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SUBJECT: Forwards response to EG&G recommendations re technical evaluation rept, "Control of Heavy Loads at Nuclear Power Plants,Diablo Canyon Unit 1 (Phase II)." Revised & addl pages to integrate changes per 830509 submittal also end.

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J. O. SCHUYLER
VICE PRESIDENT
NUCLEAR POWER GENERATION

September 26, 1984

PGandE Letter No.: DCL-84-311

Mr. George W. Knighton, Chief
Licensing Branch No. 3
Division of Licensing
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: Docket No. 50-275, OL-DPR-76
Diablo Canyon Unit 1
NUREG-0612, "Control of Heavy Loads" - Phase II TER Response

Dear Mr. Knighton:

On November 17, 1983, the NRC transmitted a copy of EG&G's Technical Evaluation Report (TER), "Control of Heavy Loads at Nuclear Power Plants, Diablo Canyon Unit 1 (Phase II)." The TER documents EG&G's evaluation of a May 9, 1983 submittal by PGandE on the same subject. PGandE has reviewed the TER and is in general agreement with its findings. EG&G recommended that PGandE's submittal be augmented in two areas: the reactor head and internals lifts and the handling of "light" heavy loads by the major cranes. Enclosure 1 quotes EG&G's recommendations in these areas and presents PGandE's responses. Enclosure 1 also corrects an apparent misunderstanding on the status of the missile shield "tugger" hoist.

Enclosure 2 provides revised pages and additional pages to integrate the changes described in Enclosure 1 into the May 9, 1983 submittal. The revised pages should replace their corresponding pages in the May 9, 1983 submittal, and the additional pages should be inserted, as noted on the cover sheet for Enclosure 2.

Kindly acknowledge receipt of this material on the enclosed copy of this letter and return it in the enclosed addressed envelope.

Sincerely,

J. O. Schuyler
J. O. Schuyler

Enclosures

cc: Service List

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ENCLOSURE 1

PGandE RESPONSE TO EG&G RECOMMENDATIONS

EG&G Recommendation #1 (TER, pp. 12-13).

"The applicant has not provided enough information for EG&G to state that they are consistent with Article 5.1.3 of NUREG-0612."

"The applicant used a probability analysis to justify compliance for lifts by the polar crane of the reactor head and the upper internals. The information provided does not conform to single-failure-proof requirements as given in Appendix C of NUREG-0612, nor does it match the requirements of Appendix A for analysis of load drops. The probabilities for load drops as presented are low but they appear to be higher than those used by the NRC for single-failure-proof cranes. We feel that an analysis of the consequences for a load drop of the reactor head and upper internals is needed."

PGandE Response

Article 5.1.3 of NUREG-0612 requires that the criteria of Section 5.1 be met. Section 5.1 states that the objectives of the Section's guidelines are met if "(1) the potential for a load drop is extremely small, or (2) for each area addressed, the ... evaluation criteria are satisfied." In the May 9, 1983 submittal, PGandE chose to show that the potential for dropping the reactor head and upper internals is very small, using a probabilistic risk analysis. EG&G compared the resulting drop probabilities with those reported in NUREG-0612 for single-failure-proof cranes, and concluded that the numbers were not low enough. To increase the reliability of the lift operations and thereby to reduce the drop probabilities, PG&E has since taken the following actions:

1) committed to install an overspeed trip for the polar crane emergency brakes, since the "overspeed" event was found to be the dominant contributor to the drop probability in PG&E's earlier PRA;

2) to determine the drop consequences, divided each of the head and upper internals lift operations into two phases. Phase 1 is an initial lift of up to 24 inches, based on the administrative requirement that the lifting rigs and attachments be inspected after the head or upper internals is lifted off the reactor to an initial height not exceeding 24 inches. Phase 2 is remainder of the removal lift, and the entire installation lift;

3) performed a deterministic evaluation of Phase 1 drop consequences, described in the enclosed revision to Section 2.3.4, that showed that the reactor vessel can absorb the drop energy from the postulated 24-inch head and internals drop events without structural failure;

4) performed a PRA for evaluating Phase 2 drop probabilities, incorporating the effect of the overspeed brake trip.

The enclosed revised Sections 2.3.3 and 2.3.4 show that the consequences of a Phase 1 head or internals drop are acceptable, and that the drop probabilities during Phase 2 of the lifts are only 2.3 X 10^{-7}/yr and 1.7 X 10^{-7}/yr, respectively. The fault-tree failure probabilities for single-failure-proof load handling systems, quoted in NUREG-0612, Figure B-3, range from 4 X 10^{-7} to 10^{-4}/yr (3.1.2(A)) and from 7 X 10^{-5} to 7 X 10^{-3}/yr (3.1.2(B)). The Phase 2 calculated failure probabilities are lower than the range of acceptable failure probabilities in NUREG-0612, and are therefore acceptable.

EG&G Recommendation #2 (TER, pp. 13, 19-20)

"The carrying of other loads by the polar crane do meet the intent of the guideline to some degree since the safety factors are high. However, information was not complete enough to make a good judgment. A more complete comparison with the single-failure-proof requirements of NUREG-0612 as presented in Appendix C should be provided or an analysis of consequences due to load drops should be performed."

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."EG&G feels that the hazard elimination categories used by the applicant are consistent with the intent of this portion of NUREG-0612 except for those cases where probability is used. The section does allow the use of "single-failure-proof crane," however the applicant has not shown that they meet the criteria necessary to satisfy the "single-failure-proof" requirements. High safety factors to meet the intent of portions of these requirements but other requirements are not clearly shown to be met. An example would be the requirements concerning braking systems. A comparison of "single-failure-proof" requirements with actual conditions should be performed if the applicant feels that this is the method by which they wish to show compliance."

PGandE Response

PGandE did not use a probability approach in the May 9, 1983 submittal, except for the reactor head and internals drops. Rather, seven specific crane/load combinations were evaluated to show that single-failure-proof levels of reliability are attained. PGandE has expanded these evaluations, addressing point-by-point each of the NUREG-0612, Appendix C guidelines. The results of this evaluation, described in the enclosed new Appendix D to PGandE's May 9, 1983 submittal, show that the specified lighter heavy loads are carried with an extremely high level of reliability, equivalent to that of a single-failure-proof crane carrying its critical load.

