable stops, for verifying that interlocks are functional prior to crane use, and for verifying that interlocks are restored to operability after operations which require bypassing have been completed.

RESPONSE: Neither mechanical stops or electrical interlocks are to be provided.

ITEM 2.4-2-b(3). Where load/target combinations are eliminated on the basis of other, site-specific considerations (e.g., maintenance sequencing), provide present and/or proposed technical specifications and discuss administrative procedures or physical constraints invoked to ensure the continued validity of such considerations.

RESPONSE: Administrative controls will be applied to restrict handling of heavy loads in the following cases:

Turbine Gantry Crane

Lifts of the salt water cooling pumps will be limited to a maximum of 5 feet above the enclosure structure. Analyses have demonstrated that the resultant impact load is well within the capability of the structure. In addition, lifts of other heavy loads will be restricted to an area westward of the salt water cooling pumps and enclosure structure. In keeping with standard SCE practice, this will be done to avoid load drops onto turbine generator equipment as well as on to the pump enclosure.

Hoisting operations with the side boom extension at the gantry crane are subject to restricted use exclusively for the following functions:

1. Transfer of the Tendon Surveillance Platforms (TSP) from side to side of the Containment Buttress No. 3. This operation is performed only once during each of the tendon surveillances, which are scheduled as: 2 times at 2 year intervals followed by 7 times at 5 year intervals.

2. Removal and transport of the Main Steam Isolation Valve (MSIV) components and the Feedwater Valves (FWV) (2.8 ton max. wt.), and potentially the Tendon Surveillance Platform (5 ton wt.), as required for maintenance.

The designated travel paths for the specific operations as defined in Figures 3-6 and 3-7 do not expose any safe shutdown/safety-related equipment to damage due to a postulated load drop.

The travel path for transfer of the TSP from side to side of Buttress No. 3 does not take place over any safe shutdown equipment since the travel is limited to the clear area between the two MSIV Enclosures; see travel paths 3 and 5, Figure 3-6. The intermediate Laydown Area No. 1 is designated for local maintenance of the TSP, if necessary, and it is provided to minimize the need for longer travel. Administrative control of the boom/gantry crane operation will assure that the TSP and other loads are transported within the designated travel paths and specifically not over the MSIV Enclosures.

Lifted load travel over the MSIV Enclosure would be required only if it were necessary to remove either the MSIV components or the FWV, both of which

would have to be performed while the Unit is shutdown. Therefore, a potential drop on the 2 ft. thick concrete roof of the MSIV Enclosure does not endanger any safe shutdown equipment, and analytical verification of the structural capacity of the roof with its various hatches and blowout panels is not warranted.

The main north-south travel path for all loads, designated as path 4 in Figure 3-6, is delineated along the exterior separation wall of the Safety Equipment Building (SEB), over the Electrical and Piping Gallery Access Building, and next to the Iso-Phase Bus and Main Transformer. The Safe Shutdown Heat Exchangers are the only essential equipment housed in the SEB at compartment levels immediately below and next to the lifted load travel path. Other essential equipment housed in the SEB at locations close to a potential load drop, namely the Safety Injection Pumps and the Component Cooling Water Pumps, are positively shielded within their separate concrete compartments at the lower level of the structure.

The two safe shutdown heat exchangers are part of redundant systems housed in separate compartments, both of which could not be impacted simultaneously by a single load drop.

The load travel path across the Electrical and Piping Gallery Access Building does not affect any essential electrical trays and conduits nor any piping since these items are housed at the lower level of the structure.

The remainder of the travel path is next to the Iso-phase Bus and Main Transformer. These items are not safety-related equipment.

<u>Small Jib Cranes</u>

Several small jib cranes are mounted upon the roof near MSIV hatches (MSIV Jib Cranes) and ventilation stacks (Jib Cranes 1 and 3 for Unit 2 and Jib Cranes 2 and 4 for Unit 3). The MSIV jib cranes lift MSIV and FWV components to the roof area for subsequent movement by the side boom extension of the gantry crane,

as described above. Since the plant must be shut down to remove these components, postulated impacts on MSIVs or piping would not affect safety.

Jib Cranes 1 and 3 for Unit 2 are shown in Figure 3-8. Lifts of the Tendon Surveillance Platform and Load Center Transformer will be restricted to a maximum height of 9 feet above the roof to allow the loads to clear ducts in the area. Analyses have demonstrated that the resultant impact load is within the capability of the structure roof. In addition to movement over the roof slab, removal of the transformer through the equipment hatch at the roof requires a total lift of 59 ft over the floor at elevation 45' - 0". A potential load drop from this height may result in extensive cracking or perforation of the floor at elevation 45' - 0". Damage to safety-related electrical and mechanical items housed below elevation 45' - 0" including component cooling water (CCW) Train B, could potentially result. However, this transformer serves non-safety related systems and electrical backup is available, the removal and lifting of the transformer will be deferred until the next cold shutdown during which time the risk of load-drop damage to the non-safeshutdown electrical and mechanical items is acceptable. In order to assure the safe removal of the transformer during a shutdown period, the Component Cooling Water (CCW) Train A will be in operation and Train B will be secured at the time of transformer removal.

AFW Pump Bridge Crane

Lifts of the AFW pump motors will be restricted to such times that the plant is in a cold shutdown mode.

SI Pump Monorail

Lifts of pump components out of the pump rooms will be restricted to a maximum height of 5 inches above the hatch and floor slab. Analyses have demonstrated that the resultant impact load is within the capability of the structure.

CCW Pump Monorail

Lifts of pump components out of the pump room will be restricted to a maximum height of 15 inches above the hatch and floor slab. Analyses have demonstrated that the resultant impact load is within the capability of the structure.

ITEM 2.4-2-c. For interactions not eliminated by the analysis of 2.4-2-b above, identify any handling systems for specific loads which you have evaluated as having sufficient design features to make the likelihood of a load drop extremely small and the basis for this evaluation (i.e., complete compliance with NUREG 0612, Section 5.1.6, or partial compliance supplemented by suitable alternative or additional design features). For each crane so evaluated, provide the load-handling-system (i.e., crane-load-combination) information specified in Attachment 1.

RESPONSE: Not applicable.

ITEM 2.4-2-d. For interactions not eliminated in 2.4-2-b or 2.4-2-c above, demonstrate using appropriate analysis that damage would not preclude operation of sufficient equipment to allow the system to perform its safety function following a load drop (NUREG 0612, Section 5.1, Criterion IV).

