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MARTIN,J.B. Region 5, Office of Director

SUBJECT: Forwards response to Allegations 25,58 & 96 described in SSER 21 re expansion anchors.Response to concern re HP Foley procedure governmin installation of anchor bolts will be submitted next wk.

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MARTIN,J.B. Region 5, Office of Director

SUBJECT: Forwards response to Allegations 45,46 & 48 described in Suppl 21 to SER expansion of response to concerns re policy & procedure governing installation of anchor bolts will be submitted next wk.

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	NRR/DE/MTEB 17	1	1	NRR/DE/MEB 18	1	1
	NRR/DE/SAB 24	1	1	NRR/DE/SGEB 25	1	1
	NRR/DHFS/HFEB40	1	1	NRR/DHFS/LQB 32	1	1
	NRR/DHFS/PSRB	1	1	NRR/DSI/ASB	1	1
	NRR/DSI/AEB 26	1	1	NRR/DSI/CSB 09	1	1
	NRR/DSI/CPB 10	1	1	NRR/DSI/METB 12	1	1
	NRR/DSI/ICSB 16	1	1	NRR/DSI/RAB 22	1	1
	NRR/DSI/PSB 19	1	1	REG FILE 04	1	1
	NRR/DSI/RSB 23	1	1	RM/DDAMI/MIB	1	0
	RGN5	3	3			
EXTERNAL:	ACRS 41	6	6	BNL(AMDTS ONLY)	1	1
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PACIFIC GAS AND ELECTRIC COMPANY

PG&E 77 BEALE STREET, SAN FRANCISCO, CALIFORNIA 94106 TELEPHONE (415) 781-4211

January 27, 1984

PGandE Letter No: DCL-84-031

Mr. John B. Martin, Regional Administrator
U. S. Nuclear Regulatory Commission, Region V
1450 Maria Lane, Suite 210
Walnut Creek, CA 94596-5368

Re: Docket No. 50-275, OL-DPR-76
Diablo Canyon Unit 1
Response to Allegations 25, 58 and 96 - SSER 21

Dear Mr. Martin:

Enclosed is the PGandE response to allegations 25, 58, and 96 described in SSER 21 pertaining to expansion anchors. PGandE's response to the concern regarding the H. P. Foley procedure governing the installation of anchor bolts will be submitted next week.

In addition, PGandE is currently developing responses to the other allegations and concerns which require resolution prior to criticality.

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

Sincerely,

J. B. Hoch

for J. O. Schuyler

Enclosure

cc: D. G. Eisenhut
H. E. Schierling
Service List

B001
1/1

ENCLOSURE

USE OF CONCRETE EXPANSION ANCHORS AT DIABLO CANYON

1. Description of Concern

Several interrelated concerns about anchor bolts were identified including embedment, spacing, angularity, and torque requirements. In the following pages we provide information addressing those concerns.

2. Resolution of Concern

Concrete expansion anchors have been frequently used to attach safety-related components to the concrete structures at Diablo Canyon Power Plant (DCPP or Diablo Canyon). The major use involved supports for piping, electrical raceways, and HVAC ductwork. Expansion anchors were used in other miscellaneous safety-related and nonsafety-related applications. For many years before Diablo Canyon was built, expansion anchors were used in the nuclear industry as well as in non-nuclear construction and have proven to be a satisfactory means of anchoring components to concrete structures. The performance of expansion anchors has been studied analytically and tested extensively for more than 30 years. While the installation procedures are basically simple repeatable operations, these numerous studies have identified design margins and installation techniques that assure adequate performance.

The use of expansion anchors at DCPP began in the early 1970s, when the major concrete structures were erected. At that time the primary source of design data and installation techniques was provided in brochures published by the individual anchor manufacturers. In order to confirm the validity of the manufacturers' data, PGandE performed its own tests on a variety of anchor types. These included both static and dynamic tests. In addition, PGandE engineers discussed installation procedures with the various anchor manufacturers' representatives. The manufacturers' data were used as the basis for design and installation of expansion anchors at Diablo Canyon.

In 1974 PGandE consolidated the design and installation data from various anchor manufacturers into a single company engineering standard--drawing 054162. This standard was subsequently incorporated into the construction procedures used by the contractors working at the Diablo Canyon jobsite. These formal construction procedures did not change the manufacturers' requirements, but rather supplemented them and emphasized their importance.