Status of Missile Shield Hoist

The TER states, on page 13:

"Lifting of the missile shield hoist appears to be consistent with the intent of the standards since two hoists are used and complete redundancy is met based on the applicant's statements."

The missile shield hoist has not yet been installed. Page 2.3-12 of the May 9, 1983 submittal commits PGandE to install the hoist. Although the rest of the Phase II commitments made in the May 9, 1983 submittal will be fulfilled by the end of the second Unit 1 refueling outage, the hoist will be installed by the end of the first refueling outage to meet the Phase I commitment to inspect and load test the hoist.

Also, to improve operational efficiency PGandE has recently decided to upgrade the committed missile shield hoist to a "single-failure-proof" design, meeting all applicable requirements of NUREG-0554, and to eliminate the containment polar crane backup. Accordingly, Figure 2.3.3-1 has been deleted, and the missile shield hoist description in Section 2.3.3 has been revised.

ENCLOSURE 2

REVISED AND ADDITIONAL PAGES FOR THE MAY 9, 1983 SUBMITTAL

Replace or insert the following pages in PGandE's May 9, 1983 Diablo Canyon Unit 1 NUREG-0612 submittal.

Page(s)	Effect of Replacement
i	adds Appendix D to Table of Contents
ii	adds reactor vessel response tables to the List of Tables
iii (additional)	adds Appendix D safety margin tables to the List of Tables
iv (rep. iii)	deletes the missile shield hoist figure from List of Figures, and renumbers the polar crane load block figure
2.2-2	describes enhanced treatment of the FHA Bridge Crane/load block combination
2.2-8	refers treatment of the FHA Bridge Crane/load block combination to Appendix D
2.3-2	describes enhanced treatment of Containment Polar Crane/small load combinations
2.3-8 thru -11	gives head & upper internals drop probabilities for drops 24", refers treatment of Polar Crane small-load combinations to Appendix D, and describes new single-failure-proof missile shield hoist
2.3-12	page renumbered
2.3-13 thru -16	adds structural analysis for postulated 24-inch drop of reactor head and upper internals
2.4-8	corrects typos in Hazard Elimination Category column
2.4-37	refers treatment of small-load combinations to Appendix D
D-1 thru -9 (additional)	evaluates large-crane/small-load combinations against NUREG-0612, Appendix C guidelines
Figure D-1 (additional)	replaces Figure 2.4.2-1

Also, remove Figure 2.3.3-1 (no longer needed), pages 2.4-37 and -38 (now in Appendix D), and Figure 2.4.2-1 (now in Appendix D).

DIABLO CANYON UNIT 1
NUREG-0612 SUBMITTAL

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PGandE Response

2.2

Only two heavy loads are carried in the vicinity of the spent fuel pool - the Fuel Handling Area Bridge Crane load block (2.5 tons) and a spent fuel shipping cask (assumed 67.5 tons). Through reference to Appendix D, Section 2.2.3 shows that the load block is adequately protected against dropping, because the crane meets the intent of all ten NUREG-0612, Appendix C guidelines while carrying the empty load block. Administrative procedures further protect the spent fuel by restricting movement of the load block over the spent fuel pool. Section 2.2.4 shows that the spent fuel cask is protected against falling onto "hot" spent fuel by redundant bridge and trolley travel limit switches that keep the cask well away from this fuel, and thus the consequences of a cask drop will not violate NUREG-0612 criteria.

PGandE Response

2.2.3

The only crane listed in Section 2.2.1 which is not excluded in Section 2.2.2 is the Fuel Handling Area Bridge Crane (AF-140-08). This crane carries two heavy loads in the Spent Fuel Pool area: the spent fuel cask (assumed 67.5 tons), and the unloaded load block (2.5 tons).

This crane has been upgraded to meet the reliability criteria of Section 5.1.6 and Appendix C of NUREG-0612, for the load block load (see Appendix D).

PGandE Response

2.3

There are seven load-handling systems in the Diablo Canyon containment. Section 2.3.1 describes the five that operate in the vicinity of the reactor. Section 2.3.2 shows that only three carry heavy loads over or in the reactor vessel -- the containment polar crane (C-140-01), the head stud tensioner monorail (C-140-06), and the missile shield hoist (C-140-13). Section 2.3.3 shows that all but four of the heavy load lifts satisfy the intent of the NUREG-0612, Section 5.1.6 guidelines. Section 2.3.4 analyzes the consequences of the remaining postulated drops, and demonstrates that the drops would have no effect on fuel integrity in the reactor, or on core uncovering.

PGandE Response

2.3.3

The following heavy loads are carried with sufficient design features to make the likelihood of a load drop extremely small:

Crane	Load	Weight
C-140-01	Reactor Head with Lifting Device (above 24")	172.5T
C-140-01	Upper Internals with Lifting Device (above 24")	77.5T
C-140-01	Unloaded Internals Lifting Device	7.5T
C-140-01	Unloaded Head Lifting Device	12.5T
C-140-01	Reactor Vessel Inspection Tool with Lifting Device	5.25T
C-140-01	Unloaded Load Block	7.3T
C-140-13	Missile Shield	17T

The next two subsections analyze the likelihood of dropping the reactor head and the reactor upper internals after they have been initially lifted and inspected. The third subsection shows that the containment polar crane, as modified, can carry the four lightest heavy loads at a level of reliability that satisfies the NUREG-0612 requirements. The last subsection describes modifications to the missile shield load handling system that provide complete redundancy of all functional parts.

C-140-01/Reactor Head (above 24")

The lifting of the reactor vessel head by the containment polar crane is done in two stages. First, the head is lifted to a height from which a load drop would not unduly damage the reactor, and the crane and rigging are extensively tested and inspected. Second, after the tests and inspections, the head is lifted the rest of the way to its storage stand. The second part of the head lift has been studied on a probabilistic basis. The study identified and quantitatively analyzed, using fault tree methods, the annual probability of dropping the reactor vessel head onto the open vessel after the initial lift. A summary of the method used and the results are presented here.

