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Iowa Electric Light and Power Company

October 17, 1980
LDR-80-283

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ASSISTANT VICE PRESIDENT
OF NUCLEAR DIVISION

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Mr. James G. Keppler, Director
Office of Inspection and Enforcement
Region III
U.S. Nuclear Regulatory Commission
799 Roosevelt Road
Glen Ellyn, IL 60137

Dear Mr. Keppler:

This letter and enclosure are Iowa Electric Light and Power Company's final response to IE Bulletin No. 79-02 concerning pipe support baseplate designs using concrete expansion anchor bolts.

Your recent Bulletins have requested cost information. As a result of Bulletin 79-02, Iowa Electric expended approximately six million dollars in preparation of the report and corrective action.

Very truly yours,

Larry D. Root

Larry D. Root
Assistant Vice President
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LDR/lb

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FINAL REPORT
ON
PIPE SUPPORT BASEPLATE DESIGNS
USING CONCRETE EXPANSION ANCHOR BOLTS
(IN RESPONSE TO NRC IE BULLETIN 79-02, REV 2, DATED NOVEMBER 8, 1979)

1.0 INTRODUCTION

This report is in response to NRC IE Bulletin 79-02, Rev 2 dated November 8, 1979, requiring all licensees and permit holders for nuclear power plants to review the design and installation procedures for concrete expansion anchor bolts used in pipe support baseplates in systems defined as Seismic Category I by NRC Regulatory Guide 1.28, Seismic Design Classification, Revision 1 dated August 1973, or by the applicable SAR. It is also intended to provide information to allow resolution of certain unresolved items from IE Inspection Report 50-331/79-18 dated September 13, 1979.

In accordance with the intent of IE Bulletin 79-02, the following types of supports have been considered in the present review: pipe anchors (Seismic Category I) and pipe supports (Seismic Category I).

Adequacy of supports in those categories which used structural steel members attached directly to the concrete by expansion anchor bolts were also verified in accordance with the intent of the bulletin.

The design and installation of the expansion anchor bolts on the Duane Arnold Energy Center (DAEC) were governed by the following documents:

1.1 Technical Specification 7884-M-119, Pipe Hangers, Supports, and Restraints

1.2 Manufacturers Standardization Society MSS-SP-58, Pipe Hangers and Valves

1.3 American Society for Testing and Materials Standards

2.0 RESPONSE TO ACTION ITEMS

Item 1

Verify that pipe support baseplate flexibility was accounted for in the calculation of anchor bolt loads. In lieu of supporting analysis justifying the assumption of rigidity, the baseplates should be considered flexible if the unstiffened distance between the member welded to the plate and the edge of the baseplate is greater than twice the thickness of the plate. It is recognized that this criterion is conservative. Less conservative acceptance criteria must be justified and the justification must be submitted as part of the response to the bulletin. If the baseplate is determined to be flexible, then recalculate the bolt loads using an appropriate analysis. If possible, this is to be done prior to testing of anchor bolts. These calculated bolt loads are referred to hereafter as the bolt design loads. A description of the analytical model used to verify that pipe support baseplate flexibility is accounted for in the calculation of anchor bolt loads is to be submitted with your response to the bulletin.

Response

All pipe anchor and support baseplates using expansion anchor/bolts were reanalyzed to account for plate flexibility, bolt stiffness, shear-tension interaction, minimum edge distance, and proper bolt spacing. Depending on the complexity of the individual baseplate configuration, one of the following methods of analysis was used to determine the bolt forces.

a. A quasianalytical method developed by Bechtel was used for baseplates with eight bolts or less. A review of the typical baseplates used in supporting the subject piping systems indicates that the majority of them were anchored either by four, six, or eight bolts. The plate thickness usually varied from 3/8 to 2 inches and was not generally stiffened. For these types of baseplates, an analytical formulation has been developed which treats the plates as a beam on multiple spring supports subjected to moments and forces in three orthogonal directions. Based on analytical considerations, as well as on the results of a number of representative finite element analyses of baseplates (using the ANSYS Code), certain empirical factors were introduced in the simplified beam model to account for 1) the effect of concrete foundation and 2) the two-way action of load transfer in a plate. These factors essentially provided a way for introducing the interaction effect of such parametric variables as plate dimensions, attachment sizes, bolt spacings, and stiffenesses on the distribution of external loads to the bolts.

A computer program for the analytical technique described above has been implemented for determining the bolt loads for routine applications. The program requires plate dimensions, number of bolts, bolt size, bolt spacing, bolt stiffness, the applied forces, and the allowable bolt shear and tension loads as inputs.

The results from a number of case studies indicate excellent correlation between the results of the present formulation and those by the finite element method (using the ANSYS Code). The quasianalytical method generally gives the bolt loads greater than the finite element method (FEM).

b. For special cases where the design of the support did not lend itself to the foregoing method, the finite element method using the ANSYS Code and/or other standard engineering analytical techniques with conservative assumptions were employed in the analysis.

c. Other cases were solved using an approach based on the strength design method given in the ACI 318-77 code.