RESPONSE: The following crane/load combinations have been evaluated to assure operability of minimum safe shutdown equipment:

Containment Polar Crane

Lifts involving reactor coolant pump motors were evaluated to determine the potential for interactions with the reactor coolant system and shutdown cooling line, located in the vicinity of pump 2A. The polar crane is used for lifts of the reactor coolant pump motor and impeller. The maximum lift height is approximately 40 feet. A number of large structural members are located between the load transfer path and the shutdown cooling line, which serves to prevent a load drop which could adversely affect the integrity of the line . This is described in more detail below. In addition, in the unlikely event that the reactor coolant system or shutdown cooling line were damaged, SCE has identified an alternate means for maintaining core cooling. This consists of

pumping water from the refueling water storage tank and/or the emergency sump using the HPSI pumps. Plant operating procedures will ensure that alternate means of core cooling exist under these conditions. Necessary procedures and lifting operation controls will be used when moving a reactor coolant pump motor with fuel in the vessel.

In the event of a pump motor or impeller drop onto the motor/pump laydown platform at 45-foot elevation, the shutdown cooling line (SCL) is shielded by the following items which are located between the platform and the SCL routed 20 feet below:

- o Steel framing of laydown structure -- two levels of steel beams (w8 x 20 on short pans) supported by heavy embedments in concrete wall and by w12 x 53 steel columns
- o Heavy lateral restraint (5 in. x 24 in. solid steel forging) for reactor coolant pump
- o Steel frame of pipe support for SCL
- o Protruding concrete wall, 29 inches thick, extending 3 feet above top of SCL.

The above items are heavy structural systems independently supported and located in the drop path of motor or impeller striking the SCL, so that complete collapse of these items would have to take place for the SCL to be impacted. The aggregate of these items overlayed in the vicinity of the transfer path for the motor/impeller is shown in Figures 3-4 and 3-5, and it demonstrates sufficient protection for the SCL.

Turbine Gantry Crane

Lifts of the salt water cooling (SWC) pumps and motors are performed by the turbine gantry crane. Analyses have been performed for the salt water cooling pump hatch covers, the floor slab and beams located above the pumps, and the enclosure structure for the SWC trains. Other heavy components are also lifted by the turbine gantry crane and could be moved over the SWC system. Because the structures protecting the SWC system do not have sufficient capacity to

resist load drops of greater than 5 tons and 5 foot drop height, administrative controls will be applied to control movement of these loads. These are described in the response to Item 2.4-2-b.

The results of structural analyses for the salt water cooling pumps are summarized in Table 3-8. Additional information on the method of analysis is provided below in a generic discussion. For these structures the calculated ductility ratios are within acceptable limits and no spalling or perforation is expected. As described in the response to Item 2.4-2-b, administrative controls will be applied to limit the lift height for the SWC pumps and motors.

Small Jib Cranes

Lifts of the Tendon Surveillance Platform and removal of the Load Center Transformer are performed by Jib Cranes 1, 2, 3 and 4. Analyses have been performed for the concrete roof slab and steel beam framing. The results of the analyses are summarized in Table 3-9. Additional information on the method of analysis is provided below in a generic discussion. For affected structures the calculated ductility ratios are within acceptable limits and no spalling or perforation is expected. As described in the response to Item 2.4-2b, administrative controls will be applied to limit the lift height for these loads, and in the case of the removal of the Load Center Transformer, to limit the performance of the lift to times when the plant is shutdown.

Component Cooling Water Pump Monorail

Lifts of the component cooling water (CCW) pump motors are performed by the CCW monorail. Analyses have been performed of the hatch covers and floor slab above the CCW pump rooms for a drop of the pump motor. The results of the analyses are summarized in Table 3-10. Additional information on the method of analysis is provided below in a generic discussion. For a maximum drop height of 15 inches, the calculated ductility ratios of the structures are within acceptable limits and no spalling or perforation is anticipated for the concrete floor slab with steel decking underneath. As described in the response to Item 2.4-2-b,

administrative controls will be applied to limit the lift height for the CCW pump motors.

Safety Injection Pump Monorail

Lifts of the safety injection (SI) pump motors are performed by the SI pump monorail. Analyses have been performed of the hatch covers and floor slab above the SI pump rooms for a drop of the SI pump motor. The results of the analyses are summarized in Table 3-11. Additional information on the method of analysis is provided below in a generic discussion. For a maximum drop height of 5 inches, the calculated ductility ratios are within acceptable limits and no spalling or perforation is anticipated for the hatch cover or floor slab with steel decking underneath. As described in the response to Item 2.4-2-b, administrative controls will be applied to limit the lift height for the SI pump motors.

Analysis Methods

A conservative structural design basis for impactive loads is to consider the kinetic energy of the impacting body as fully absorbed by the strain energy developed in the resisting structural system, disregarding other energy losses. The strain energy is accounted by material deformation through the elastic range and extending into the plastic yielding range subject to upper bound strain levels substantially below the ultimate strain of the material.

The ductility ratio is an index of the plastic yielding deformation expressed with respect to the elastic deformation of the structural system. It is defined as the ratio of the total deflection to the deflection at the elastic limit beyond which the structural system becomes a yielding mechanism. The mechanism of the yielding structural system continues to offer energy absorption at nearly constant load levels without any implication of structural collapse, which is imminent only after the higher ultimate strain levels of the material are approached.

Ductility ratio limits prescribed in accordance with BC-TOP-9-A, Revision 2, are as follows:

Reinforced concrete (flexural): beams $\mu \leqq 10$
slabs $\mu \leqq 30$

Steel (flexural): beams $\mu \leqq 20$

The above limits represent strain energy absorption with a margin factor of at least 8 with respect to the ultimate-strain energy capacity of the material whereupon structural collapse could be postulated. Such ductility ratios are regarded as acceptable provided that (1) the large deflections that may result do not compromise the serviceability of the structure nor the function of essential equipment housed within the structure and (2) the ultimate shear capacity and elastic stability capacity are at least 20 percent higher than the flexural resistance of the yielded system.

For the structural systems under consideration, the maximum deflection response tabulated is totally acceptable from the standpoint of structural service ability and, above all, there is no equipment by virtue of its direct attachment to the structure that would be affected by such deflection. The available shear capacity and elastic stability capacity also afford the prescribed margin. Therefore, compliance with the stated ductility ratio limits is the basic acceptance criterion used for the structures subject to impactive loading.

CRANE: CONTAINMENT POLAR CRANE

TABLE 3-1

LOCATION	CONTAINMENT BUILDING		
IMPACT AREA / LOADS	AREA AROUND REACTOR COOLANT PUMP 2A		
	ELEVATION	SAFETY-RELATED EQUIPMENT	HAZARD ELIMINATION CATEGORY
Reactor Coolant Pump Motor and Impeller	25'	Shutdown Cooling Line	See discussion under Item 2.4-2-d.

