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Dalwyn R. Davidson
VICE PRESIDENT
SYSTEM ENGINEERING AND CONSTRUCTION

July 6, 1979

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

Re: Perry Nuclear Power Plant
IE Bulletin Nos. 79-02, 79-02 Rev. 1

Dear Mr. Keppler·

In accordance with your request, the enclosed attachments have been provided in response to IE Bulletins 79-02 and 79-02 Rev. 1.

Attachment 1 was prepared by our Architect/Engineer, Gilbert Associates, Inc., at our request to address the technical items of the Bulletins. Attachment 2 is our response to Item 4 of the Bulletin regarding QC documentation.

If you have any questions regarding our response, please let me know.

Very truly yours,

Dalwyn R. Davidson

Dalwyn R. Davidson
Vice President
System Engineering and Construction

DRD/cmw

Enclosures

cc: Mr. Victor Stello
Office of Inspection and Enforcement
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

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July 2, 1979

ATTACHMENT 1

PERRY NUCLEAR POWER PLANT
UNIT 1 & 2
NRC IE BULLETIN 79-02 (REV. 1)

1.0 INTRODUCTION

A detailed review was performed in response to the United States Nuclear Regulatory Commission (NRC) request, IE Bulletin No. 72-02 (Rev. 1) - "Pipe Support Base Plate Design Using Concrete Expansion Anchor Bolts", dated June 21, 1979 for Perry Nuclear Power Plant Unit 1&2, Docket Nos. 50-440 and 50-441. The review was performed on a representative sample of safety-related supports (Seismic Category I). Possible effects of base plate flexibility on base plate anchors were considered. This report presents the methods and results of the review.

2.0 SUMMARY AND CONCLUSIONS

2.1 Summary of Design Review

1. Most plates were determined to be flexible as defined by the NRC 2:1 ratio criteria. Therefore, plates were reanalyzed using a method in which the effects of plate flexibility, anchor preload and shear-tension interaction were considered. The results of the reanalysis generally confirmed the adequacy of the original design.
2. A representative sample consisting of 10 Perry designs and 96 similar designs were investigated. These Perry specific and similar designs are anchored with Hilti "Kwik-Bolts". The

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analytical investigations indicate that approximately 5% of the Perry designs may have a factor of safety less than 4.0 if plate flexibility is considered. These kinds of situations will be resolved as described in Section 3.6.

3. All Seismic Category I supports are potentially subject to a relatively low number of seismic loading cycles which can be accommodated by the design. Operational loads which could, during the lifetime of the plant, undergo a large number of load cycles are identified during startup testing, and modifications to the pipe sup, rt system are made as required to assure that such loads are eliminated.

2.2 Summary of QC Documentation OR of In-Place Inspection

Content to be provided by CEI.

2.3 Conclusion

The results of the investigation for the effects of plate flexibility on pipe support base plate anchors indicate that, for most plates anchored to concrete surfaces with Hilti "Kwik Bolts", prying forces did not exist. Prying forces were found to be present in approximately 5% of the cases. In those cases the prying was responsible for an average increase in the bolt tension of less than 30%.

3.0 Review Results

In consideration of the requested action, all base plates for large bore (2½" and larger) Safety Category I pipes are being reanalyzed. There are approximately 500 base plates in the two units which fit this category.

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Small bore (2" and smaller diameter) pipe was designed using a seismic support spacing criteria. The criteria was developed based on a conservative pipe stress and a multi-span model for each pipe size and schedule. The model analysis provides pipe spans and support loads. This approach has been verified by sample computer analyses to be conservative relative to applicable code requirements.

A series of typical support designs were generated and load rated by analytical techniques. The supports were analyzed for structural adequacy for all members, welds and the expansion anchor bolts. In generating the load rating, the most conservative geometry combination of the maximum distance from the pipe to the structure was used in conjunction with the smallest allowed spacing between expansion anchor bolts. This resulted in the worst load case.

The results of this conservative approach indicate that about 15% of the supports on any of the small bore piping runs could fail and the piping stresses would remain within code allowables. Therefore, detailed analyses and inspection of these expansion anchor bolts is considered unnecessary.