The crane and its associated controls, the head removal and installation procedures, the testing and inspection procedures, and the training procedures were reviewed. Basic events were identified, and a fault tree constructed. The combinations of basic events (i.e., minimal cut sets) that would result in the drop of the vessel head were determined. Using estimated and published basic event probability data, the annual probability of a head drop was computed.

The top event for the analysis was defined as a head drop from a height exceeding 24 inches. The procedures in use at Diablo Canyon require that during removal from the vessel the head be checked for level at one inch above the vessel flange. This is followed by a test of the crane brakes at six inches above the flange. These inspections increase the reliability of the lifting system during the subsequent lift, by allowing correction of rigging errors and incipient equipment failures.

From a careful review of the crane control systems and operating procedures, a large number of basic events were identified. The main events contributing to the head drop above 24 inches are overspeed (from both human error and equipment malfunction, but primarily equipment), and structural failure (from inadequate structural strength). The risk contribution from the overspeed event has been reduced by the planned installation of an overspeed device on the containment polar crane, as described in Appendix D, Section D4. Other descriptor events, such as two-blocking and load binding (from catching the head on the alignment pins), were also considered. However, the contribution from these events is insignificant.

The basic event probability data and the associated uncertainties (defined by error factors) were obtained from the following sources:

- o "Control of Heavy Loads at Nuclear Power Plants" (NUREG-0612), USNRC, 1980;
- o Rasmussen et al., "Reactor Safety Study" (WASH-1400), USNRC, 1975;
- o Swain and Guttman, "Handbook of Human Reliability Analysis With Emphasis on Nuclear Power Plant Applications" (NUREG/CR-1278), Sandia National Laboratories, 1980; and
- o "System Reliability Service Data Bank" (SYREL), UKAEA.

The structural failure data taken from the above sources include the effects of design/fabrication and other human errors in addition to the effects of inadequate structural strength. The probability of structural failure after the initial lift was computed by performing structural reliability analyses for the applicable crane loads. These structural reliability analyses were based on the very conservative assumption that ten independent elements, each with the minimum specified design strength, are present in series. Other conservatisms in the PRA analysis are:

- o In most cases, the occurrence of first operator error in a minimal cut set was set to be 10^{-2}/event with an error factor of 10.
- o In many cases, a crane operator error subsequent to the first operator error was assumed to be completely coupled (i.e., dependent in a statistical sense). For example, in a load hangup event or a two-blocking event, it was assumed that the operator would fail, with probability one, to press the stop pushbutton, given that he failed to place the master switch in the off position.
- o No credit was taken for corrective action by the operator during overspeed events.

A total of 77 minimal cut sets for the Vessel Head drop were considered. The resulting drop probability is 2.3×10^{-7}/yr, which compares favorably with the failure probability estimates for single-failure-proof handling systems given in NUREG-0612, Figure B-3 (4×10^{-7} to 1×10^{-4}/yr and 7×10^{-5} to 7×10^{-3}/yr). Therefore, no specific analysis of the consequences is necessary.

C-140-01/Upper Internals (above 24")

Lifts of the upper internals were analyzed using the same general method as for the reactor vessel head drop analysis. Specific modifications were made to account for differences in the structural failure probability, since failure is less likely given the successful lift of the heavier reactor vessel head. The data sources and assumptions used for the quantitative analysis were the same as for the head drop analysis.

A total of 78 minimal cut sets were considered in the Upper Internals drop analysis. The resulting probability of a drop exceeding 24 inches is 1.7×10^{-7}/yr, which compares favorably with the failure probabilities of single-failure-proof handling systems given in NUREG-0612, Figure B-3. Therefore, no specific analysis of the consequences is necessary.

C-140-01/Small Loads

The containment polar crane carries several loads that qualify as heavy loads, but are much smaller than the polar crane's 200-ton capacity. These are the unloaded internals lifting device (weighing 7.5 tons), the unloaded head lifting device (12.5 tons), the reactor vessel inspection tool with its lifting device (5.25 tons), and the unloaded main hoist load block (7.3 tons). The containment polar crane, as modified, has sufficient design features to carry these smaller loads with single-failure-proof levels of reliability. Appendix D evaluates these four crane/load combinations against each of the ten single-failure-proof guidelines of NUREG-0612, Appendix C, and finds that the intent of each guideline is met.

C-140-13/Missile Shield

The reliability of the missile shield load handling system will be raised to a very high level with the installation of a new single-failure-proof "tugger hoist" (C-140-13). The new hoist will be mounted on the steam generator shield wall above the missile shield. It will be designed, fabricated, and installed in accordance with the applicable portions of NUREG-0554, "Single-Failure-Proof Cranes for Nuclear Power Plants." (For instance, Section 5 of NUREG-0554, "Bridge and Trolley," does not apply because the hoist will be stationary.) Procurement of the hoist has been initiated, and installation will be completed before the end of the first refueling outage.

Conclusion

Based on the evaluations presented here and in Appendix D, the following crane load combinations have an extremely small probability of load drop:

Crane(s)	Load	Justification
C-140-01	Reactor Head with Lifting Device (above 24")	PRA
C-140-01	Reactor Upper Internals with Lifting Device (above 24")	PRA
C-140-01	Unloaded Head Lifting Device	(See Appendix D)
C-140-01	Unloaded Internals Lifting Device	(See Appendix D)
C-140-01	RVIT with Lifting Device	(See Appendix D)
C-140-01	Unloaded Load Block	(See Appendix D)
C-140-13	Missile Shield	Single-failure-proof

NRC Request (Enclosure 3)

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. This response should include the following information for each crane:

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.

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.

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."