Although the effect of plate flexibility has been explicitly considered in the formulation described above, the impact of prying action on the anchor bolts was determined not to be critical for the following reasons:

a. Where the anchorage system capacity is governed by the concrete shear cone, the prying action would result in an application of an external compressive load in the cone and therefore would not affect the anchorage capacity.

b. Where the bolt pullout determines the anchorage capacity, the additional load carried by the bolt due to the prying action will be self-limiting because the bolt stiffness decreases with increasing load. At higher loads, the bolt expansion will be such that the corners of the baseplate will lift off and the prying action will be relieved. This phenomena was found to occur when the bolt stiffness in the finite element analysis was varied from a high to a low value to correspond typically to the initial stiffness and that beyond the allowable design load.

Item 2

Verify that the concrete expansion anchor bolts have the following minimum factor of safety between the bolt design load and the bolt ultimate capacity determined from static load tests (e.g., anchor bolt manufacturers who simulate the actual conditions of installation [i.e., type of concrete and its strength properties]):

a. Four - for wedge and sleeve type anchor bolts

b. Five - For shell type anchor bolts

The bolt ultimate capacity should account for the effects of shear-tension interaction, minimum edge distance, and proper bolt spacing.

If the minimum factor of safety of four for wedge type anchor bolts and five for shell type anchors cannot be shown, then justification must be provided. The bulletin factors of safety were intended for the maximum support load, including the safe shutdown earthquake (SSE). The NRC has not yet been provided adequate justification that lower factors of safety are allowed on an interim basis by the provisions of Supplement 1 to IE Bulletin 79-02. The use of reduced factors of safety in the factored load approach of ACI 349-76 has not yet been accepted by the NRC.

Response

In the design review, the maximum support load cases (including the SSE) used factors of safety (i.e., ratio of manufacturer's specified anchor bolt ultimate capacity to bolt design load) of four for wedge type anchor bolts and five for shell type anchor bolts that have a center-to-center distance between anchor bolts of 10d (i.e., 10 times the anchor bolt diameter) or greater and a center-to-edge distance of 5d or greater. For anchor bolts with a center-to-center distance of less than 10d or a center-to-edge distance less than 5d, the allowables were reduced using a shear cone interaction reduction as outlined in the PCI Design Handbook.

The shear-tension interaction in the anchor bolts has been accounted for in the following manner:

In most cases, the total applied tension and shear is considered to be carried by the bolts in accordance with the following interaction formula:

$$\left(\frac{T}{T_A}\right)^2 + \left(\frac{S}{S_A}\right)^2 \leq 1.0$$

T and S are the calculated tensile and shear forces and T_A and S_A are the respective allowable values for the specified anchors.

In isolated cases where the applied shear force is less than the frictional force developed in the shear plane between the steel and the concrete surface for balancing the imposed loads, no additional provisions are considered for shear.

In all cases where the calculated safety factor for the existing anchor bolt was found to be less than the minimum, the support was modified and the anchor bolt was replaced with a bolt which equals or exceeds the required minimum.

All (643 total) large pipe supports using concrete expansion bolts have been reviewed. The 100 supports which were identified to have no tension loads for all loading cases were determined not to require testing. Also included in the review were 166 spring hangers which have no seismic function. They were inspected for gross failures and no testing was performed. All other supports (377) have been analyzed against the design condition to confirm the bolt design load. In addition, the safety factor between the design load and the specified manufacturer's bolt ultimate capacity has been calculated to meet bulletin requirements. On the CRD system equipment, the concrete expansion bolts on the large pipe have been tested and the results will be reported on in the final response to NRC Bulletin IE 80-17.

For small pipe systems (less than 2-1/2 inches in diameter) that are computer-analyzed, all the concrete expansion bolts (on 73 supports) have been reviewed. Of these, four supports have been identified as having no tension loads in all loading cases and nine supports have required modification of either the baseplates or anchor bolts (modifications have been completed). Calculations for the remaining 60 supports have been performed, and their concrete expansion bolts meet bulletin requirements. On the CRD system equipment, the concrete expansion bolts on the computer-analyzed small pipe have been tested and the results will be reported in the final response to NRC Bulletin IE 80-17.

Item 3

Describe the design requirements, if applicable for anchor bolts to withstand cyclic loads (e.g., seismic loads and high cycle operating loads).

Response

In the original design of the piping systems, deadweight, thermal stresses, seismic loads, and dynamic loads were considered in the generation of the pipe support design loads.

To the extent that these loads include cyclic considerations, these effects would be included in the design of the hangers, baseplates, and anchorages.

The safety factors used for concrete expansion anchors installed on supports for safety-related piping systems were not increased for loads which are cyclic in nature. The use of the same safety factor for cyclic and static loads is based on the FFTF tests. The test results indicated:

a. The expansion anchors successfully withstood two million cycles of long-term fatigue loading at a maximum intensity of 0.20 of the static ultimate capacity. When the maximum load intensity was steadily increased beyond the aforementioned value and cycled for 2,000 times at each load step, the observed failure load was approximately the same as the static ultimate capacity.

b. The dynamic load capacity of the expansion anchors, under simulated seismic loading, was approximately the same as their corresponding static ultimate capacities.