CRANE: TURBINE GANTRY CRANE

TABLE 3-2

LOCATION	TURBINE DECK		
IMPACT AREA / LOADS	SALT WATER COOLING SYSTEM ENCLOSURE STRUCTURE		
	ELEVATION	**SAFETY-RELATED EQUIPMENT**	**HAZARD ELIMINATION CATEGORY**
SWC Pump SWC Motor	35' 0" 35' 0"	Salt water cooling pumps Salt water cooling lines	Lift heights will be limited such that a load drop would not damage remaining SWC trains.
Generator Rotor Other heavy components	72' 6" 72' 6"	Salt water cooling pumps Salt water cooling lines	Movement of heavy components will be limited by administrative controls.
Tendon Surveillance Platforms MSIVs/FWVs	95' 0" 40' 0"	Safe shutdown heat exchangers MSIVs	Movement of heavy components will be limited by administrative controls. See discussion under Item 2.4-2b(3)

CRANE: COMPONENT COOLING WATER PUMP MONORAIL

TABLE 3-3

LOCATION	SAFETY EQUIPMENT BUILDING		
IMPACT AREA / LOADS	CCW PUMP ROOMS		
	ELEVATION	**SAFETY-RELATED EQUIPMENT**	**HAZARD ELIMINATION CATEGORY**
CCW Pump Motor	- 5' 3"	CCW Pumps, piping	a. Drops of components within a CCW pump room will only affect the equipment in that room. Full capability is maintained by the remaining two CCW pumps located in separate rooms. b. Drops of a CCW pump motor on the ceiling and hatch cover of adjacent CCW pump rooms is addressed in response to Item 2.4-2d.

CRANE: SAFETY INJECTION PUMP MONORAILS

TABLE 3-4

LOCATION	SAFETY EQUIPMENT BUILDING		
IMPACT AREA / LOADS	PUMP ROOMS 002, 005, 015		
	ELEVATION	**SAFETY-RELATED EQUIPMENT**	**HAZARD ELIMINATION CATEGORY**
SI Pump Motor LPSI Pump Motor	– 15' 6" – 15' 6"	Rooms 002 and 005: o Shutdown cooling system cable, equipment o LPSI pump o HVAC cable, fan o Component cooling water valves o Emergency chilled water system valves Room 015: o Shutdown cooling system cable, equipment o Component cooling water valves o Emergency chilled water system valves	a. Drops of an SI pump motor on the ceiling and hatch cover of adjacent pump rooms is addressed in the response to Item 2.4-2-d. b. Drops of pump components within Rooms 002 and 015 will only affect safety related equipment in that room. Full capability is maintained by redundant equipment located in other separate rooms. c. A drop of the LPSI motor in Room 005 in the vicinity of the shutdown cooling line and isolation valve is addressed in the response to Item 2.4-2-b(3).

CRANE: AFW PUMP BRIDGE CRANE

TABLE 3-5

LOCATION	TANK STORAGE BUILDING		
IMPACT AREA / LOADS	AFW PUMP ROOM		
	ELEVATION	**SAFETY-RELATED EQUIPMENT**	**HAZARD ELIMINATION CATEGORY**
AFW Pump Motor	30' 0"	AFW pumps and supporting equipment	Administrative controls will be implemented to restrict lifting of pump components to such times that the plant is in cold shutdown.

CRANE: MSIV JIB CRANES

TABLE 3-6

LOCATION	MSIV ENCLOSURE		
IMPACT AREA / LOADS	MSIV ENCLOSURE		
	ELEVATION	SAFETY-RELATED EQUIPMENT	HAZARD ELIMINATION CATEGORY
MSIV Components FWV Components Misc. light equipment	40' 0"	MSIVs, piping	Movement of heavy components will be limited by administrative controls to such times that the plant is in cold shutdown.

CRANE: JIB CRANES 1, 2, 3 AND 4

TABLE 3-7

LOCATION	ADJACENT TO SAFETY EQUIPMENT BUILDING		
IMPACT AREA / **LOADS**	PENETRATION AREA		
	ELEVATION	**SAFETY-RELATED EQUIPMENT**	**HAZARD ELIMINATION CATEGORY**
Tendon surveillance platform Load Center transformer	95'	Safety related Electrical Cable Trays and Conduits	a. Drops of loads on the roof from a maximum height of 9 feet is addressed in Item 2.4-2d. b. Administrative controls will be implemented to restrict lifting of Load Center Transformer for removal to such times that the plant is in cold shutdown.

TABLE 3-8

SALT WATER COOLING PUMP LOAD DROP ANALYSIS

LOAD	BARRIER	DROP HEIGHT	MAXIMUM DEFLECTION UNDER IMPACT LOAD	DUCTILITY RATIO
SWC Pump	Concrete Hatch Cover (18 in.)	5 ft	1.6 in.	6.9
	Concrete Floor Slab/Beams (24 in.)	5 ft	4.6 in.	11
SWC Motor	Concrete Hatch Cover (18 in.)	5 ft	0.7 in.	3.2
	Concrete Floor Slab/Beams (24 in.)	5 ft	2.2 in.	5.7

TABLE 3-9

JIB CRANES 1, 2, 3 AND 4 LOAD DROP ANALYSIS

LOAD	BARRIER	DROP HEIGHT	MAXIMUM DEFLECTION UNDER IMPACT LOAD	DUCTILITY RATIO
Load Center Transformer	Concrete Roof Slab (14 in.)	9 ft.	2.6 in.	19
Tendon Surveillance Platform	Structural Steel Beam	9 ft.	1.7 in.	15

TABLE 3-10

COMPONENTS COOLING WATER PUMPS LOAD DROP ANALYSIS

LOAD	BARRIER	DROP HEIGHT	MAXIMUM DEFLECTION UNDER IMPACT LOAD	DUCTILITY RATIO
CCW Pump	Steel Plate Hatch Cover (½ in. with stiffeners)	15 inches	2.6 in.	5.3
	Concrete Floor Slab	15 inches	1.5 in.	10

TABLE 3-11

SAFETY INJECTION PUMPS LOAD DROP ANALYSIS

LOAD	BARRIER	DROP HEIGHT	MAXIMUM DEFLECTION UNDER IMPACT LOAD	DUCTILITY RATIO
SI Pump Motor	Concrete Hatch Cover (24 in.)	5 in.	0.04 in.	10
	Concrete Floor Slab (24 in.)	5 in.	0.4 in.	2.8

4.0 LIFT RIG EVALUATION

In the six-month report certain information requested in Item 3(d) was not supplied for the reactor vessel head and upper guide structure (UGS) lifting rigs. At that time our evaluation had not been completed because of a need to obtain information from the fabricator. Specifically, comparisons to the design requirements in ANSI Standard N14.6-1978, Sections 3, 5 and 6, were not complete and all exceptions were not identified.

Both the reactor vessel head and UGS lifting rigs were designed and fabricated before ANSI Standard N14.6 was issued. Additionally, this standard is not applicable to these lifting rigs, since it was issued for lifting rigs associated with irradiated fuel shipping casks. Lifting rigs for these loads might be expected to have far greater usage, in less controlled environments and without the tight procedural controls imposed upon the lifting rigs for the reactor vessel head and UGS. Also, the load drop evaluations in this report show that neither the reactor vessel head nor the UGS should be classified as a critical load. Therefore, we believe a detailed comparison to Section 6.0 of the ANSI standard is not useful or warranted. We have, however, reviewed the design requirements for both the reactor vessel head and UGS lifting rigs and believe that appropriate and conservative requirements were imposed. These design requirements are discussed below.