In the following years, a series of anchor installation inspections were performed to verify that the anchors were properly installed. Extensive walkdowns were performed on the piping, raceway, and HVAC supports. The relatively few deviations that were found (2 to 3 percent of all installations) demonstrate that the installation procedures were understood and were properly executed. In order to determine the acceptability of anchors deviating from the established installation requirements, analytical evaluations and testing programs were performed. Attachment 1 is a chronology describing the continuous reviewing and monitoring of the use of expansion anchors at Diablo Canyon. The chronology shows that when problems were encountered in one contractor's installation, the existence of similar problems in the other contractors' work was investigated. Resolutions of specific concerns are addressed in Attachments 2 through 6. The dynamic testing program for the DCPP expansion anchors is described in Attachment 7.

In 1979 the NRC recommended minimum design margins for piping support anchors in I&E Bulletin 79-02. The Diablo Canyon piping support anchors were then requalified in conformance with this bulletin.

In 1982 and 1983 the Diablo Canyon verification program reviewed the usage of expansion anchors. Factors of safety achieved in the installations using drawing 054162 (e.g., raceway, HVAC, and instrumentation supports) were quantified. These safety factors were summarized in a report attached to the verification program EOI 1016 (Attachment 8, Ref. 1). Previously approved deviation reports were also reviewed. The verification program did not address each individual anchor with a deviation. Rather, the verification program established the acceptability of expansion anchors as follows:

(1) For anchors installed in accordance with drawing 054162, a factor of safety of at least 3 between demand and capacity was confirmed (see Attachment 2).

(2) For anchors not conforming with drawing 054162, the previous resolutions were reviewed. Based on these previous resolutions, it was established that the deviations would not cause an unsafe condition.

(3) Expansion anchors with known installation deviations were sampled. The anchor capacities were analytically reduced and, in every case, the evaluation found a factor of safety greater than 3.

(4) The support systems using expansion anchors are highly redundant, such that the existence of a few anchors with factors of safety less than 3 would not reduce design margins unacceptably or in any way compromise the integrity of the supported systems.

In conclusion, expansion anchor usage at Diablo Canyon has always been carefully implemented and reviewed. As shown in the attachments, a high degree of confidence in the adequacy of the anchor installation has been established. In the verification program the factors of safety were quantified. For properly installed anchors, factors of safety of at least 3 were verified in every case reviewed and most anchors were shown to have factors of safety markedly above 3. While the potential exists that 2 to 3 percent of the expansion anchors may have lower factors of safety due to installation deviations, the overall margin and redundancy in the design of expansion anchors at DCPP is reasonable, conservative, and acceptable.

Attachment 1 - Expansion Anchor Chronology

Governing Procedure	Date	Inspection (I) or Test (T)	Description
Manufacturers' Instructions	Mar 1972	T	PGandE performed static tests to validate data in manufacturers' catalogs. Approximately 54 tests of Wej-it, Kwik-Bolt, Parabolt, Phillips anchors were performed.
Manufacturers' Instructions	May 1972	T	PGandE performed 18 dynamic (sine) tests at UC Berkeley to define the performance of expansion anchors when subjected to dynamic loads. 16 static tests were performed as well.
Drawing 054162	Nov 1974	-	PGandE Standard Drawing 054162 was issued. (Foley procedures were issued in 1975.)
Drawing 054162	Feb 1975	I	Foley was instructed to sample expansion anchor spacing. Some spacing violations were found which led to a complete walkdown in July 1975. Some edge distance violations were found which led to testing in September 1975.
Drawing 054162	July 1975	I	A 3-month-long 100% walkdown of all raceway installations was made. Construction tagged and logged all spacing violations. Engineering established a review criteria and inspected all violations. Modifications were made when necessary.
Drawing 054162	Oct 1975	-	PGandE Calculation Binder 52, sheets 150 through 156, contains calculations addressing spacing violations arising from the July 1975 walkdown.