3.1 NRC Item 1 - Question

Verify that pipe support base plate flexibility was accounted for in the calculation of anchor bolt loads. In lieu of supporting analysis justifying the assumption of rigidity, the base plates should be considered flexible if the unstiffened distance between the member welded to the plate and the edge of the base plate is greater than twice the thickness of the plate. It is recognized that this criterion is conservative. Less conservative acceptance criteria must

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be justified and the justification submitted as part of the response to the Bulletin. If the base plate is determined to be flexible, then recalculate the bolt loads using an appropriate analysis. If possible, this is to be done prior to seating 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 base plate flexibility is accounted for in the calculation of anchor bolt loads is to be submitted with your response to the Bulletin.

It has been noted that the schedule for analytical work on base plate flexibility for some facilities extends beyond the Bulletin reporting time frame of July 6, 1979. For those facilities for which an anchor bolt testing program is required (i.e., sufficient QC documentation does not exist), the anchor bolt testing program should not be delayed.

Response

Base plates were considered rigid in the original design. For reexamination of the base plates considering plate flexibility, procedures were developed for the analysis of the plates and anchorages for moment and axial load applied to the plate surfaces. (Figures 1, 2, 3, and 4)

Wedge anchors were installed in accordance with manufacturer's recommendations. Bolts were torqued to the degree necessary to ensure a preload equal to or greater than the allowable working load on the bolt. A field test program was conducted to establish for each bolt size the torque value required to ensure the required level of bolt tension.

The magnitude of the residual preload directly influences the plate rotation at the anchor, and full fixity against anchor rotation is obtained when:

$$(T_i - V) \quad (L) = V \frac{e}{2}$$

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Where T_i = Anchor residual preload

V = Plate shear

L = Effective edge distance of the plate from the tensile anchors

e = Distance from the edge of the attachment to the tensile anchors

With full fixity against anchor rotation, the plate deflection transverse to the surface of the plate at the face of the attachment is the same as support settlement of a member fixed at both ends.

As long as preload exceeds plate shear, some resistance to anchor rotation exists. When $T_i < V$, there is free rotation of the plate at the anchor, and the plate deflects as a cantilever.

Preloaded wedge anchors have a memory of their maximum load and will not experience inelastic displacements until a load larger than the installation preload occurs. At loadings less than the installation preload, the anchors will function essentially elastically even though the actual loading exceeds the residual preload on the anchor. If the actual load is less than the residual preload, the bolt is essentially prestressed, and the stress remains approximately constant under this load. The performance of a preloaded wedge anchor is the same under dynamic as under static loadings; that is, the anchor will not experience inelastic displacements (in addition to that which occurs during installation) until the anchor is subjected to a load greater than the installation preload.

Based on the plate and anchor response as described above, procedures were developed to determine tensile forces in the anchors, as shown in Figures 1, 2, 3 and 4. Shear and tension effects were combined

directly to evaluate the factor of safety of the anchors, with the shear force ing distributed equally to all anchors in the connection. The method of combining these effects is described in Section 3.2.

3.2 NRC Item 2 - Question

"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 manufacturer's) which 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."

Response

The concrete expansion anchor bolts used at Perry are the "Kwik Bolts" as manufactured by Hilti, Inc. This is a wedge type anchor required to have a minimum factor of safety of four (4) in accordance with aforementioned NRC Item 2a. The results of the reanalysis are summarized in attached Table 1.

The factor of safety against failure (F.S.) is conservatively determined using the following shear-tension interaction equation:

$$\frac{(F.S.)\ (T_o)}{(T_a)} + \frac{(F.S.)\ (S_o)}{(S_a)} = 1$$

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Where: F.S. = factor of safety against failure

T_o = Tension force induced into an anchor (considering plate flexibility)

T_a = ultimate tension capacity of an anchor*

S_o = Shear force induced into an anchor

S_a = ultimate shear capacity of an anchor*

*From manufacturer's static load tests

Expansion bolt placement in the structure is governed by the following criteria:

a. A minimum spacing between adjacent bolts of 10d, where d is the diameter of the bolt hole.

b. A nominal edge distance of 3 inches (±2 inches) between the bolt centerline and the edge of the base plate.

c. A minimum edge distance between the bolt centerline and the edge of a concrete member equal to 17 1/2d.