<u>Reactor Vessel Head Lift Rig</u>

The design of the reactor vessel head lift rig was included in the Reactor Vessel Stress Report. Section III of ASME Boiler and Pressure Vessel Code was used for its analysis including all addenda through the summer of 1971. This structural analysis concluded that the lift rig was structurally adequate to lift the reactor vessel head. Section 210.10 of the CE design manual was used to govern the design requirements of the lifting rig. This standard outlines the design criteria for handling, lifting and shipping structures. Additionally, a dynamic analysis was conducted using a finite element model of the lifting rig structure for seismic loads. The extensive analyses, conservative stress limits and material

strengths of the ASME code assure an adequately designed lifting rig for the reactor vessel head.

UGS Lift Rig

The UGS Lift Rig also used the 1971 edition of the ASME Boiler and Pressure Vessel Code, Section III, Article NB-3000. In addition to the conservatisms implicit in this code, a design load of twice the operating load was assumed. Therefore, the peak stresses in the lift rig are essentially a factor of 3 less than the conservative yield stresses set by code for the materials. Based on use of the ASME code requirements and on doubling the load for design, we have concluded that the UGS lift rig is adequate.

5.0 REFERENCES

1. Bechtel Corporation, Design of Structures for Missile Impact, Rev. 2, Topical Report BC-TOP-A, San Francisco, September 1974.

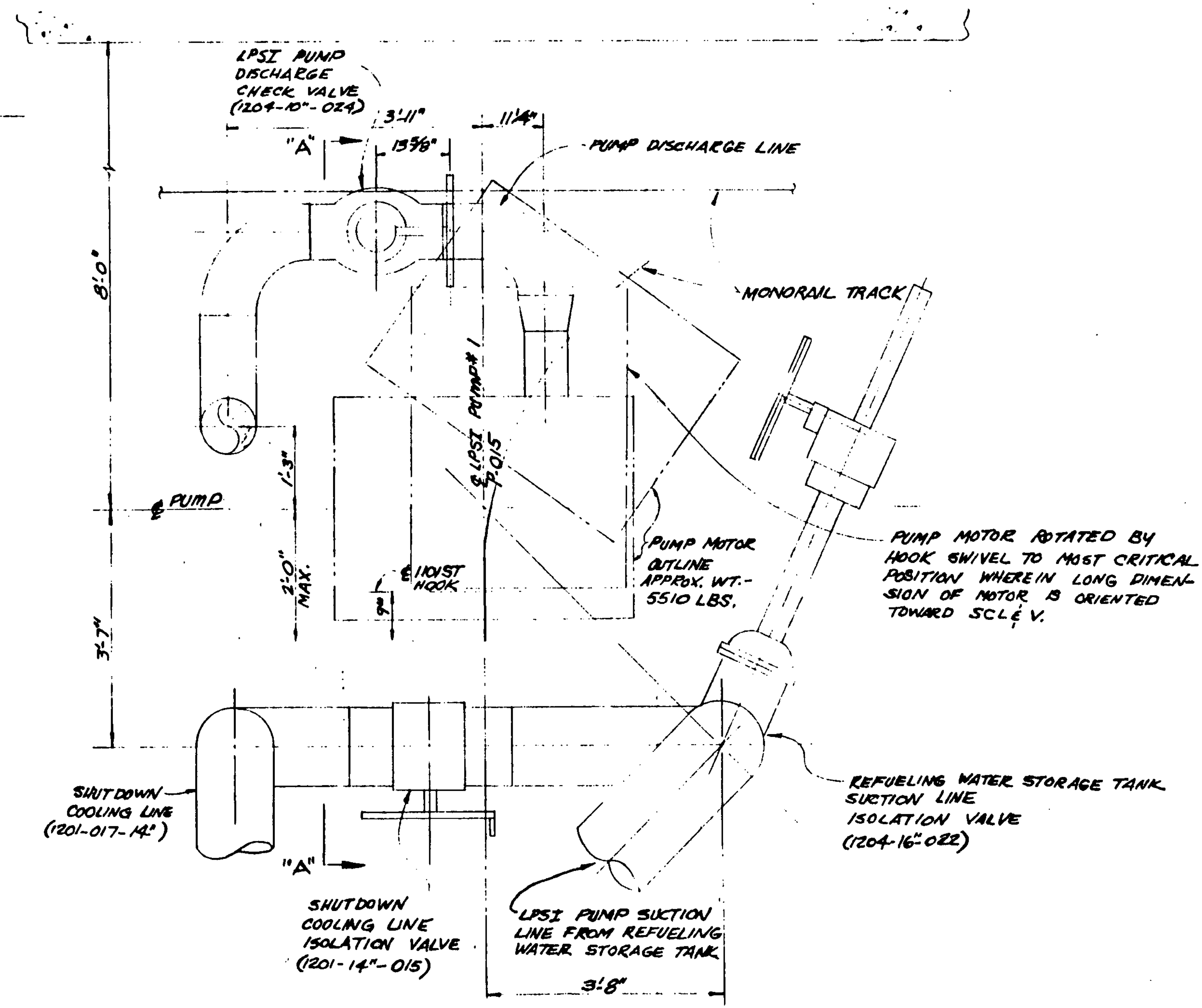
2. Westinghouse, Reactor Vessel Head Drop Analyses, WCAP-9198.