Governing Procedure	Date	Inspection (I) or Test (T)	Description
Drawing 054162	Oct 1975	T	PGandE tested performance of anchors close to chamfered edges of concrete. 12 tests in shear and pullout were done for 1/2" dia. and 5/8" dia. Hilti anchors.
Drawing 054162	Feb 1976	I	Discrepancy report DR E-1235 documented edge distance violations discovered in the July 1975 walkdown and resolved by the October 1975 tests.
Drawing 054162	Dec 1976	I	Piping expansion anchors were inspected per Inspection Procedure for Installed Flush Shell Concrete Anchors. The following items were inspected: obvious flaws, cut off anchors, over embedment, angular alignment, and depth that expansion plugs were driven.
Drawing 054162	Dec 1976	T	Procedure for Establishing Acceptance Criteria for Concrete Anchor Installations was implemented. Testing was performed for various setting depths for expansion plugs (approximately 80 tests), cut off anchors (approximately 30 tests), angular misalignment (7 tests), and over-embedment (10 tests).
Drawing 054162	Feb 1977	I	Discrepancy report 282 documented the generic review of expansion anchors used in piping supports.

Governing Procedure	Date	Inspection (I) or Test (T)	Description
Drawing 054162	Mar 1977	I, T	Discrepancy report 283 extended the anchor review into HVAC area. A generic review was made on sampling basis (77 anchors). Anchors were inspected for: obvious flaws, cut off ends, overembedment, angular alignment, and depth that expansion plugs were driven. 3 anchors had plugs not "fully driven." 11 anchors were tested and all exceeded allowable load values. No other deviations were found.
Drawing 054162	Mar 1977	I	Use of 2-3/4" long Hilti Kwik-Bolts identified as a potential problem. Usage had stopped in January 1975.
Drawing 054162	Apr 1977	I, T	Discrepancy report 288 was issued documenting raceway support anchor embedment inspections. For 3/8" dia. anchors, 448 were checked by measuring bolt projections and 64 were UT inspected. For 1/2" dia. anchors, 508 were measured. Testing program WA-1 was performed in which 110 anchors were tested at embedments less than required by drawing 054162.
Drawing 054162	May 1977	I, T	Discrepancy report 3373 was issued. Spacing between good and abandoned holes/anchors did not always meet drawing 054162 requirements. 65 tests were performed to evaluate problem. 1/2" dia., 5/8" dia., and 3/4" dia. Hilti wedges and 5/8" dia., 3/4" dia., and 7/8" dia. Phillips wedges were tested.

Governing Procedure	Date	Inspection (I) or Test (T)	Description
Drawing 054162	Sep 1978 (through 1980)	I	NCR DC1-80-RE-002 documented a generic (grid) raceway support review. Foley procedure GI-I was followed and checked 100% of raceway installations, including inspecting anchors for: spacing, edge distance, angular alignment, nut engagement, embedment depth, and cut off bolts.
Drawing 054162	Oct 1980	I, T	A procedure was issued for developing ultimate pullout capacity criteria for imperfectly installed shell-type concrete anchors. In 1976 piping anchor problems were resolved (DR 282), but to meet IEB 79-02 additional tests were performed. Expansion plug depths were varied and the anchors were pulled to define their ultimate strength. Approximately 150 tests were done for 1/2" dia., 5/8" dia., and 3/4" dia. HDI anchors and 1/2" dia., 5/8" dia., 3/4" dia. and 7/8" dia. Phillips self-drilling anchors.
Drawing 054162	Nov 1980	I, T	A report was issued concerning inspections, tests, analyses, and rework of seismic Category I pipe supports and concrete expansion anchors in conformance with IEB 79-02. The acceptability of piping anchors was confirmed. Testing was performed to better define shear-tension interaction (refer to Teledyne report TR 4121-1, July 1980).
Drawing 054162	Oct 1981	T	PGandE performed a series of in-situ tests on raceway supports to confirm their behavior. The static tests showed linear behavior.