3.3 NRC Item 3 - Question

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

Response

Pipe support reactions are generated as an output of a dynamic analysis and are utilized for the design of the individual pipe supports. Therefore, a dynamic amplification factor was not theoretically required. However, to provide for the effects of hardware and erection tolerances, the OBE seismic part of the reaction is multiplied by a factor of 2 to produce a design load. This factor provides additional design margin on the dynamic part of the loads.

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The governing load combination including the 2.0 factor is:

Deadweight +	Thermal +	(2.0) OBE +	Occasional	$\leq$	Allowable
		Seismic	Mechanical		Anchor
			Loads		Bolt Load

In order to ensure cyclic load carrying capability, wedge type anchors are installed by applying a torque of sufficient magnitude to set the wedges at a bolt preload equal to or greater than the maximum allowable working load.

3.4 NRC Item 4 - Question

"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, assure 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 assure that minimum design requirements have been met with respect to subitems (a) and (b) above. A sampling technique is acceptable. One acceptable technique is to randomly select and test one anchor bolt in each base plate (i.e. some supports may have more than one base plate). The test should provide verification of subitems (a) and (b) above. If the test fails, all other bolts on that base plate should be similarly tested. In any event, the test program should assure that each Seismic Category I system will perform its intended function."

The preferred test method to demonstrate that bolt preload has been accomplished is using a direct pull (tensile test) equal to or greater than design load. Recognizing this method may be difficult due to accessibility in some areas an alternative test method such as torque testing may be used. If torque testing is used it must be shown and substantiated that a correlation between torque and tension exists. If manufacturer's data for the specific bolt used is not available, or is not used, then site specific data must be developed by qualification tests.

Bolt test values of one-fourth (wedge type) or one-fifth (shell type) of bolt ultimate capacity may be used in lieu of individually calculated bolt design loads where the test value can be shown to be conservative.

The purpose of Bulletin 79-02 and this revision is to assure the operability of each seismic Category I piping system. In all cases an evaluation to confirm system operability must be performed. If a base plate or anchor bolt failure rate is identified at one unit of a multi-unit site which threatens operability of safety related piping systems of that unit, continued operation of the remaining units at that site must be immediately evaluated and reported to the NRC. The evaluation must consider the generic applicability of the identified failures.

Appendix A describes two sampling methods for testing that can be used. Other sampling methods may be used but must be justified. Those options may be selected on a system-by-system basis.

Justification for omitting certain bolts from sample testing which are in high radiation areas during an outage must be based on other testing or analysis which substantiates operability of the affected system.

Bolts which are found during the testing program not to be preloaded to a load equal to or greater than bolt design load must be properly preloaded or it must be shown that the lack of preloading is not detrimental to cyclic loading capability. If it can be established that a tension load on any of the bolts does not exist for all loading cases then no preload or testing of the bolts is required.

If anchor bolt testing is done prior to completion of the analytical work on base plate flexibility, the bolt testing must be performed to at least the original calculated bolt load. For testing purposes, factors may be used to conservatively estimate the potential increase in the calculated bolt load due to base plate flexibility. After completion of the analytical work on the base plates, the conservatism of these factors must be verified.

For base plate supports using expansion anchors, but raised from the supporting surface with grout placed under the base plate, for testing purposes it must be verified that leveling nuts were not used. If leveling nuts were used, then they must be backed off such that they are not in contact with the base plate before applying tension or torque testing.

Bulletin No. 79-02 requires verification by inspection that bolts are properly installed and are of the specified size and type. Parameters which should be included are embedment depth, thread engagement, plate bolt hole size, bolt spacing, edge distance to the side of a concrete member and full expansion of the shell for shell type anchor bolts.

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If piping systems 2 1/2-inch in diameter or less were computer analyzed then they must be treated the same as the larger piping. If a chart analysis method was used and this method can be shown to be highly conservative, then the proper installation of the base plate and anchor bolts should be verified by a sampling inspection. The parameters inspected should include those described in the preceding paragraph. If small diameter piping is not inspected, then justification of system operability must be provided.

Response

Content to be provided by CEI.