3. R.J. Roark and W.C. Young, Formulas for Stress and Strain, 5th edition, McGraw-Hill, New York, 1975.

B-81-380

FIGURE 3-1

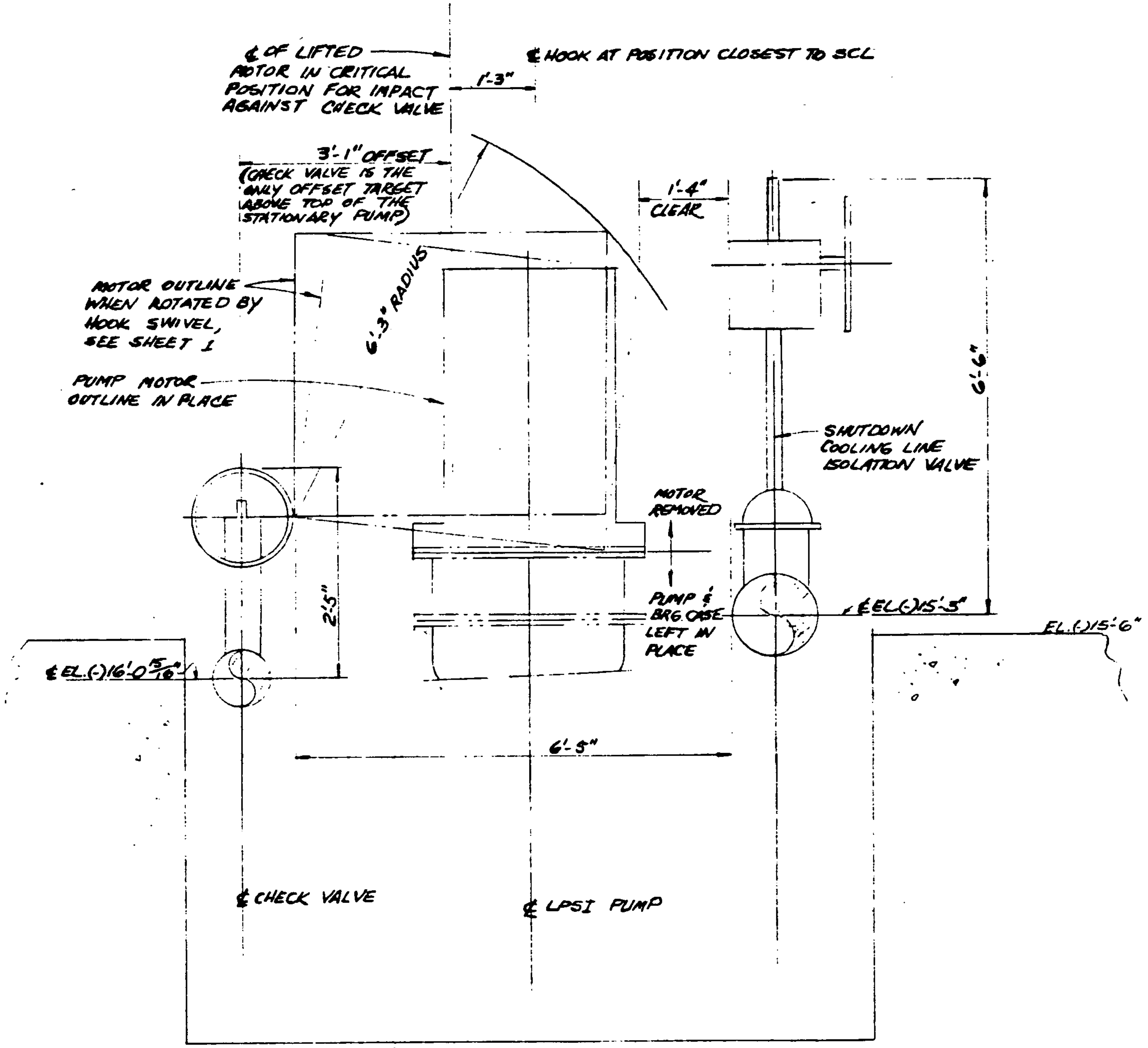
LPSI PUMP MOTOR LIFT-
ORIENTATION OF SHUTDOWN
COOLING LINE & ISOLATION VALVE



PLAN UNIT 2

SCALE: 1"=1'-0"

TERA CORPORATION



SECTION A-A UNIT 2

1" = 1'-0"