Governing Procedure	Date	Inspection (I) or Test (T)	Description
Drawing 054162	Jun 1982	I	The grid program inspection data was reviewed in the verification program. All anchor bolt deviations were reviewed (3746 problems were identified in the grid walkdown). The verification program reviewed the acceptability of these anchors.
Drawing 054162	Jun 1982	-	EOI 1016 report was prepared to address factors of safety inherent in the drawing 054162 allowable loads.
Drawing 054162	Dec 1982	I	55 anchors with threads cut off had been identified in the June 1982 grid walkdown review. These anchors were re-inspected and dispositioned in compliance with verification program criteria.
Drawing 054162	Jan 1983	I	44 anchors with insufficient embedment identified in the grid walkdown were UT examined. Based on the UT results, the design calculations were revised and the embedment problem was resolved.
Drawing 054162	Sep 1983	I	NCR-DC1-83-RM-N004 required testing tightness of 2400 HVAC bolts. Only 8 were found loose and were all able to be reset without replacement.
Drawing 054162	Dec 1983	I, T	Per NRC's request, 40 raceway anchors were torque-tested to determine adequacy of installation. All were found to be tightly installed. These 40 were then UT inspected and 1 had less embedment than required by drawing 054162 (2-3/4" long Hilti anchor).

Attachment 2 - Factors of Safety

Table A of drawing 054162 gives allowable loads for expansion anchors. These values have been used in design of expansion anchors at Diablo Canyon. In response to verification program EOI 1016 (Ref. 1), the factors of safety achieved by using the Table A allowable loads were quantified. This demonstrated that factors of safety ranging from nearly 4 to 9.1 were achieved between maximum allowable working level loads (DE seismic loads) and the anchor capacities published in the manufacturers' brochures. In accordance with drawing 054162, the allowables in Table A were doubled for severe environmental level loads (Hosgri and DDE seismic loads), thus reducing by half the safety factors stated above.

A review of the electrical raceway support calculations was recently performed. This review shows that for 100% of the raceway supports, with properly installed anchors, a factor of safety of at least 3 has been maintained between demand and capacity for Hosgri and DDE level loads. A sample of 45 raceway support calculations found the following distribution in the factors of safety:

Factor of Safety	% of Supports
≥ 3	100
≥ 4	98
≥ 5	89
≥ 10	82

A similar sampling was made of 50 HVAC duct support calculations with the following results:

Factor of Safety	% of Supports
≥ 3	100
≥ 4	80
≥ 5	62
≥ 10	26

The factors of safety listed in the tables above are conservative for the following reasons:

(a) Many calculations envelope loads to expedite the analysis.

(b) Expansion anchor capacities are based on concrete strengths achieved in the 28-day and 60-day cylinder break tests. Concrete typically strengthens 35 to 50% between the test cylinder strength and the 2-year strength. This would result in a 20 to 25% increase in capacity for most anchors.

(c) Most anchors are subjected to both shear and pullout loads. The 5/3 interaction equation specified on drawing 054162 was used to combine shear and pullout loads. This equation results in a conservative design when compared to test results.

Instrumentation supports were also designed using drawing 054162. The instrumentation supports have higher design margins than the raceway and HVAC supports because the instrumentation supports are almost always very lightly loaded.

Traditional factors of safety for expansion anchors range from 3, recommended by Appendix B of the ACI 349 code, to 4 or 5, recommended by NRC I&E Bulletin 79-02. Factors of safety for expansion anchors have been set at these high levels primarily to account for variability in workmanship (installation) and to account for reduced capacity in case a concrete crack subsequently passes through the anchor's location (tension zones of reinforced concrete elements). Reference 2 addresses expansion anchor performance in cracked concrete. This report concludes that a factor of safety of 3 (to account for variations in installation) is adequate even for anchors in cracked concrete.

As shown in the preceding tables, the overall margins in the Diablo Canyon expansion anchor designs are large. Factors of safety of at least 3 (and usually much more) have been maintained in the support designs. Only in cases where anchors were not properly installed is there a potential for the factor of safety to be less than 3. Installation deviations, addressed in the following attachments, have been reviewed and it has been found that the factors of safety have not been reduced to unacceptable levels.

Attachment 3 - Embedment

In order to achieve the pullout strengths which were used to compute the factors of safety listed in Attachment 2, minimum embedments of the expansion anchors into the concrete structures must be achieved. The manufacturers' brochures and drawing 054162 specify the required minimum embedments.