3.5 NRC Item 5 - Question

This question does not apply to the Perry Project.

3.6 NRC Item 6 - Question

All holders of construction permits for power reactor facilities are requested to complete items 1 through 4 for installed pipe support base plates with concrete anchor bolts within 120 days of date of issuance of the Bulletin. No extension of time to complete notion requested in Bulletin 79-02 is granted by issuance of this revision of the Bulletin. For pipe support base plates which have not yet been installed, document your actions to assure that items 1 through 4 will be satisfied. Maintain documentation of these actions on site and available for NRC inspection. Report in writing within 120 days of date of Bulletin issuance, to the Director of the appropriate NRC Regional Office, completion of your review and describe any discrepancies in meeting items 1 through 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

Analytical work and appropriate redesign to ensure that all pipe support base plates conform to the requirements of IE Bulletin 79-02 and the ASME Boiler and Pressure Vessel Code, Section III, will be included in the design verification efforts for Seismic Category I supports. Such efforts will be completed prior to placing plant systems into operation.

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TABLE 1
RESULTS OF BASE PLATE ANCHOR REANALYSIS

MARK NO.	ANCHOR SIZE Ø	FACTOR OF SAFETY
1E12-H356	3/4" Ø	5.82
1E12-H382	3/4" Ø	10.4
1E12-H561	3/4" Ø	11.00
1E12-H568	3/4" Ø	7.9
1E51-H048	3/4" Ø	8.6
1G41-H251	3/4" Ø	23.0
1P45-H358	1/2" Ø	3.5*
1P45-H589	3/4" Ø	20.0
1P47-H131	1/2" Ø	106.0
1P47-H141	1/2" Ø	17.7

* To be reanalyzed and/or redesigned to increase factor of safety to 4.0.

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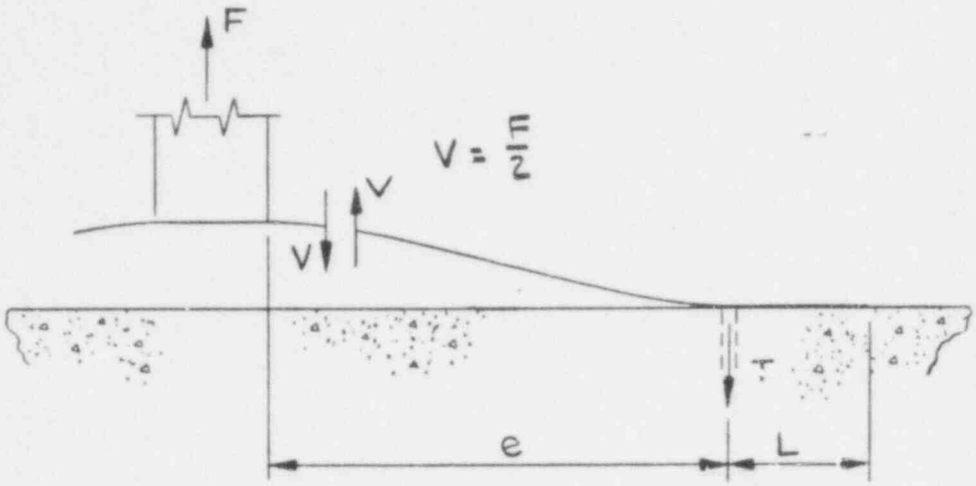
CONDITION 1