PGandE Response

2.3.4

Four heavy loads are analyzed in this section for post-drop compliance with Criteria I through III of Section 5.1. These loads are:

Crane	Loads	Weight
C-140-01	Reactor Head with Lifting Device (up to 24")	172.5T
C-140-01	Upper Internals with Lifting Device (up to 24")	77.5T
C-140-01	Lower Internals with Lifting Device	142.5T
C-140-06	Reactor Head Stud Tensioner	1.3T

Criteria I through III are satisfied, no matter which load is dropped, if the drop occurs anywhere but over the reactor vessel. Criteria I and II limit the allowable radioactive releases and neutron multiplication factor resulting from a drop onto fuel; outside the reactor, fuel assemblies must be handled one at a time, due to the design of the manipulator crane. Sections 2.1 and 2.2 of NUREG-0612 show that damage to a single 100-hour-cooled PWR fuel assembly does not have unacceptable consequences, even in an unfiltered containment. Criterion III requires assurance that the core will not be uncovered as a result of a drop; the Diablo Canyon reactor vessel penetrations are several feet above the top of the core, so nothing short of a reactor vessel failure or failure of the residual heat removal system (covered in Section 2.4, below) could cause core uncovering. Therefore, only drops onto or into the reactor vessel will be considered.

The containment polar crane may carry other heavy loads besides those listed above, but the load paths for other loads are outwards to the annulus region. These loads are kept from moving over the reactor by administrative means.

Reactor Head (up to 24")

The reactor head lift is done in two stages. After an initial lift of no more than 24 inches, the brakes are tested and the entire load handling system is inspected. After the tests and inspections, the lift proceeds very reliably. Section 2.3.3 above has shown that the reliability of the load handling system after the initial lift and inspections is equivalent to that of a single-failure-proof system. Therefore, the maximum height for a credible head drop onto the open reactor vessel is 24 inches.

The reactor vessel was therefore structurally analyzed to determine the consequences of this maximum drop. A dynamic analysis model was developed in which the vessel internals, vessel shell, supporting nozzles, attached piping, and nozzle supports were represented by finite elements. The dynamic structural response of the vessel model to the dropped head's impact was calculated using the time-history method. The resulting peak stresses or loads for the critical vessel components are listed in Table 2.3.4-1 and compared with the components' ultimate stresses or loads as applicable.

Note that these safety margins are based on a comparison of predicted stresses or loads to the component's stress or load capacity. However, for an impact loading event with limited drop energy, it is more appropriate to compare the

predicted ductility demand to the allowable ductility ratio. This is because excursion into the plastic range is usually permitted if the ductility ratio is not excessive. But since the stresses and loads were within the elastic limit or very close to it, conventional strength safety margins were computed. If the safety margins had been computed on the basis of ductility, they would have been much higher than those shown in Table 2.3.4-1, because all the reserve plastic energy would still have been available.

The comparisons of Table 2.3.4-1 show that the critical components have ample safety margin, so no vessel failure or other unacceptable consequences would result from the postulated head drop.

Upper Internals (up to 24")

The reactor upper internals are lifted the same way as the reactor head, with tests and inspections after an initial lift of no more than 24 inches. The second stage of the lift, after the tests and inspections, was shown in Section 2.3.3 above to be much more reliable than the generic single-failure-proof load handling systems analyzed in NUREG-0612, Appendix B. Therefore, the maximum height for a credible upper internals drop into the open reactor vessel is 24 inches.

The critical vessel components impacted by the dropped upper internals were modeled with nonlinear finite elements as in the head drop analysis, and a time-history calculation yielded the peak deformations from the drop. Table 2.3.4-2 compares these peak deformations with the yield deformations of the critical vessel components. The table shows that all the critical components would remain in the elastic deformation region except for the guide thimbles, which would deform to a ductility ratio of 2.73. Such a low ductility ratio is considered safe, especially since before this deformation is reached the upper internals would contact the hold-down spring, which would transfer the impact load primarily to the vessel support. The vessel support was already shown, in Table 2.3.4-1, to be able to withstand the much larger impact load of the reactor head.

The comparisons of Table 2.3.4-2 show that the postulated 24-inch drop of the upper internals into the open reactor vessel would have no unacceptable safety consequences.

Lower Internals

The lower internals are lifted only after all the fuel is out of the reactor, so no radioactive release, criticality, or core uncovering is possible.

Reactor Head Stud Tensioner

The reactor head stud tensioner is handled by a single-purpose monorail (C-140-06), which is permanently attached to the reactor head lifting device. Furthermore, the tensioner is mounted and used only while the head is installed on the reactor vessel, and it travels only over the vessel flange. Therefore, the stud tensioner presents no threat to the fuel, since it will not penetrate the six-inch thick reactor head at a location where only a glancing impact is possible.

TABLE 2.3.4-1

REACTOR VESSEL RESPONSE
TO 24-INCH REACTOR HEAD DROP

Component	Predicted Stress (ksi) or Force (kips)	Ultimate Capacity	Safety Margin (1)
Vessel Shell	22.9 ksi	50 ksi	2.2
Core Barrel	30.1 ksi	75 ksi	2.5
Vessel Nozzle	8,010 kips	10,750 kips	1.3
Nozzle Support Box Beam	8,149 kips	15,080 kips	1.9
Nozzle Support Wall	8,149 kips	18,830 kips	2.3

(1) Based on stress or loads, since components are within or near elastic limits. If based on more appropriate ratio of ultimate deformation to drop deformation, values would be much higher.

TABLE 2.3.4-2

REACTOR VESSEL RESPONSE
TO 24-INCH UPPER INTERNALS DROP

Component	Predicted Deformation (inches)	Deformation at Yield (inches)	Post-Drop Status
Hold Down Spring	.054	.076	Elastic
Preload Spring	1.069	1.789	Elastic
Guide Thimble	1.864	.684	Plastic (ductility ratio = 2.73)
Fuel Rod	.142	.160	Elastic
Lower Core Support	.053	.067	Elastic

PGandE Response

2.4.1

While the cranes at Diablo Canyon were not designed to satisfy the criteria of NUREG-0612, Section 5.1.6, for all loads to be carried, they are nevertheless designed for high operating reliability. For example, the Containment Polar Crane has been shown in Section 2.3.3 above, to have a reliability of 99.99998% per lift. Moreover, in some cases the heavy loads are very light in relation to the crane's design capacity, and all of the major cranes have been modified with fully redundant hoist travel limit switches, so the probability of dropping these "light" heavy loads is negligible. These crane/load combinations are discussed in Section 2.4.2.c.