Item 4

Verify from existing QC documentation that design requirements have been met for each anchor bolt in the following areas:

a. Cyclic loads have been considered (e.g., anchor bolt preload is equal to or greater than bolt design load). In the case of the shell type, ensure that it is not in contact with the back of the support plate prior to preload testing.

b. Specified design size and type is correctly installed (e.g., proper embedment depth).

If sufficient documentation does not exist, then initiate a testing program that will ensure that minimum design requirements have been met with respect to Items a and b above. A sampling technique is acceptable. One acceptable technique is to randomly select and test one anchor bolt in each baseplate (i.e., some supports may have more than one baseplate). The test should provide verification of Items a and b above. If the test fails, all other bolts on that baseplate should be similarly tested. In any event, the test program should ensure that each Seismic Category I system will perform its intended function.

Response

Sufficient documentation did not exist; therefore, a testing program was initiated at the DAEC. The intent of the program was to inspect, test, and/or replace 100% of the concrete expansion bolts in Seismic Category I large piping systems. This was accomplished except for five hangers that are not considered feasible to test. One support is in a high-radiation area on a nonseismic line connected to a seismic line. This support is approximately 85'-0" away from the seismic boundary with eight supports in between, and it is judged that any failure of this support would have a negligible effect on the seismic line. The other four supports are located underwater. Assuming that one anchor bolt in four was defective (a higher rate than ever encountered during the DAEC anchor testing) analysis has shown that the supports are still adequate.

Each anchor, except those delineated above, was inspected to verify adequate thread engagement, anchor size, spacing, and distance to a concrete edge. Shell type anchors were inspected to verify that the shell is not in contact with the baseplate during testing. Anchors in grouted baseplates were inspected to verify that leveling nuts, if used, will not interfere with testing.

Because sufficient documentation does not exist to verify which manufacturer's type of concrete expansion bolt was installed at a given location at the DAEC, the test values for the program were based on the manufacturer's type of bolt with the lowest ultimate capacity. Each anchor was tested to twice the allowable values for the lowest capacity anchors based on the torque/tension relationship shown in Attachment A. For the higher capacity anchors, this torque resulted in a value somewhat less than twice the design using this relationship. A testing program was performed (see Attachment B) to determine the site-specific torque/tension relationship. The results of these tests (see Attachment B) show that the torque/tension relationship used is conservative relative to applying tension directly.

If the anchor passed the testing and inspection described above, it was preloaded to a value that ensured a preload equal to or greater than the minimum design allowable anchor load for the type of anchors used at the DAEC. If the anchor did not pass the testing and inspection described above, it was replaced with a wedge type anchor installed in accordance with the manufacturer's recommendations. The wedge type replacement anchors were also preloaded to a value greater than the bolt design load.

For piping systems less than 2-1/2 inches in diameter that were computer-analyzed, 100% of the anchor bolts were tested. Depending upon the ease with which the test could be performed, either the anchor bolts were tested using the torque/tension relationship as described for large pipe, or a load of twice the design load under earthquake conditions was applied to the support (i.e., loading the baseplates and anchor bolts to twice the design load seen by the support).

For piping systems less than 2-1/2 inches in diameter that used the chart analysis method, this rigid range method of analysis is considered highly conservative. For these small pipe systems, a sampling program (Attachment C) was developed to demonstrate system operability. Of approximately 700 small pipe supports, 100 were tested to five times their design load. The results, as shown in Attachment C, show that there is a 95% confidence level that 97% of the supports will support the design load and 90% of the supports will support 4-1/2 times the design load.

Item 5

Determine the extent that expansion anchor bolts were used in concrete block (masonry) walls to attach piping supports in Seismic Category I systems (or safety-related systems as defined by Revision 1 of IE Bulletin 79-02). If expansion anchor bolts were used in concrete block walls:

a. Provide a list of the systems involved, with the number of supports, type of anchor bolt, line size, and whether these supports are accessible during normal plant operation.

b. Describe in detail any design consideration used to account for this type of installation.

c. Provide a detailed evaluation of the capability of the supports, including the anchor bolts and block wall, to meet the design loads. The evaluation must describe how the allowable loads on anchor bolts in concrete block walls were determined and also what analytical method was used to determine the integrity of the block walls under the imposed loads. Also describe the acceptance criteria, including the numerical values, used to perform this evaluation. Review the deficiencies identified in the information notice on the pipe supports and walls at Trojan to determine if a similar situation exists at your facility with regard to support using anchor bolts in concrete block walls.

d. Describe the results of testing of anchor bolts in concrete block walls and your plans and schedule for any further action.

Response

In all cases where expansion anchor bolts were found to support Seismic Category I large piping systems and computer-analyzed small piping systems in block walls, they have been removed and replaced by thru-bolted installations. Out of approximately 1,600 large pipe supports, 15 of these cases have been found.

Small piping systems (less than 2-1/2 inches in diameter) that used a chart analysis method have 105 pipe supports bolted to block walls. Of the 105 supports, 33 were tested as part of the sample program for Item 4 (see Attachment C). It was found that 30 of the supports withstood the test load of 5 times design load, 2 withstood a load of 2-1/2 times the design load (these were then thru-bolted or welded to structural steel), and 1 withstood a load of 1-1/2 times the design load (this was then thru-bolted or welded to structural steel). The systems which have supports anchor-bolted to block walls are the emergency service water, residual heat removal, core spray, standby liquid control, containment atmosphere control, and essential chilled water systems. All of the supports are accessible during normal plant operation.