FIGURE 3-2

LPSI PUMP MOTOR LIFT-
OFFSET OF CHECK VALVE

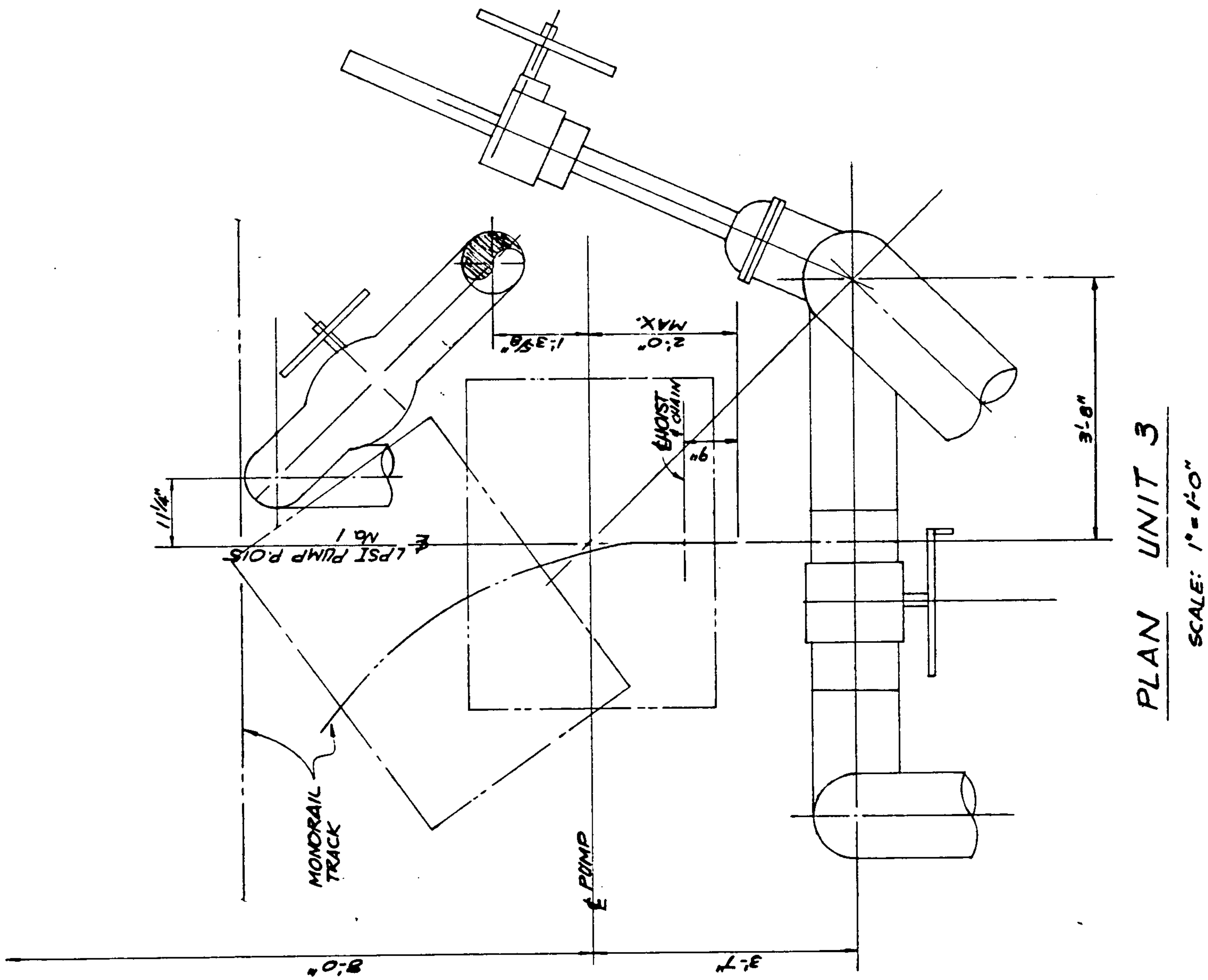


FIGURE 3-3

LPSI PUMP MOTOR LIFT - MOVEMENT
OF MOTOR ALONG CURVED SECTION
OF MONORAIL TRACK

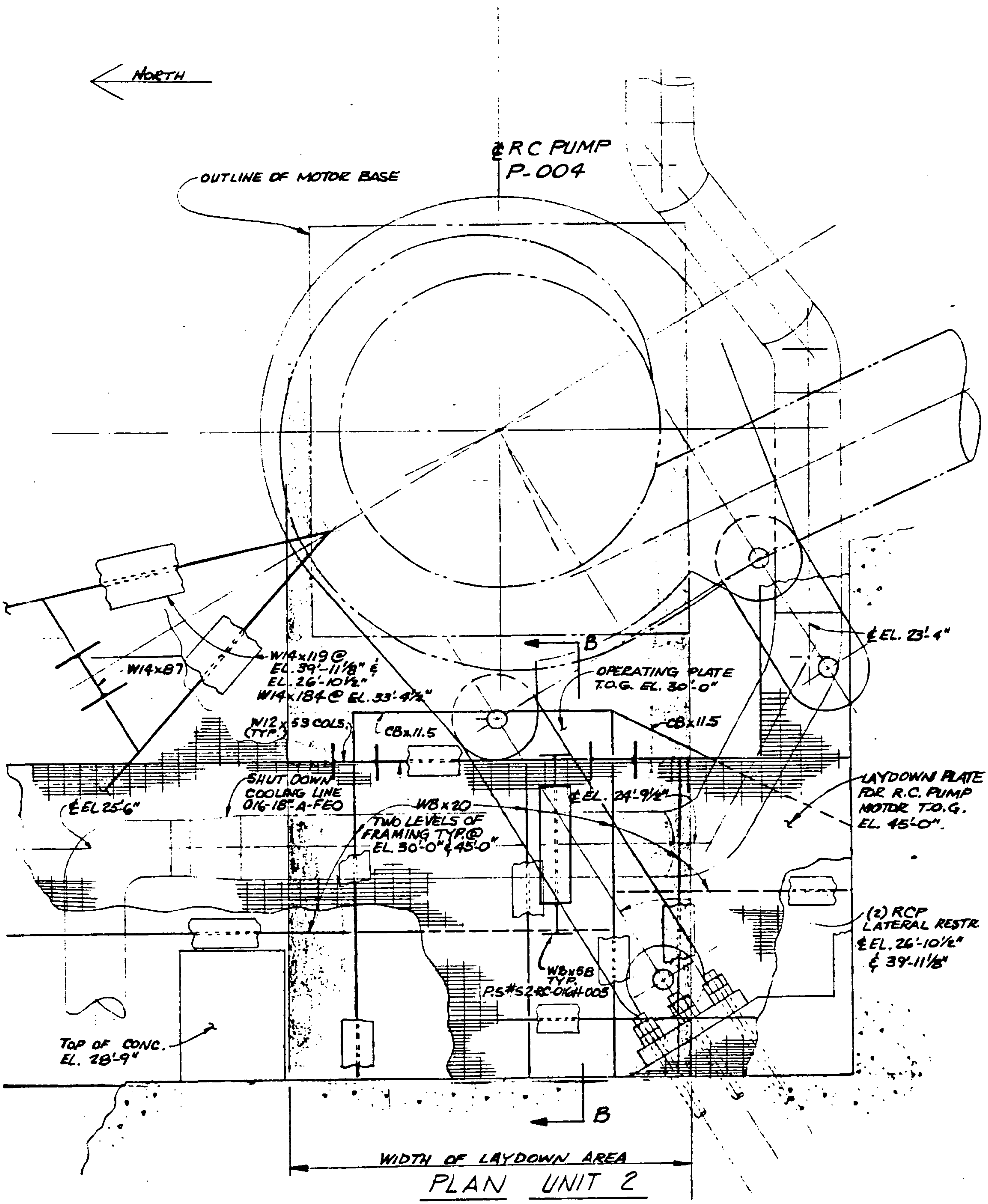
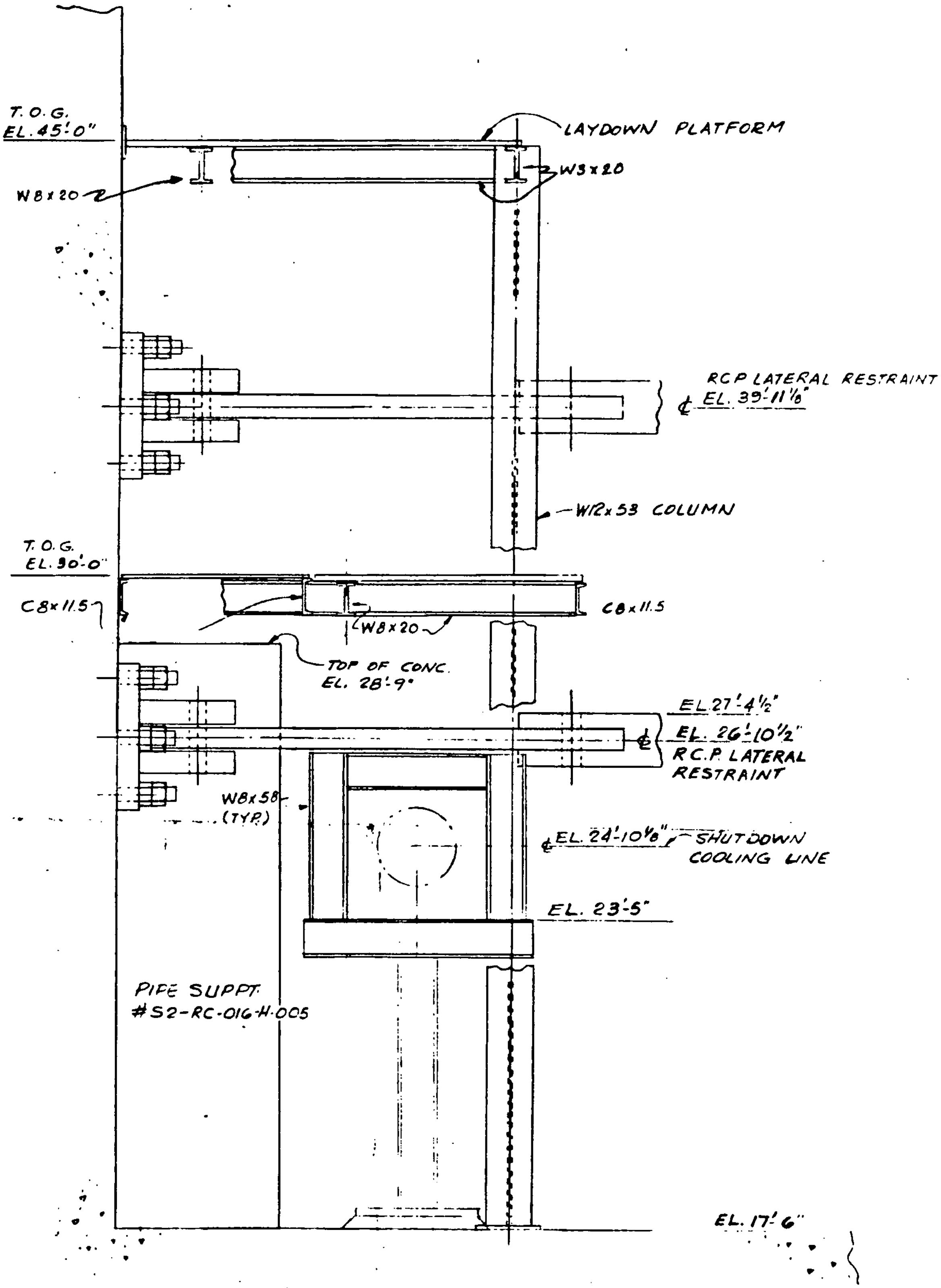