Table 2.4.2-1 Load/Impact Matrix (Sheet 1 of 24)

Part I. Containment Polar Gantry Crane (C-140-01)

Load	Elevation	Floor Coordinates	Component Impacted	Hazard Elim. Category	Notes
A. Reactor Head (172.5T)	117'	310°, 26'	Line 1140 (E1, E2)	b	Redundant RHR Path (E3)
	100'	290°, 9'	Line 9 (E1, E2)	b	Redundant RHR Path (E3)
	100'	290°, 23'	Line 1994 (E2)	b	Redundant RHR Path (E3)
	100'	290°, 31'	Line 24 (E1, E2)	b	Redundant RHR Path (E3)
	100'	310°, 26'	Line 1140 (E1, E2)	b	Redundant RHR Path (E3)
	107.5'	285°, 45'	Conduit X419 (TE-413B, Reactor Coolant Temperature)	b	Redundant TE-423A, -433A, -433B, -443A, and -443B
	107.5'	285°, 45'	Conduit X418 (TE-413A, -413B, and -423B, Reactor Coolant Temperature)	b	Redundant TE-423A, -433A, -443A, and -443B
	107.5'	285°, 45'	Conduit X420 (TE-413A and -423B, Reactor Coolant Temperature)	b	Redundant TE-423A, -433A, -433B, -443A, and -443B
B. Upper Internals (77.5T)	100'	240°, 18'	Line 12 (E2, E3)	d	See Internals Drop Analysis, Section 2.3.3
	100'	260°, 22'	Line 1991 (E2)	b	Redundant RHR Paths (E1, E3)
	100'	250°, 18'-25'	Line 1994 (E2)	b	Redundant RHR Paths (E1, E3)
	100'	290°, 18'	Line 9 (E1, E2)	d	See Internals Drop Analysis, Section 2.3.3
C. Lower Internals (142.5T)	100'	120°, 11'-17'	Line 11 (E2, E3)	c	Fuel Removed Before Lift
	100'	60°, 11'-17'	Line 10 (E1, E2)	c	Fuel Removed Before Lift
E. Internals Lifting Device (7.5T)	107.5'	135°, 21'	Conduit X417 (TE-433B, Reactor Coolant Temperature)	b	Redundant TE-413A, -413B, -423A, -423B, -433A, -443A, and -443B
G. RCP Flywheel (6.4T)	107.5'	210°, 50'	Conduit X119 (PT-405, Reactor Coolant Pressure)	b	Redundant PT-403
H. RCP Motor (43.8T)	117'	320°, 58'	Line 3844 (E1)	b	Redundant RHR Paths (E2, E3)
	100'	300°, 44'	Line 24 (E1, E2)	b	Redundant RHR Path (E3)
	100'	325°, 39'-44'	Line 13 (E1, E2)	b	Redundant RHR Path (E3)
	100'	320°, 45'	Line 24 (E1, E2)	b	Redundant RHR Path (E3)
	100'	220°, 40'	Line 238 (E2)	b	Redundant RHR Paths (E1, E3)
	100'	215°, 39'-46'	Line 109 (E2)	b	Redundant RHR Paths (E1, E3)
	100'	215°-220°, 47'	Line 24 (E1, E2)	b	Redundant RHR Path (E3)
	100'	145°, 43'	Line 246 (E2, E3)	b	Redundant RHR Path (E1)
	100'	145°-155°, 47'	Line 24 (E1, E2)	b	Redundant RHR Path (E3)
	117'	290°, 58'	Conduit X512 (TE-443A, Reactor Coolant Temperature)	b	Redundant TE-413A, -413B, -423A, and -423B

PGandE Response

2.4.2.c

Section 2.3.3 above showed that the conservative design of the Containment Polar Crane, combined with lifting procedures designed to catch any problems before they cause a drop, results in a highly reliable lifting system for the reactor head and upper internals. Nevertheless, because of their importance to safety, these load drops were analyzed both into the reactor (Section 2.3.4) and along their load paths to their laydown areas (Table 2.4.2-1). The following heavy loads are very light in relation to their cranes' capacity, and safety modifications have been made to the cranes. Therefore, the probability of dropping these particular loads is extremely small.

Crane	Load	Weight [tons]
C-140-01	Main Hoist Load Block	7.3
C-140-01	Load Block + Internals Lifting Device	14.8
C-140-01	Load Block + Head Lifting Device	19.8
C-140-01	Load Block + RVIT	12.55
AF-140-08	Main Hoist Load Block	2.5
T-140-01(-02)	Main Hoist Load Block	3
I-17.5-01	Main Hoist Load Block	1.7

Appendix D details why dropping these loads is considered incredible, by showing that the cranes satisfy the intent of all ten single-failure-proof guidelines in NUREG-0612, Appendix C.

APPENDIX D

LIGHTER CRANE/LOAD COMBINATIONS

PGandE has performed a point-by-point comparison, against the NUREG-0612, Appendix C guidelines, for seven lighter crane/load combinations for which NUREG-0612 compliance was based on low load-drop probability. The following crane/load combinations were evaluated:

Crane	Load	Weight (tons)
C-140-01	Main Hoist Load Block	7.3
C-140-01	Load Block + Internals Lifting Device	14.8
C-140-01	Load Block + Head Lifting Device	19.8
C-140-01	Load Block + RVIT	12.55
AF-140-08	Main Hoist Load Block	2.5
T-140-01(-02)	Main Hoist Load Block	3
I-17.5-01	Main Hoist Load Block	1.7

The ten sections of this Appendix evaluate these crane/load combinations against the ten Appendix C guidelines. In each section, the guideline is quoted directly from NUREG-0612, Appendix C, and the evaluation follows.

D1. STRESS LIMITS

Guideline

"The allowable stress limits should be identified and be conservative enough to prevent permanent deformation of the individual structural members when exposed to maximum load lifts."