The integrity of the block walls under design loads was verified by checking worst-case loading for sample walls.

These walls were the wall with the largest span and high span to thickness ratio and a wall with high imposed loads. These walls are not relied upon to act as shear walls.

The following load combinations were considered in the review.

1.25(D+L+Ho+E)+1.0 To

D+L+E'+To+Ho+R

where

D = dead load
L = live load
Ho = piping thermal
To = thermal
E = OBE (operating basis earthquake)
E' = SSE (safe shutdown earthquake)
R = pipe rupture (inside drywell only)

These combinations are consistent with the criteria presented in the FSAR (Chapter 12) for reinforced concrete structures.

Acceptance criteria for the load combinations given above are as follows. For loads involving E, use the Uniform Building Code (denoted as S). For loads involving E', use 1.5 times the Uniform Building Code (denoted as 1.5S).

These acceptance criteria are consistent with those presented in the FSAR (FSAR Question 12.5).

Using these load combinations and acceptance criteria, the following critical load case was selected:

1.5S = E' + Ho

The walls were reviewed on a global basis using the following procedure.

a. The spectral accelerations, frequency calculations, and blockwall properties were taken from the original design calculations. These calculations considered the wall to act as a simply supported beam spanning vertically. Cracking was considered in the frequency calculations.

b. The SSE accelerations were applied as transverse loads to the wall modeled as a plate with the spectral acceleration applied at the center decreasing to the upper floor acceleration at all edges. This resulted in loads in the wall due to its own inertia.

c. The total weight of all large pipe (Seismic Category I and non-Seismic Category I) within 6 feet of the wall was evaluated. This weight was uniformly distributed on the wall and an increase factor was applied for other items, such as cable tray and small piping, that could be attached to the wall. The lateral loading due to SSE seismic piping responses was evaluated by multiplying the distributed piping load by both the peak of the SSE 1% response spectrum and an additional factor of 1.5 to account for multimodal piping responses. This load was then reduced by a factor of the square root of two to account for phasing differences between the different piping systems. The uniformly distributed load described above was applied to the wall modeled as a plate. This resulted in an upper bound for loads in the wall due to SSE piping responses.

d. Piping thermal loads were applied as a uniformly distributed load to the wall modeled as a plate. This resulted in an upper bound for loads in the wall due to piping thermal reactions.

e. The wall loads due to wall inertia, piping inertia, and piping thermal reactions were summed on an absolute basis and checked against the acceptance criteria.

The maximum calculated global loading did not exceed the calculated acceptance criteria for these walls.

Local effects due to a pipe hanger were evaluated for pullout and local shearing. The maximum calculated local loading did not exceed the acceptance criteria allowables for these walls. No further actions are planned.

Item 6

Determine the extent that pipe supports with expansion anchor bolts used structural steel shapes instead of baseplates. The systems and lines reviewed must be consistent with the criteria of IE Bulletin 79-02, Revision 1. If expansion anchor bolts were used as described above, verify that the anchor bolt and structural steel shapes in these supports were included in the actions performed for the bulletin. If these supports cannot be verified to have been included in the bulletin actions:

a. Provide a list of the systems involved, with the number of supports, type of anchor bolt, line size, and whether the supports are accessible during normal plant operation.

b. Provide a detailed evaluation of the adequacy of the anchor bolt design and installation. The evaluation should address the assisted distribution of loads on the anchor bolts. The evaluation can be based on the results of previous anchor bolt testing and/or analysis which substantiates operability of the affected system.

c. Describe your plans and schedule for any further action necessary to ensure that the affected systems meet technical specifications operability requirements in the event of an SSE.

Response

A significant portion of the pipe supports at the DAEC used structural steel shapes such as channels which were bolted directly to the concrete. In all cases where this design was encountered, the entire support was treated in accordance with the criteria for this bulletin.

Item 7

For those licensees that have had no extended outages to perform the testing of the inaccessible anchor bolts, the testing of anchor bolts in accessible areas is expected to be completed by November 15, 1979. The testing of the inaccessible anchor bolts should be completed. The testing in accessible areas should continue as rapidly as possible, but no longer than March 1, 1980. The analysis for the bulletin items covering baseplate flexibility and factors of safety should be complete by November 15, 1979. Provide a schedule that details the completion dates for IE Bulletin 79-02, Revision 2, Items 1, 2, and 4.

Response

Testing and repair (when required) of the anchor bolts in accessible and inaccessible areas have been completed. Calculations verifying the required minimum factor of safety have been completed. The design requirement for bolt preload and proper installation was met and verified on QC documentation during the repair and testing of each support.