In 1977, a discrepancy report (DR 288) documented a potential embedment deficiency in electrical raceway support anchors. Between 1972 and 1975 approximately 14,000 1/2"-diameter, 2-3/4"-long, wedge-type expansion anchors were bought by the electrical contractor (raceway supports are estimated to contain a total of approximately 125,000 expansion anchors). To install these 1/2"-diameter anchors at the required 2-1/4" embedment, only 1/2" of the anchor stud would project out from the concrete surface; thus, any of these that were used would likely have been installed at less than required embedment.

Under the assumption that some of these "short" anchors were used in safety-related raceway supports, a testing program was undertaken in 1977. Test anchors were installed at 1-1/2" of embedment and were successfully proof-loaded to Hosgri design level loads. A field sampling program was then undertaken in which over 500 1/2"-diameter expansion anchor embedments were measured. This sampling program found all anchors have at least the 1-1/2" embedment used in the testing program. The combination of field sampling and proof testing provided assurance that the use of 2-3/4"-long anchors was acceptable (factor of safety of at least 1).

Between 1978 and 1980, a systematic (grid) program inspected the conformance of all raceway supports to the design drawing requirements. In this inspection, anchor embedment was determined by subtracting the projecting length of the anchor from the overall anchor length. It was assumed that expansion anchors were at least 3-3/4"-long. While this grid program would not have identified 2-3/4"-long anchors that were set at less than required embedment, it verified that the vast majority of the raceway anchors had the expected embedment.

In the 1982 verification program, the data compiled in the 1978 grid inspections were reviewed. Only 44 out of approximately 125,000 anchors were found to have less than required embedment. The embedment of each of these anchors was checked by UT examination and the allowable loads on these anchors were appropriately reduced in the verification program calculations. Every one of the 44 cases was found to be acceptable (faotor of safety greater than 3) when the reduced allowables were compared to the actual demand.

In December 1983, 40 raceway support anchors were selected for torque-testing. Results showed that all 40 anchors were properly set. The embedment on the 40 anchors was then measured. One of the 40 was found to have less than the minimum embedment required by drawing 054162 and was a 2-3/4"-long anchor. Assuming that the 40 anchors were randomly selected, this sample would indicate, to about a 75% confidence level (as determined by a statistical consultant), that 2-1/2 percent of the raceway support anchors were the 2-3/4"-long anchors.

An evaluation of the significance of short embedment for the raceway support anchors was made recently. Forty-five raceway support calculations were selected for review. Under the assumption that all anchors had been set at 1-1/4" embedment*, the capacities of all anchors were analytically reduced. The factors of safety for the anchors were then calculated and exhibited the following distribution:

Factor of Safety	Percentage of Supports
$\geq$ 1	100
$\geq$ 3	82
$\geq$ 4	80
$\geq$ 5	76
$\geq$ 10	51

The results above overwhelmingly demonstrate the safety margins in the raceway support designs. Since only about 2-1/2 percent of all anchors are likely to have reduced embedment, and since only 18 percent of all anchors would have a factor of safety less than 3 even if embedded at 1-1/4", the combined probability that any particular anchor would actually have a factor of safety less than 3 is very low. Even with short embedments, the factors of safety for the raceway support anchors would be between 1 and 3 and would not create an unsafe condition.

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*The grid program inspections verified 2-1/4" embedment for anchors assumed to be 3-3/4"-long. So if some anchors were actually 2-3/4"-long, their actual embedments would be at least 1-1/4".

Attachment 4 - Spacing

Drawing 054162 and manufacturers' brochures specify minimum spacing requirements for installation of adjacent anchors. Spacing between anchors is important for the anchors whose capacities are controlled by pullout of concrete cones around the anchor. When anchors are placed close together, their pullout cones overlap and reduce their pullout capacities.

In 1975, anchor inspections revealed numerous spacing deviations. Resolution of the deviations was achieved by inspecting all supports using expansion anchors. Anchors with spacing deviations were entered in a construction log and red-tagged for engineering disposition. In July 1975, a 3-month-long walkdown was performed by PGandE engineering. Each spacing deviation was resolved in one of the following ways:

(a) One of the two adjacent anchors was very lightly loaded; i.e., anchors securing grounding cables, lighting conduits, etc. More than 50 percent of all violations were of this type.

(b) Both of the adjacent anchors would not experience simultaneous loading. For example, one anchor might be installed in a brace designed to resist north-south seismic loads, while the other anchor was installed in an east-west seismic brace.