WHEN $(T_i - V)L = V\frac{e}{2}$, ANCHOR LOAD $T = T_i$ = PRELOAD IN THE ANCHOR

T = TOTAL LOAD IN ANCHOR

T_i = PRELOAD IN ANCHOR

FIGURE 1

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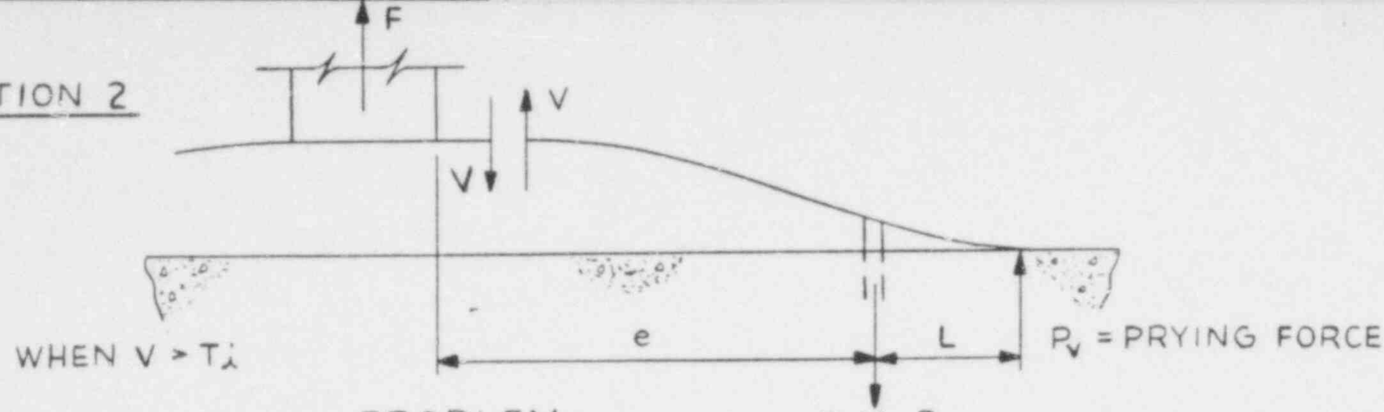
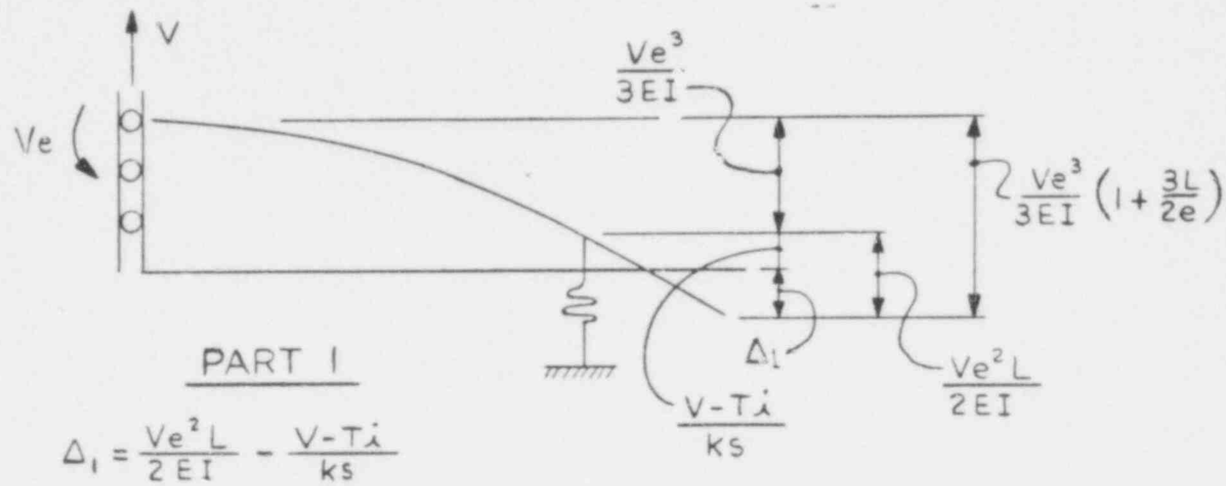
CONDITION 2