Item 8

Maintain documentation of any sampling inspection of anchor bolts required by Item 4 onsite and available for NRC inspection. All holders of operating licenses for power reactor facilities are requested to complete Items 5, 6, and 7 within 30 days of the date of issuance of Revision 2. Also describe any instances not previously reported in which you did not meet the revised (R2) sections of Items 2 and 4 and, if necessary, your plans and schedule for resolution. Report in writing within 30 days of the date of this revision issuance, to the director of the appropriate regional office, completion of your review. For action not yet complete, a final report is to be submitted upon completion of your action. A copy of your report(s) should be sent to the United States Nuclear Regulatory Commission, Office of Inspection and Enforcement, Division of Reactor Operations Inspection, Washington, D.C. 20555. These reporting requirements do not preclude nor substitute for the applicable requirements to report as set forth in the regulations and license.

Response

Documentation for the anchor bolt testing and repair program is maintained onsite at the DAEC. Items 5, 6, and 7 are addressed as noted in the previous responses for Items 5, 6, and 7 in this report.

The calculations for required factors of safety included SSE loads as required in the revised section of Item 2, and anchor bolt testing and repair has proceeded in a manner consistent with the provisions of Supplement 1 to the bulletin.

For all tested or repaired anchor bolt installations, the requirement for preload has been met as outlined in Item 4 of the bulletin.

Item 9

All holders of construction permits for power reactor facilities are requested to complete Items 5 and 6 for installed pipe supports within 60 days of date of issuance of Revision 2. For pipe supports which have not yet been installed, document your action to ensure that Items 1 through 6 will be satisfied. Maintain documentation of these actions onsite available for NRC inspection. Report in writing within 60 days of date of issuance of Revision 2, to the director of the appropriate NRC Regional Office, completion of your review and describe any instances not previously reported in which you did not meet the revised (R2) sections of Items 2 and 4 and, if necessary, your plans and schedule for resolution. A copy of your report should be sent to the United States Nuclear Regulatory Commission, Office of Inspection and Enforcement, Division of Reactor Construction Inspection, Washington, D.C. 20555.

Response

No response is required.

ATTACHMENT A

TABLE 1

MINIMUM ANCHOR SPACING AND EDGE DISTANCES WITHOUT ENGINEERING EVALUATION

Anchor Size (in.)	Minimum Center-Of-Anchor Edge of Concrete (in.)
1/4	3-1/2
3/8	4
1/2	4-1/2
5/8	5-1/8
3/4	5-3/4
7/8	5-3/4
1	5-1/2

Note: Edge distances are taken from the manufacturers' recommendations for products listed in Table 2, Note 3

TABLE 2

CONCRETE ANCHOR LOADINGS[3]

Anchor Size (in.)	Allowable Tension (lb)	Test Tension (lb)[1]	Test Torque (ft/lb)[1,2]
1/4	321	642	7
3/8	475	950	15
1/2	967	1,934	39
5/8	1,400	2,800	70
3/4	1,845	3,690	111
7/8	2,967	5,934	208
1	4,000	8,000	320

(1) Values reflect test tension and torque loads equal to or greater than twice the allowable tension loads given above.
(2) Values may be verified using site specific testing.
(3) The values shown are applicable under the following conditions:

a. Minimum $f'_c = 3{,}000$ psi

b. The requirements of Table 1 are satisfied

c. The anchors are one of the following:

1. Phillips self-drilling, nondrilling, multiset, wedge or standard anchors
2. Standard Wej-it
3. Hilti Drop-in or Kwik-bolt

ATTACHMENT B

TORQUE-TENSION RELATIONSHIP

I. PURPOSE

The purpose of this torque-tension test was to verify the following relationship which was used to establish test torque values.

$T = 0.04\ P\ D$

T = test torque (foot-pounds) Eq (1)

D = bolt diameter (inches)

P = test tension value (pounds)

II. ANALYSIS

The development of the torque versus tension relationship for various anchor bolt diameters is based on the combined friction resistance in the bolt threads and between the bolt head (or nut) and the bearing surface (baseplate or washer).

The torque T_1 due to friction in the threads would be approximately equal to the product of the friction factor μ, the bolt radius r, and the bolt tension P.

$$T_1 = \mu P\ r$$

The torque T_2 due to friction under the bolt head would be approximately equal to the product of the friction factor , the bolt tension P, and the mean radius of the loaded area of the bolt head or nut $\bar{r}$.

$$T_2 = \mu P\ \bar{r}$$

The torque T required to turn the nut or bolt under a preload P would be

$$T = T_1 + T_2$$

$$T = \mu P\ (r + \bar{r}) \qquad \text{Eq (2)}$$

substituting

$$r = \frac{D}{2}$$

$$\bar{r} = \frac{\bar{D}}{2}$$

$$\bar{D} = \frac{D + 1.5D}{2}$$

$$T = \mu P \left(\frac{D}{2} + \frac{D + 1.5D}{4}\right)$$

$$T = \frac{9}{8} \mu P D$$

= friction factor

P = bolt tension preload (pounds)

D = bolt diameter (inches)

T = torque (inch-pounds)

For torque T expressed in foot-pounds

$$T = \frac{3}{32} \mu P D \qquad \text{Eq (3)}$$

T = torque (foot-pounds)

Letting $\frac{3}{32}\mu$ equal the bolt friction factor K, the relationship between applied torque and bolt tension is then

$$T = K P D \qquad \text{Eq (4)}$$

III. TESTING

The testing was performed upon concrete expansion anchors that are representative of those in service at the Duane Arnold Energy Center (DAEC). This included two types of anchors (Hilti Drop-In and Red Heads) with bolt sizes ranging between 3/8 and 3/4 inch. (Note: Test data for Hilti 3/4-inch bolts are contained in the test report entitled Onsite Test Program for Pipe Supports in Categorys I, II, and III MC ASME Section III, Division I, Subsection NF, Component Supports Drilled-In Expansion Type Anchors Hilti Kwik Bolts, performed August 6, 1979, at the DAEC.)