FIGURE 3-4

B-81-380

ORIENTATION OF REACTOR
COOLANT PUMP AND SHUTDOWN COOLING LINE

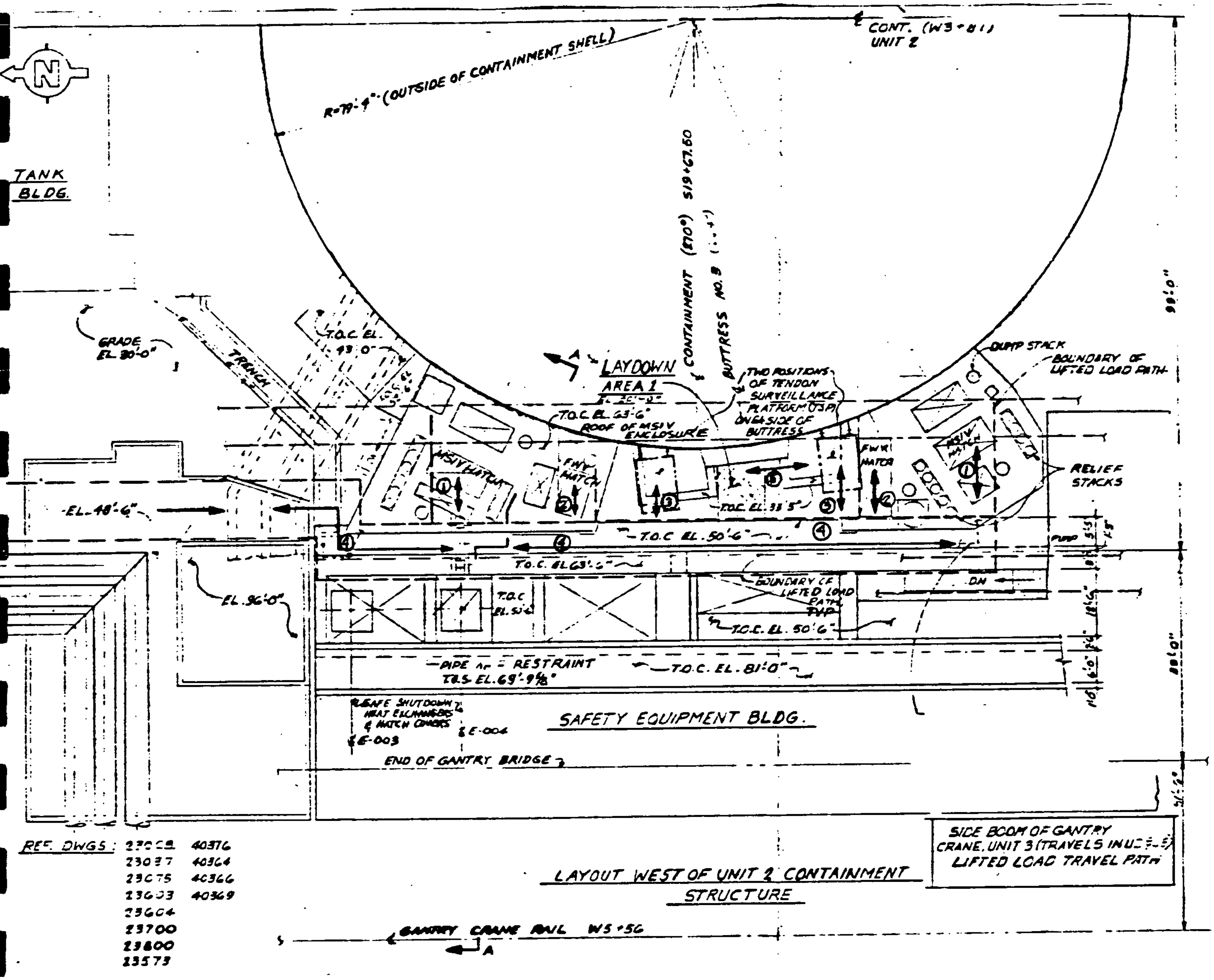
TERA CORPORATION



SECT. B-B
3/4" = 1'-0"

FIGURE 3-5

MAJOR STRUCTURAL MEMBERS
IN THE VICINITY OF THE
SHUTDOWN COOLING LINE



SAFE LOAD PATHS

(1) East-west travel for removal of MSIV components.
(2) East-west travel for removal of FWV.
(3) East-west travel for removal of TSP.
(4) Main north-south travel for transport of all loads to laydown area 2.
(5) Local north-south travel for transfer of TSP from side to side of buttress no. 3.