(c) Both of the adjacent anchors were loaded in shear only. Shear capacities are governed by the shear capacities of the individual anchor's steel shank, not by anchor spacing.

(d) The design loads were less than the reduced allowable loads. Engineering reviewed the design calculations of some deviations and analytically reduced the anchor strengths in accordance with drawing 054162.

(e) Physical changes to the supports were made. Modifications were made to eliminate the spacing deviations in cases that were not resolved by the means described above.

In 1982 and 1983, extensive walkdowns and design calculation reviews of the supports were made for the verification program. Where spacing deviations occurred between anchors installed within one support, anchor capacities were reduced in accordance with drawing 054162. For spacing deviations occurring between anchors installed in different supports, the deviations were resolved as follows:

(a) A sampling of design calculations qualifying supports containing anchors with support-to-support spacing deviations was made. In all cases the actual demand, when compared to reduced capacity, resulted in factors of safety greater than 3.

(b) The spacing deviation acceptance criteria used in the 1975 walkdown (items (a) through (e) above) were reviewed. With the exception of the deviations sent to engineering for review, the 1975 criteria remain valid. Thus, the 1975 walkdown satisfactorily resolved the majority of the spacing deviations.

(c) Analytical techniques (Ref. 3) for reducing anchor pullout strength, based on overlapping cones, show anchor capacity to be relatively insensitive to reductions in spacing. For example, at half the required spacing, 80 percent of the capacity remains.

(d) A series of spacing tests (Ref. 4) was performed by Doberne and Elgenson in 1962. Phillips Red-Head Self-Drilling expansion anchors were set at varying spacings and pulled to capacity. Evaluation of the test data showed 100 percent capacity available at 10 diameters (10d) spacing (drawing 054162 requires 12d) and 80 percent capacity available at 5d spacing. These data agree with the analytical method referenced above and corroborate the relative insensitivity of anchor capacity to reduced spacing.

The 1975 spacing review resolved spacing deviations on a case-by-case basis. In 1982, the verification program resolved spacing deviations on a sampling basis. Every case sampled was found to have an adequate factor of safety (greater than 3). While some spacing deviations may exist in which there are factors of safety less than 3, these would be very few and would not result in unsafe conditions.

Attachment 5 - Angular Alignment

Drawing 054162 and the contractor's procedures require expansion anchors to be installed not more than 5o out-of-plumb. This angular tolerance was based on the engineering judgment that a 5o misalignment would have no effect on the anchor's strength. At one time some of the manufacturers' brochures included a 5o misalignment tolerance, also based upon engineering judgement.

PGandE Engineering subsequently approved anchors installed up to 15o out-of-plumb, although the installation procedures retained the 5o tolerance. Thus, the only time that the 15o tolerance was used was when an anchor had inadvertently been installed at an angle greater than 5o.

The Engineering acceptance of 15o angularity was based on two sets of tests. The first were proof load tests performed in conjunction with discrepancy report 288 (Ref. 5). Wedge-type test anchors were installed 20o out-of-plumb and proof loaded in pullout to the Hosgri design load levels (twice Table A values). The second testing program was performed for piping anchors in conjunction with DR 282 (Ref. 6). These shell-type test anchors were installed 15o out-of-plumb and were proof loaded to more than 150 percent of the Hosgri design level loads (three times Table A values). All anchors in both test programs held the proof loads.

Bechtel is currently performing ultimate strength (failure) tests on expansion anchors installed 10o out-of-plumb. Preliminary results from tests on 3/4" diameter Hilti Kwik-Bolts (wedge-type anchors) indicate that there is no reduction in ultimate strength due to 10o misalignment, thus establishing that the factors of safety are retained in cases when the anchors are misaligned.

Although none of the tests referenced above were performed explicitly on Phillips Stud anchors, the anchorage mechanism on the stud-type anchors is identical to that used on the shell-type anchors. As mentioned above, the shell-type anchors installed 15o out-of-plumb were successfully proof tested to loads 50 percent above the Hosgri level allowables.

In summary, expansion anchors installed between 5o and 15o out-of-plumb are very rare occurrences. All of the test data cited above indicate that the anchors perform satisfactorily when installed within the 15o tolerance. Therefore, approval of the use of anchors at angles up to 15o is reasonable and acceptable.