The testing apparatus used is shown in Figure 1.

The data collected for the torque-tension relationship were analyzed using a least-squares analysis to determine the best fitting line for the data. Using the slope from this analysis, the value of K for Equation 4 was determined. The slope is equal to T/P; therefore K = T/P x I/D. A summary of the K values are shown in Table 1 for each set of data.

IV. CONCLUSION

The K value of 0.04 used is conservative because the median test value was 0.029 with a standard deviation of $\pm$ 0.008 (see Table 1). A combined result was used for comparison because one value of K was used for all types and sizes of anchor bolts. It can also be noted from Table 3 that the average value of K for each bolt size is either equal to or less than K = 0.04. Therefore, Equation 1 will ensure that the tension preload value will be greater than or equal to the test tension value P.

TABLE 1

Bolt Size	Hilti K (Trial) 1	Hilti K (Trial) 2	Hilti K (Trial) 3	Hilti Average K	Red Head K (Trial) 1	Red Head K (Trial) 2	Red Head K (Trial) 3	Red Head Average K
3/8"	0.026	0.029		0.028	0.031	0.041		0.036
1/2"*	0.016	0.015	0.022 / 0.018	0.018	0.031	0.037	0.024	0.031
5/8"	0.046	0.035		0.040	0.030			0.030
3/4"					0.030	0.034	0.028	0.031

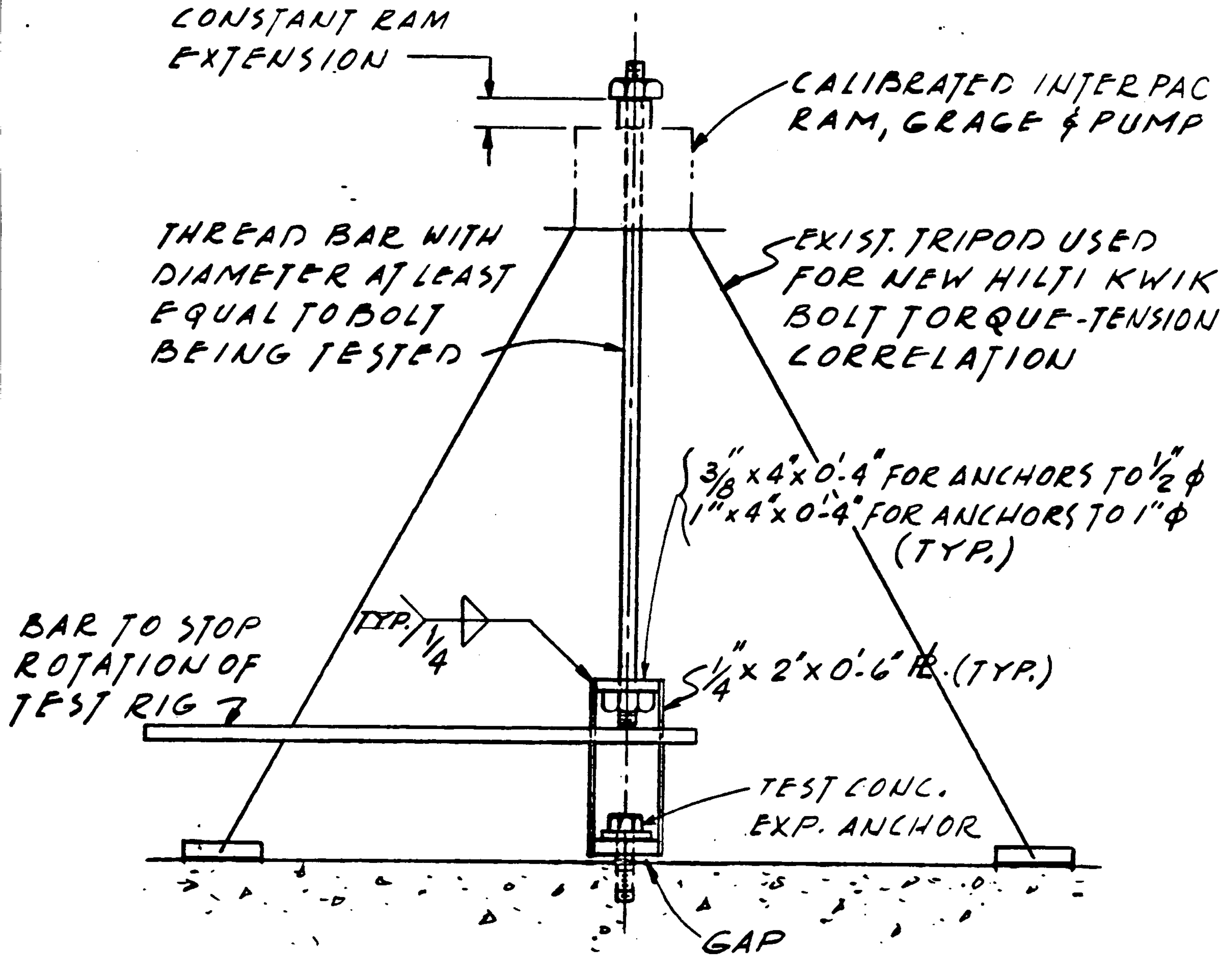
*Four trials were run for 1/2" Ø Hilti anchor bolts