FIGURE 3-6

SAFE TRAVEL PATH
FOR SIDE BOOM EXTENSION -
TURBINE GANTRY CRANE

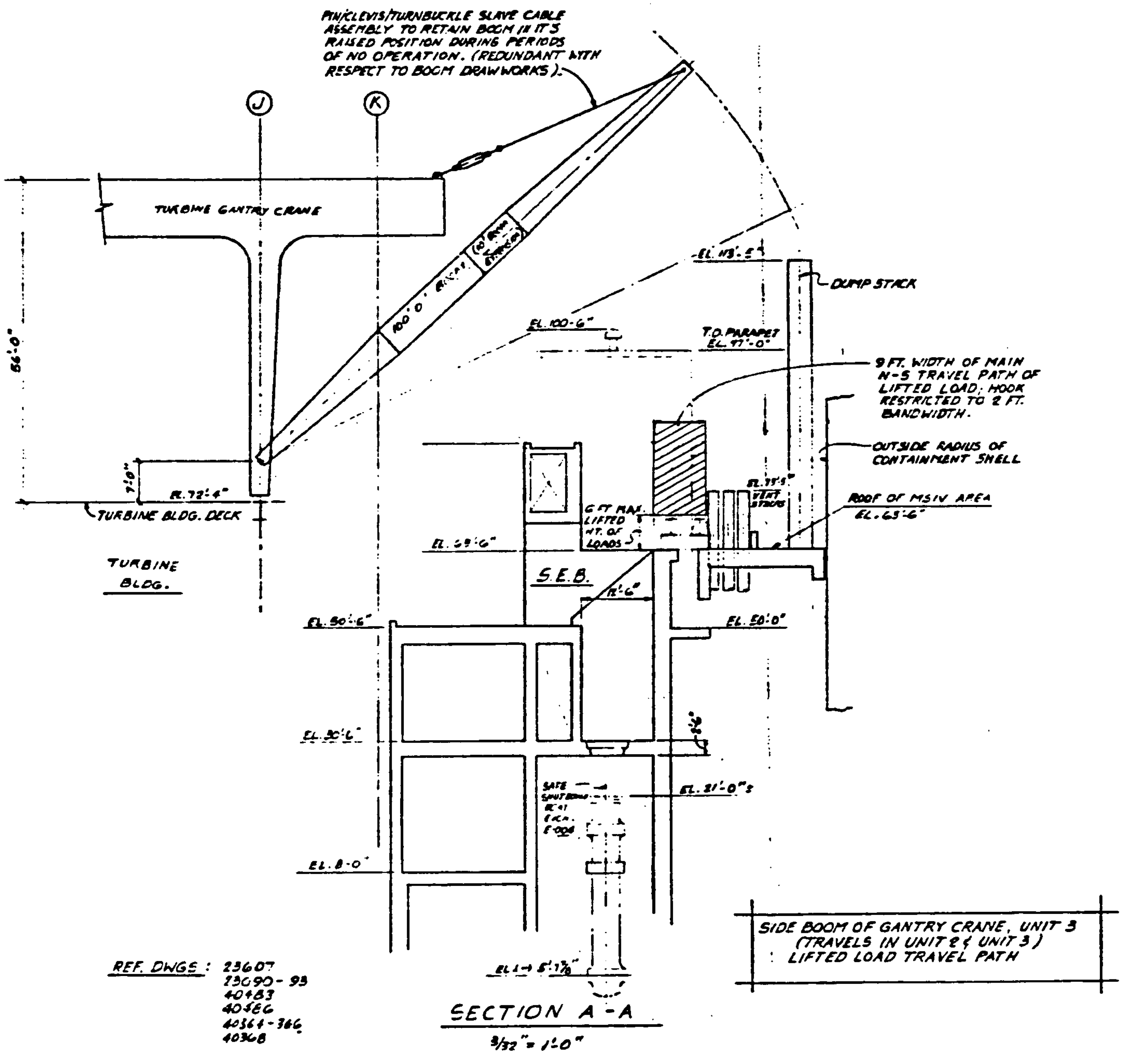
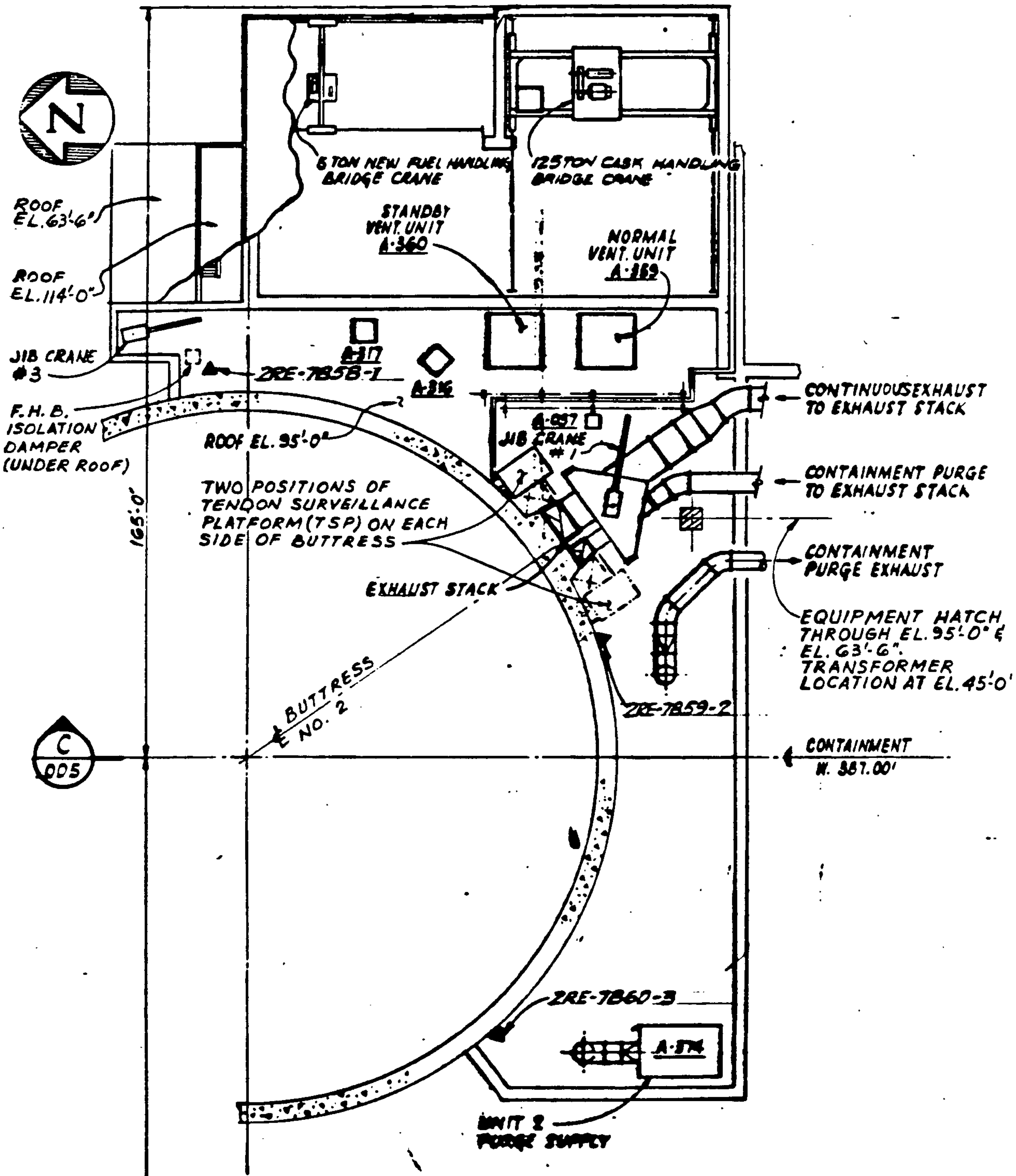


FIGURE 3-7

SIDE BOOM EXTENSION - TURBINE GANTRY CRANE



PARTIAL PLAN AT EL. 95'-0"

UNIT 2 AS SHOWN - UNIT 3 OPP. HAND ABOUT E-W AXIS

FIGURE 3-8

JIB CRANES