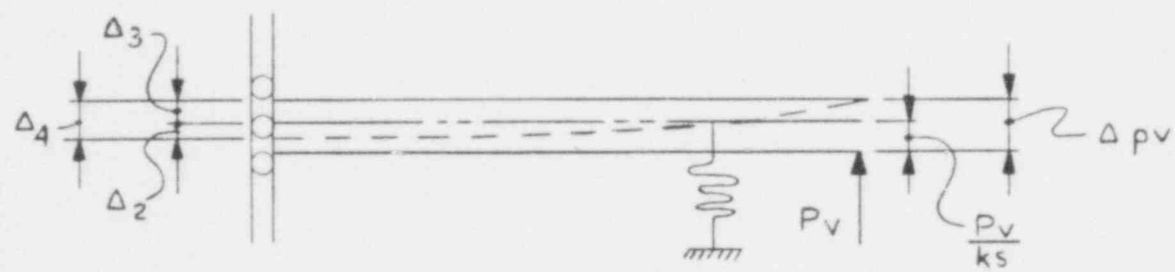
PROBLEM

THE PROBLEM IS SOLVED BY SUPERPOSITION, USING PARTS 1 AND 2 BELOW



PART 1

$$\Delta_1 = \frac{Ve^2L}{2EI} - \frac{V-T_i}{ks}$$



PART 2

$$\Delta_3 = \Delta_4 - \Delta_2 = \frac{P_v L^2 e}{EI} + \frac{P_v L^3}{3EI} + \frac{6}{5}\,\frac{P_v L}{AG}$$

$$\Delta pv = \Delta_3 + \frac{P_v}{ks} = \frac{P_v L^2 e}{EI} + \frac{P_v L^3}{3EI} + \frac{6}{5}\,\frac{P_v L}{AG} + \frac{P_v}{ks}$$

(EQ. 1) EQUATING $\Delta_1 = \Delta pv$; $P_v = \left[\frac{Ve^2L}{2EI} - (V-T_i)\frac{1}{ks}\right] \div \left[\frac{1}{ks} + \frac{L^2e}{EI} + \frac{L^3}{3EI} + \frac{6}{5}\frac{L}{AG}\right]$

IF $\frac{Ve^2L}{2EI} < \frac{V-T_i}{ks}$ NO PRYING EXISTS AND $T = V$

IF $\frac{Ve^2L}{2EI} > \frac{V-T_i}{ks}$ SOLUTION OF EQ-1 YEILDS THE PRYING FORCE P_v

TOTAL BOLT FORCE IS $V + P_v$

FIGURE 2

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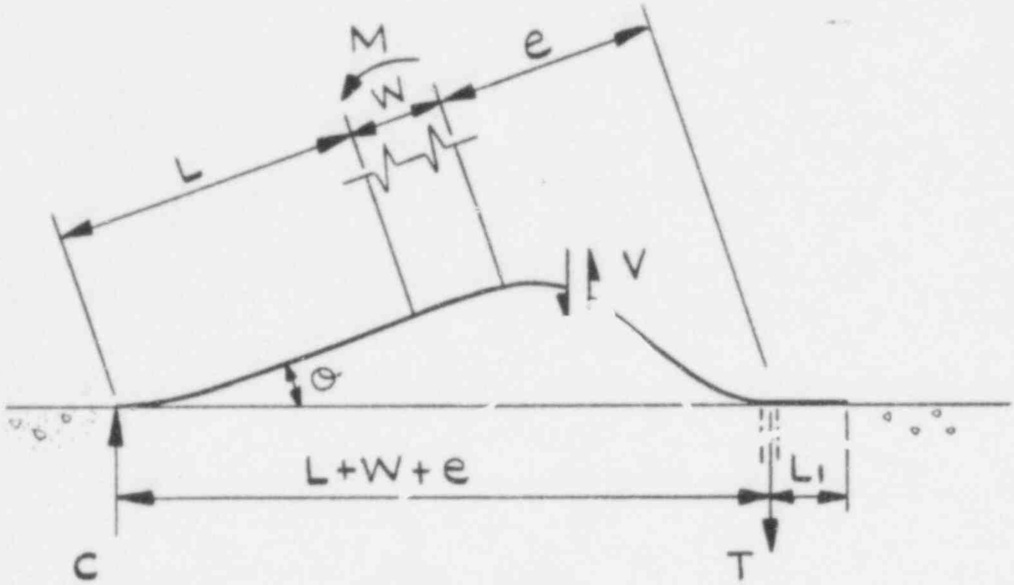
CONDITION I: NO TENSION ANCHOR ROTATION OR DISPLACEMENT