Attachment 6 - Miscellaneous Irregularities

The inspection and walkdown reports referenced in Attachment 1 note a few irregularities in anchor installation that are not addressed in Attachments 3 through 5. Examples of these irregularities include tapping stud anchors sideways to improve alignment and torquing anchors to achieve full nut engagement. These are extremely rare occurrences and no test data are available to quantify the effects, if any, that these irregularities have on anchor capacities.

As noted on page 2 of this submittal, it is expected that 2 to 3 percent of all anchors experienced some deviations (or irregularities) in installation. These deviations could reduce an anchor's factor of safety below 3 if that specific anchor were required to carry the maximum load allowed by drawing 054162. However, it is believed that the irregularities of the type mentioned above would have only minimal adverse impact on the anchor capacities and a factor of safety of at least 3 exists between demand and capacity.

Due to the infrequency of occurrence and the large factor of safety built into the design, installation irregularities would have no significant effect on the overall safety of the attached components.

Attachment 7 - Simulation of Expansion Anchors in Dynamic Testing Program

In 1983, dynamic testing of the Diablo Canyon raceway supports was performed at ANCO Engineers, Inc., at the testing facility. In this dynamic testing program, it was not feasible to use expansion anchors due to limitations in mounting concrete slabs on the shake-table. Therefore, A307 machine bolts were used in lieu of expansion anchors. The A307 bolts were torqued to produce a preload of about 1050 pounds. The torque necessary to produce this preload was small, typically 10 to 12 ft-lbs. This preload value was used because it provided a reasonable representation of the expansion anchors in field conditions. Further justifications for the use of a 1050-pound preload are:

(a) It is a common practice to torque expansion anchors to produce a preload about equal to the working design load (1025 pounds for 1/2"-diameter bolts in 4000 psi concrete). For example, Hilti recommends 3 or 4 turns after finger-tight condition, which produces the desired preload.

(b) The use of a wrench for installing expansion bolts is necessary and experience has shown that 12 ft-lbs torque is very easily attained when the nut is turned, even with a 6-inch wrench. This was further verified in the three field-sampling programs, described below. During an onsite audit, NRC inspectors examined 140 raceway supports. All but 12 anchors were found to be at least snug-tight. Estimating 4 anchors per support, only 2 percent did not have a preload. In another NRC inspection, 40 anchors were randomly selected and all 40 were found to be snug-tight. A third program, executed in response to an NCR (Ref. 7) sampled the tightness of 2400 HVAC duct support bolts. All except 8 bolts were found to be tightly installed.

In the dynamic testing, at intermediate level shaking (average Hosgri design load level), almost all of the A307 bolts retained their preload. In the supports where there was some loosening of the A307 bolts, no adverse changes occured in the support's response.

Numerous field inspections have shown that with the exception of an occasional loose bolt, the concrete expansion anchors in place at Diablo Canyon are installed snug-tight. This condition was reflected in the ANCO testing by using preloaded A307 bolts. As observed in the testing, bolt preload did not preclude bolt loosening and the supports performed satisfactorily. Therefore, modeling of the expansion anchors in the dynamic testing with preloaded A307 bolts was reasonable and appropriate.

Attachment 8 - References

(1) "Resolution of RLCA EOI 1016," Diablo Canyon Project Electrical Raceway Support Calculation EOI 1016, Rev. 0, June 1982.

(2) "Expansion Anchor Performance in Cracked Concrete," R. W. Cannon, Tennessee Valley Authority, 1981.

(3) "Structural Engineering Aspects of Headed Concrete Anchors and Deformed Bar Anchors in the Concrete Construction Industry," KSM Welding Systems Division, Omark Industries, 1971.

(4) "Pullout Capacities of Phillips Red Head Concrete Anchors as Affected by Spacing," Doberne and Elgenson, File 626, September 1962.

(5) "Test Procedure WA-1, Concrete Wedge Anchors," Rev. 1, PGandE, March 1977.

(6) "Procedure for Establishing Acceptance Criteria for Concrete Anchor Installations," Rev. 2, PGandE, December 1976.

(7) Nonconformance Report DC1-83-RM-N004, September 1983.