Evaluation

All of the lighter loads are very small compared to the design capacities of the cranes. Table D-1 summarizes the maximum stresses due to the loads, and compares them to the material allowable stresses (yield or ultimate as applicable) of the critical components. In this table, the margins of safety were computed by comparing the weights of the above listed lifted items with the design loads, assuming that the stress level in the crane components due to the design load is equal to the allowable design stress. This is a conservative assumption, since the design stress is generally kept lower than the allowable value.

Table D-1 shows that the stress levels in the crane components due to the above listed loads are extremely small and could not cause any permanent deformation.

D2. MINIMUM OPERATING TEMPERATURE

Guideline

"The minimum operating temperature of the crane should be determined from the toughness properties of the structural materials that are stressed by the lifting of the load."

Evaluation

Material toughness properties for the crane structural members are not critical while lifting and moving the lighter loads, because:

a) The stress levels are only a small fraction of the yield stress (see Table D-1), and

b) The minimum design temperature inside the containment is 70°F, and the operating temperature is much higher.

D3. SEISMIC CAPACITY

Guideline

"The crane should be capable of stopping and holding the load during a seismic event equal to a Safe Shutdown Earthquake (SSE) applicable to that facility."

Evaluation

The structural components of each crane were evaluated for the scenario of a Hosgri seismic event simultaneous with the lifting of the design load, even though the probability of an extreme earthquake such as the Hosgri to occur during such infrequent lifts may be insignificant. These evaluations were performed as part of the overall seismic safety evaluation of the plant structures. Results showed that the crane structures can withstand the Hosgri event without collapse, even while lifting the design loads.

The stresses in the crane structures due to Hosgri seismic event while lifting and moving the lighter loads were not computed because these loads are very small compared to the design loads. However, to estimate the seismic safety margin associated with these smaller loads, Table D-2 has been prepared by proportioning the results of the crane seismic analysis for the design loads. Even though the design-load analyses were non-linear, such proportioning is considered conservative because these loads are much lighter than the design load. The computed margins are high, so it is concluded that the cranes are capable of safely withstanding a Hosgri-level seismic event while lifting and moving these smaller loads.

D4. FAIL-SAFE BRAKES

Guideline

"Automatic controls and limiting devices should be designed so that component or system malfunction will not prevent the crane from stopping and holding the load safely."

Evaluation

Each of the subject hoists is provided with two electrically released, spring set holding brakes, except for I-17.5-01, which has one mechanical holding brake. Each brake is rated at 150% of the rated torque of the main hoist motor. Each brake is automatically applied upon loss of voltage to the hoist motor.

The cranes with two mechanical holding brakes have one brake located on a hoist motor shaft extension at the opposite end from the output shaft, and one brake on an extension shaft from the hoist motor pinion at the first stage of the speed reducer. Crane I-17.5-01 has one mechanical holding brake located on an extension from the hoist motor pinion. Braking torque is transmitted through the speed reducer gearing to the drum gear.

The lighter loads evaluated here are very small compared to the design capacities of the cranes. As a result, the safety margins for mechanical crane components are very high for these crane/load combinations. Therefore, transmission of braking torque through these substantially designed mechanical components will provide adequate braking to hold the subject crane loads, even upon loss of power to the main hoist motors.

The reliability of the mechanical holding brakes and other mechanical components is further enhanced by periodic inspections and maintenance performed under Mechanical Maintenance Procedure 50.3, "Overhead, Gantry, and Mobile Crane Inspection, Testing, and Maintenance." In addition, an overspeed switch will be added to the Containment Polar Crane, the Fuel Handling Area Bridge Crane, and the Turbine Building Bridge Cranes. The switch will de-energize both the existing undervoltage relay and the brake solenoid coils directly. Addition of this device will provide redundancy of automatic braking controls.

For the Intake Structure Gantry Crane, load handling procedures will ensure that the crane main hoist mechanical brakes are set (brake solenoids deenergized), whenever the load block is not over a safe load path. This will ensure that any braking control failure will not result in a load block drop except over a safe load path, where Section 2.4.2 of this submittal shows there would be no unacceptable safety consequences.

Further, if the Intake Structure Gantry load block is over a safe load path with safe-shutdown components underneath, the load handling procedures will require verification of the operability of redundant equipment before the main hoist brakes are released. This will ensure continued safe-shutdown function capability should the load block drop onto safe-shutdown components under the load path.

D5. DUAL REEVING

Guideline

"Design of the wire rope reeving system should include dual wire ropes."

Evaluation

Instead of dual wire rope reeving, each of the subject hoists has one continuous wire rope with two attaching points, one at each end of the drum.

However, the safety margins for the wire ropes and other mechanical crane components are extremely high for the lighter crane/load combinations. Indeed, Table D-1 shows that the minimum crane reeving safety margin is 54.6 for the heaviest of these light lifts. This is much greater than the 10:1 safety factor discussed as an acceptable alternative to duality in NUREG-0612, Appendix C, paragraph 5 of the section on "Implementation of NUREG-0554 for Operating Plants."

In addition, wire rope reeving system reliability is enhanced by periodic inspections of crane components performed under Mechanical Maintenance Procedure 50.3, "Overhead, Gantry, and Mobile Crane Inspection, Testing, and Maintenance."

D.6 HOISTING LIMIT SENSORS AND CONTROLS

Guideline

"Sensing devices should be included in the hoisting system to detect such items as overspeed, overload, and overtravel and cause the hoisting action to stop when limits are exceeded."

Evaluation

All five cranes have redundant overtravel sensing devices, in the form of hoist limit switches to prevent two-blocking. They are described in Section D.7 below.

The cranes do not have sensing devices to detect overspeed at present. Operating procedures require that hoisting and lowering speeds be monitored visually at all times during a heavy load lift, both by the crane operator and the rigger-in-charge. In addition, an overspeed device will be added to the Containment Polar Crane, the Fuel Handling Area Bridge Crane, and the Turbine Building Bridge Cranes, as described in Section D4 above.