Average K = 0.029

Mean value K = 0.029

Standard deviation = ± 0.008

FIGURE 1



NOTES:

1- ALL STEEL FOR TESTING RIG TO BE A-36 OR EQUIV.

2- CONSTANT RAM EXT. IS TO BE USED FOR ALL TESTS FOR ALL CONC. EXPANSION ANCHORS. EXTENSION TO BE DETERMINED BY FIELD AND RAM IS TO BE CALIBRATED WITH THIS EXTENSION.

3- GAP BETWEEN CONC. EXP. ANCHOR & TEST RIG TO BE DETERMINED BY FIELD.

ATTACHMENT C

TESTING OF TWO-INCH AND UNDER PIPE
FOR
SUPPORTS NOT COMPUTER-ANALYZED

1.0 PURPOSE

The purpose of this test program is to satisfy NRC Bulletin 79-02, Revision 2 requirements for verification of adequacy of expansion anchor bolts in bolted supports in 2-inch and smaller (small pipe), Seismic Category I systems which were chart-analyzed.

2.0 SCOPE

The program tested a sample of 100 chart-analyzed small pipe supports to five times the design load to verify the adequacy of the anchor bolts. The hangers were selected from 16 safety-related systems which have small pipe in the Seismic Category I boundary.

3.0 SAMPLE PLAN

Considering 100 supports out of a population encompassing approximately 700 supports which utilized expansion anchor bolts, a binomial distribution will give the following confidence of the acceptability of total supports. (Note: Reference An Introduction to Probability Theory and its Applications, Volume 1, third edition, by William Feller.)

Number of Failures	Percent Confidence	Percent of Total Supports Acceptable
0	95	97
1	95	95.3
2	95	94
3	95	92.3
4	95	91
5	95	90

These criteria are used to consider acceptability of the chart-analyzed small pipe for the Duane Arnold Energy Center (DAEC).

4.0 SURVEY

The small pipe design guide used at the DAEC calls for a pipe support type and location on the hanger isometric, but does not specify whether or not the support is welded to the building structure or uses a bolted plate. Instead, it calls for a typical support structure, and either a welded connection or a baseplate and anchor bolts are used, as applicable. Therefore, the piping systems were surveyed to locate those supports where anchor bolts had been used.

4.1 Small pipe isometrics, hanger isometrics, and hanger detail sheets were used to locate lines in accessible areas. Attachment 1 lists the safety-related systems that were surveyed to locate the 100 hangers tested.

4.2 Using the sample group of lines selected, supports to be tested were chosen by Bechtel. Limitations were placed on the supports chosen because of ALARA (keeping personnel exposure as low as reasonably achievable), limitations of the testing apparatus, physical interferences, and where the steel configuration might be compromised. Because of congestion and limitation of the testing apparatus, testing was limited to one plane. Supports of the same type outside the Seismic Category I boundary were included because of a lack of appropriate supports within the Seismic Category I portion of those systems. A breakdown of the supports chosen by system and area is shown in Attachment 2.

5.0 TESTING

The procedure used was independent of the manufacturer and specific subtypes of anchors used at the DAEC. The supports were not tested in any specific order. This is justified because the anchor bolt installation is independent of the support type.

The test consisted of loading the support with a load five times the design load in each of the directions where the pipe support was expected to show resistance.

The test support was a reject if it failed to support the test load for 1 minute.

6.0 DOCUMENTATION

Hanger isometric drawings have been marked up to show the location of each support which has been tested.

The hanger test data sheets include the following information (Attachment 3).

6.1 A sketch of the installed condition of the support

6.2 Identifies if the support is attached to a block wall

6.3 The test load applied to the support

6.4 The direction in which the load was applied

6.5 Any other information, such as general conditions of the support

All original data are retained by the DAEC quality department.

7.0 INSPECTION

7.1 A Level 1 or higher inspector was present during the testing and recorded the data.

7.2 The inspector checked the hanger and support plate for general conformance to the support drawing and the criteria listed in the data sheet.

8.0 CONCLUSION

Of the 100 supports tested, there were five failures. Of these, four were due to anchor bolt failure. The failures occurred at 1.67, 1.83, 2.50, and 2.92 times the design load. One failure was due to steel buckling at 4.58 times the design load. The steel failure was predictable because of its unbraced length. Because the anchor bolts held the required load, this need not be considered a failure.