T = TOTAL LOAD IN ANCHOR

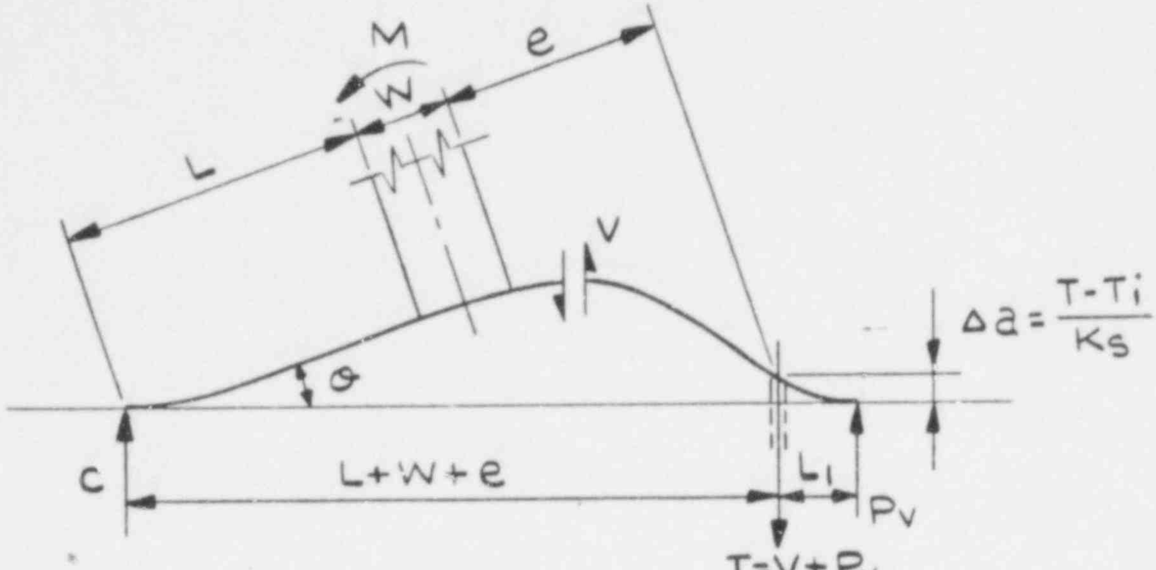
T_i = PRELOAD IN ANCHOR

$$\text{FOR } M \leq \left(\frac{T_i L_1}{e/2 + L_1}\right)(L+W+e), \quad T = T_i$$

PRYING FORCE = 0

FIGURE 3

CONDITION 2: TENSION ANCHOR ROTATION AND DISPLACEMENT



T = TOTAL LOAD IN ANCHOR

T_i = PRELOAD IN ANCHOR

$$T = V + P_v$$

$$\Delta a = \frac{T-T_i}{K_s}$$

$$\theta = \frac{VL^2}{2EI_p}$$

$$L = \frac{3}{\theta}\left\{\left[\Delta a - \frac{P_v L_1 e^2}{2EI} + \frac{Ve^3}{3EI}\right] - \theta W - \theta e\right\}$$

$$V = \frac{M + P_v L_1}{e + W + L}$$

$$P_v = \frac{\frac{Ve^2 L_1}{2EI} - \frac{V-T_i}{K_s} - \theta L_1}{\frac{1}{K_s} + \frac{L_1^2 e}{EI} + \frac{L_1^3}{3EI} + \frac{6}{5}\frac{L_1}{AG}}$$

IF $\frac{V-T_i}{K_s} \geq \frac{Ve^2 L_1}{2EI} - \theta L_1$, NO PRYING EXISTS AND $T = V = C$

IF $\frac{V-T_i}{K_s} < \frac{Ve^2 L_1}{2EI} - \theta L_1$, SIMULTANEOUS SOLUTION OF THE SIX EQUATIONS GIVEN ABOVE WILL YIELD THE LOCATION OF THE COMPRESSIVE FORCE C AND THE MAGNITUDE OF THE PRYING FORCE P_v

FIGURE 4.

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4. The current status of the installation of safety-related pipe support base plate anchor bolts is that only twelve have been installed and none have received final torque. The twelve installed bolts have been visually inspected to verify that they have been correctly installed and are the specified design size and type.

   The Perry Nuclear Power Plant QC program requires 100% first line inspection of all safety-related pipe support base plate anchor bolts. This program will verify that:

   a. The bolt preload is equal to or greater than the bolt design load (note: shell type bolts are not used).

   b. The bolts have been installed correctly and are of the specified design size and type.

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