Overload sensing devices are not necessary for these lighter loads. They weigh only a small fraction of the design capacity of the cranes, so the only overload possible would come from load hangup on a stationary object, the potential for which is minimal. Hangups occur when some protrusion of a load is caught under a stationary object, or when a protruding stationary object catches on a hook of the load or sticks into the space over it. The following paragraphs present the results of PGandE's review of potential crane load hangups.

C-140-01/Main Hoist Load Block

Figure D-1 shows that the load block has no protrusions to catch on a stationary object (such as the crane's gantry leg cross brace), since the hook is protected from above by the sheaves. Since the main hoist load block has no specific load path, its entire travel range was surveyed for protruding stationary objects that could stick through the reeving or catch on the hook. Inspection of the containment between Elevations 140 feet and 202 feet revealed no such object. As for the reactor cavity area, the only overhanging or protruding stationary objects are the reactor missile shield, the reactor cavity service crane, and the manipulator crane. The missile shield is well away from any of the load paths that go over the reactor; it is north, and the load paths are all in the east-west direction. In any case, it has no protrusions in either its operating or stored position (see Figure 2.3.3-1). The two cranes must be stowed away--the reactor cavity service crane latched to the reactor cavity wall, and the manipulator crane moved to the east end of its rails - as a prerequisite to moving any load over the reactor cavity. This prerequisite is in the Maintenance Procedure for every load whose load path is over the reactor cavity, including the load block. The lack of suitable objects for load hangup within the range of the load block, plus the very high safety factors and redundant limit switches, make a load block drop extremely unlikely.

C-140-01/Load Block + Head Lifting Device

Figure 2.1.1-2 shows that there are no protrusions on the head lifting device to catch any looped or overhanging stationary objects, and inspection of the load path (C-140-01F) has revealed no protruding stationary objects that could fit into the loop between the diagonal brace and cross-brace of the device, or into the crane reeving.

C-140-01/Load Block + Internals Lifting Device

Figure 2.1.1-3 shows that the internals lifting device has no protrusions that could hang up on a looped or overhanging stationary object. Inspection of the load path, from the equipment hatch counterclockwise along the annulus at 140 feet to 130 degrees, then in over the gantry leg cross-brace to the reactor, has revealed no protruding stationary objects that could fit into the loop between the device's diagonals and spreader or into the crane reeving.

C-140-01/Load Block + Reactor Vessel Inspection Tool (RVIT)

The RVIT is assembled inside the crane rail, near the RCP 1-3 motor maintenance mount area, then carried into the reactor along the same load path as the internals lifting device, but not in such a way as to engage in a looped or overhanging stationary object, unless the overhang is hooked downward or 8 feet deep. There are no such overhangs on the RVIT load path. The transducer arm is fully retracted and positioned under one of the support legs during the installation and removal of the RVIT, so the support leg protects the transducer arm from hangups. Finally, the load path has no protruding stationary objects that could catch in the RVIT or the crane reeving.

One other conceivable source of load hangups is the binding of the RVIT guide bushings on the vessel guide studs during tool removal. This is prevented by the design of the tool; the guide bushings have a nominal radial clearance of 3/8", and a hydraulic leveling arrangement on the RVIT lifting rig keeps the RVIT firmly levelled. The RVIT is discussed further in Section 2.4.2(c)(4), and Figure 2.4.2-3 shows the RVIT and its lifting rig.

AF-140-08/Main Hoist Load Block

There are no protruding objects in the Spent Fuel Pool area within the limits of motion for the load block. It is possible to have a load hangup in the Hot Shop, with all the machinery located there. However, a load block drop in the Hot Shop is scoped by the much more severe RCP Motor drop (AF-140-08R), which is analyzed in Section 2.4.2 of this submittal. Outside the Hot Shop there are no objects that could cause a load hangup with the load block.

T-140-01(-02)/Main Hoist Load Block

The load block has no protrusions outside the reeving, and there are no protruding objects anywhere in the traveling range of the load block that would fit over the hook of the load block or into the loops of the reeving.

I-17.5-01/Main Hoist Load Block

The load block has no protrusions outside the reeving, and there are no protruding objects anywhere in the traveling range of the load block that would fit over the hook of the load block or into the loops of the reeving.

D7. TWO-BLOCKING

Guideline

"The reeving systems should be designed against the destructive effects of 'two-blocking'."

Evaluation

All cranes have redundant (geared and weighted) limit switches to prevent "two-blocking." These limit switches will be wired to meet the requirements of NUREG-0554, Section 4.5. The modifications will be installed by the end of the second refueling outage, and tested by the alternate method described in Paragraph 8 of NUREG-0612, Appendix C.

D8. HOIST DRUM CATCHER

Guideline

"The hoisting drum(s) should be protected against dropping should its shafts or bearings fail."

Evaluation

Each subject crane is provided with one main hoist drum supported by two stub shafts, one extending from each end. Each shaft is supported by bearings and associated structures mounted directly to the trolley structure.

The lighter loads are very small compared to the design capacities of the cranes. Therefore, the safety margins for the drum support components are very high for these crane/load combinations, and the drums are held against falling with very high reliability while holding these loads.

Drum support component reliability is further enhanced by periodic inspection and maintenance performed under Mechanical Maintenance Procedure 50.3, "Overhead, Gantry, and Mobile Crane Inspection, Testing, and Maintenance."

D9. ADDITIONAL SAFETY DEVICES

Guideline

"Safety devices such as limit switches provided to reduce the likelihood of a malfunction should be in addition to those normally provided for control of maloperation or operator error."

Evaluation

Both the geared limit switches to prevent "two-blocking" on all five cranes, and the overspeed device on the Containment Polar Crane, are in addition to those provided for control of maloperation or operator error.

D10. COLD PROOF TEST

Guideline

"The crane system should be given a cold proof test if material toughness properties are not known."

Evaluation

Refer to Section D2.