As shown in Attachment 4, the percent of total acceptable supports varies depending on the excess capacity considered. With 95% confidence, 97% of the total supports will withstand the design load, 94% of the supports will withstand a load of 1.67 times the design load, and 90% will withstand a load of 4.67 times the design load.

The conclusion to be drawn from this program is that the chart-analyzed small pipe supports are adequate to withstand the loads for which they were intended. The safety factor of five times the design load has been demonstrated by the testing program to be present in a very high percentage of the supports.

ATTACHMENT 1

SEISMIC CATEGORY I PIPING SYSTEMS

System

Well water

River water supply

Reactor building cooling water

Residual heat removal cooling water

Radwaste sumps

Diesel oil

Standby diesel generators

Chilled water-control building

Condensate and demineralized water

Residual heat removal service water

Feedwater

Residual heat removal

Reactor core isolation cooling

Core spray

High-pressure coolant injection

Standby liquid control

Emergency service water

Control rod drive hydraulic

Primary containment

System

Heating and ventilation primary containment

Reactor water cleanup

Nuclear boiler

Reactor vessel recirculation

Standby gas treatment

Containment atmosphere control

ATTACHMENT 2

BULLETIN 79-02 SMALL BORE HANGER PROOF LOAD TEST PROGRAM
BREAKDOWN OF SAMPLE BY SYSTEM AND AREA

System	P&IDs	Torus Room	HPCI Room	RCIC Room	NW Corner Room	SE Corner Room	RHR Valve Room	RB El 757'-6"	RB El 786'-0"	RB El 812'-0"	RB El 833'-6"	Control Bldg	DG Rooms (Turbine Bldg)	Pumphouse	Totals
Well water	(1)														
River water supply	M-146													4	4
RB closed cooling water	M-112[2]								2						2
RHR cooling water	M-113, M-146		1			1								6	8
Radwaste sumps	(1)														
Diesel oil	M-132												2		2
Diesel generator	M-132												4		4
Chilled water for control building	M-169									3					3
Condensate and demineralizer water	M-109[2]									8					8
RHR service water	(3)														

Attachment 2 (continued)

System	P&IDs	Torus Room	HPCI Room	RCIC Room	NW Corner Room	SE Corner Room	RHR Valve Room	RB El 757'-6"	RB El 786'-0"	RB El 812'-0"	RB El 833'-6"	Control Bldg	DG Rooms (Turbine Bldg)	Pumphouse	Totals
Feedwater	(1)														
RHR	M-119, M-120				1	3	5								9
RCIC	M-129			3											3
Core spray	M-119, M-121	4			3			3	1						11
HPCI	M-122, M-123		3												3
Standby liquid control	M-126										6				6
Emergency service water	M-113							5							5
CRD	(1)														
Primary containment	M-143	8													8
HVAC in containment	(1)														
RWCU	(1)														
Nuclear boiler	(1)														
Reactor recirculation	(1)														

Attachment 2 (continued)

System	P&IDs	Torus Room	HPCI Room	RCIC Room	NW Corner Room	SE Corner Room	RHR Valve Room	RB El 757'-6"	RB El 786'-0"	RB El 812'-0"	RB El 833'-6"	Control Bldg	DG Rooms (Turbine Bldg)	Pumphouse	Totals
Standby gas treatment	M-173								5						5
Containment atmospheric control	M-119, M-143, M-181	2	1				2	1	2						8
Containment atmospheric monitoring	M-181							7							7
Fire protection	M-113, M-173											4			4
TOTALS		14	5	3	4	4	7	16	10	11	6	4	6	10	100

(1) No seismic, chart-analyzed, bolted hangers in low-radiation areas.
(2) The hangers tested in this system were nonseismic.
(3) RHR service water was combined with RHR cooling water.

TEST DATA SHEET

Part I

Support ID ______________ Support Type ______________

No. Pipes Supported ______________ Vertical or Horizontal ______________

Insulated (yes/No) ______________ Block Wall or Concrete ______________

Direction that load(s) to be applied (sketch):

Released for Testing ______________________ Date ______________
Resident Engineer

Part II

Dynamometer ID No(s) ______________ Calibration Due Dates ______________
(loadcell) ______________ ______________

Test Data:

	1st Direction		2nd Direction
Dynamometer	#1 ________ lbs.	#1	________ lbs.
Dynamometer	#2 ________ lbs.	#2	________ lbs.
Actual Load	(#1 & #2) ________ lbs.	(#1 & #2)	________ lbs.
Angle of Load	________ o		________ o

One Minute Holding Time Verified (Yes/No) ______________

		REMARKS
(1) Signs of Concrete Failure (Yes/No)		
(2) Plate Movement (inches)		
(3) Sign of Support Members Yielding (Yes/No)		
Status per Rejection Criteria of Paragraph 6.0 (A-Accept R-Reject)		

DATA BY (QC) ______________ DATA ACCEPTED BY ______________

DATE ______________ DATE ______________

NOTES:

(1) All measurements read to 1/16".
(2) All supports classified "Reject" (R) to be repaired in accordance with DCR 867.

ATTACHMENT 4

GRAPH OF PERCENT OF SUPPORTS VERSUS MULTIPLE OF DESIGN LOAD FOR A 95% CONFIDENCE LEVEL