Table D-1

CRANE COMPONENT STRUCTURAL SAFETY MARGINS

Crane	Heaviest Evaluated Load	Critical Component	Design Load (tons)	Stress Due to Load[1]	Safety Margin to Yield (y) or Ultimate (u) Strength
C-140-01	Load Block & Head Lifting Device[2] (19.8 tons)	Reeving	269.5[3]	$.018f_u$	54.6(u)
		Hook & Load Block Structure	269.5[3]	$.047f_y$	21.3(y)
		Crane Structure	269.5[3]	$.057f_y$	17.7(y)
AF-140-08	Main Hoist Load Block (2.5 tons)	Reeving	159.4[4]	$.0038f_u$	266.0(u)
		Crane Structure	159.4[4]	$.012f_y$	83.1(y)
T-140-01 (-02)	Main Hoist Load Block (3 tons)	Reeving	153.4[3]	$.0049f_u$	205.0(u)
		Crane Structure	153.4[3]	$.015f_y$	67.0(y)
I-17.5-01	Main Hoist Load Block (1.7 tons)	Reeving	62.0[5]	$.006f_u$	159.0(u)
		Crane Structure	62.0[5]	$.021f_y$	47.6(y)

Notes:

(1) Includes dynamic load factor of 1.15 (per CMAA 70 for hoisting speed up to 30 fpm) on the lifted item. f_u = ultimate stress, f_y = yield stress.

(2) This is the heaviest of the four lighter heavy loads carried by this crane.

(3) Includes impact factor of 1.3 per AISE 6-1969.

(4) Includes impact factor of 1.25 per AISC - 1969.

(5) Includes impact factor of 1.2.

Table D-2

CRANE SEISMIC SAFETY MARGINS

Crane	Heaviest Evaluated Load	Minimum Seismic Safety Margin While Lifting or Moving Load
C-140-01	Load Block + Head Lifting Device (19.8 tons)	10
AF-140-08	Main Hoist Load Block (2.5 tons)	64
T-140-01 (-02)	Main Hoist Load Block (3 tons)	42
I-17.5-01	Main Hoist Load Block (1.7 tons)	22

Note: $\text{Safety Margin} = \frac{\text{Allowable Load or Stress}}{\text{Computed Load or Stress}}$

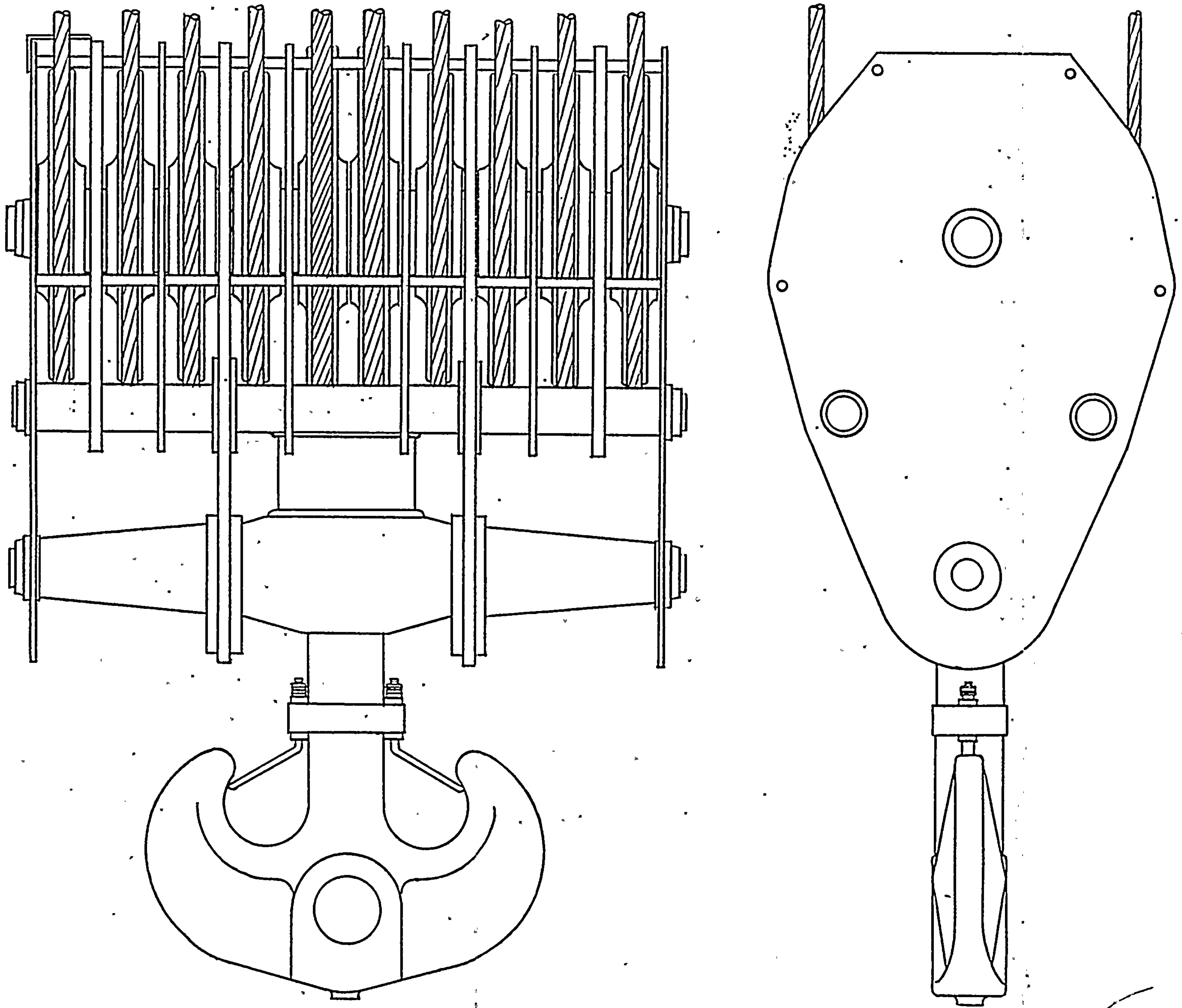

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FIGURE D-1

CONTAINMENT POLAR CRANE LOAD BLOCK

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