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VICE-PRESIDENT AND GROUP EXECUTIVE
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July 5, 1979

Mr. James P. O'Reilly, Director
United States Nuclear Regulatory Commission
Region II
101 Marietta Street, N. W.
Atlanta, Georgia 30303

Subject: Virgil C. Summer Nuclear Station
Inspection & Enforcement Bulletin
79-02/79-02 Rev. 1
Docket No. 50-395
Nuclear Engineering File 2.8950

Dear Mr. O'Reilly:

South Carolina Electric & Gas Company has reviewed IE Bulletin 79-02 dated March 8, 1979, and IE Bulletin 79-02 Revision 1 dated June 21, 1979, and submits the attached written response as required.

Should you have further questions concerning this matter, please contact us.

Very truly yours,

E. H. Crews, Jr.

RW:EHC:md

CC: Office of Inspection & Enforcement
Washington, D. C.

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V. C. SUMMER NUCLEAR STATION
UNIT 1
NRC IE BULLETIN 79-02 REVISION 1

1.0 INTRODUCTION

A design review was performed in response to the United States Nuclear Regulatory Commission (NRC) request, IE Bulletin No. 79-02, "Pipe Support Base Plate Design Using Concrete Expansion Anchor Bolts," dated March 8, 1979, and Revision 1, dated June 21, 1979, for Virgil C. Summer Nuclear Station, Unit 1, Docket No. 50-395. 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 CONCLUSION

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.
2. A representative sample totaling ninety-six (96) pipe support base plates for pipe of a diameter 2 1/2" and larger, all anchored with Hilti "Kwik Bolts", was reanalyzed. Of the ninety-six (96) supports studied, one (1) had a factor of safety less than 3.0 (actual value = 2.98), three (3) had a factor of safety between 3.0 and 3.5, and six (6) exhibited a factor of safety between 3.5 and 4.0. The factors of safety less than 4.0 were determined to exist only for the faulted and upset load combinations.
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 will be identified during

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startup testing, and modifications to the pipe support system will be made as required to assure that such loads are eliminated.

2.2 Summary of QC Documentation OR of In-Place Inspection

QC procedures provide for inspection requirements as discussed in Section 3.4. At the Virgil C. Summer Nuclear Station, QC documentation that design requirements have been met exists for 100% of the expansion bolts.

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 on four (4) of the ninety six (96) plates considered and in those cases the prying was responsible for an average increase in the bolt tension of less than 30%. It is also seen that the factors of safety of the supports reanalyzed meet the minimum established by IE Bulletin 79-02 in most cases, with the only exceptions existing for the faulted and upset load combinations. Under these conditions, the factors of safety are conservative. Since QC inspection is made on 100% of all expansion bolts, the results of this reanalysis confirm the adequacy of the original design.

3.0 REVIEW RESULTS

In consideration of the requested action, a representative sampling of base plates for large bore (2 1/2" and larger) Seismic Category I pipes was reanalyzed. There are approximately seven hundred (700) base plates in the plant which fit this category, and ninety-six (96) have been investigated. Small bore (2" and smaller diameter) pipe was originally designed using a seismic support spacing criteria. The criteria were 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 was 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 combination of the maximum distance from the pipe to the structure and the smallest allowed spacing between expansion anchor bolts was used.

As a result of this conservative approach, if 15% or more of the supports on any of the small bore piping runs would fail, the piping stresses would still remain within Code allowables. Therefore, detailed analyses and inspection of these expansion anchor bolts is considered unnecessary.

3.1 Response to NRC Item 1

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:

$$(T_1-V)\ (L) = V\ \frac{e}{2}$$

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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 being distributed equally to all anchors in the connection. The method of combining these effects is described in Section 3.2.

3.2 Response to NRC Item 2

The concrete expansion anchor bolts used at V. C. Summer, Unit 1, are the "Kwik Bolts" as manufactured by Hilti, Inc. This is a wedge type anchor for which NRC Item 2(a) specifies a minimum factor of safety of four (4). The results of the reanalysis are summarized in attached Tables 1 & 2.

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

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

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 edge distance between the bolt centerline and the edge of a concrete member equal to 5d or 4 inches, whichever is greater.

b. A minimum spacing between adjacent bolts on each base plate of 10d, where d is the diameter of the bolt, unless otherwise approved by the Engineer. Also, due to various field installation problems with locations of adjacent base plates, there is a small percentage (estimated at less than 3% of all attachments) of occurrences where the minimum spacing of 10d has not been maintained between anchor bolts of adjacent plates. This situation is presently being investigated and such occurrences will be evaluated on a case by case basis for design adequacy.

3.3 Response to NRC Item 3

Pipe support reactions are generated as an output of a dynamic analysis and are utilized for the design of the individual pipe supports. Therefore, theoretically, a dynamic amplification factor was not 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 1.5 to produce a design load. This factor provides additional design margin on the dynamic part of the loads.

The governing load combination including the 1.5 factor is:

Deadweight + Thermal +	(1.5) OBE +	Occasional ≤	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 Response to NRC Item 4

(a) As described in Section 3.3, 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. Also, a field test program was conducted which established for each bolt size the torque value required to ensure the required level of bolt tension. The QC inspection requirements are described in sub-item (b) below where it is stated that documentation exists for 100% of the expansion bolts on the torque value applied in the field. This level of inspection verifies that the design requirements have been met for each anchor bolt.

It is also noted that there are no shell type anchor bolts being used at the Virgil C. Summer Nuclear Station.

(b) The design specification and associated QC procedures require inspection of expansion bolts relative to the installation criteria. In addition, all bolts in one out of every ten connections, but not less than 10% of the connections made by each crew, shall be inspected for compliance with skewness. Connections shall also be inspected for bolt tightness with a calibrated manual torque wrench in not less than 10% of the connections made by each crew.

The above are the minimum inspection requirements; however, for the Virgil C. Summer Nuclear Station, QC documentation that design requirements have been met exists for 100% of the expansion bolts as follows: bolt hole location, cleanliness of hole, depth of hole, bolt size and length, depth of grout, bolt torque and skewness.

Based upon the requirements of IE Bulletin 79-02, for all subsequent expansion bolt installations the QC inspection checklist will include bolt spacing within the plate and to adjacent holes, minimum embedment depth and thread engagement. We do not feel that it is necessary to verify the embedment depth and thread engagement for existing installations due to the 100% inspection program already in effect.

At the Virgil C. Summer Nuclear Station, base plates which have been grouted were raised from the supporting surface by shims and washers. Leveling nuts were not used.

TABLE 1
RESULTS OF BASE PLATE ANCHOR REANALYSIS

UPSET LOAD COMBINATION

Mark	Anchor Size Ø	Factor of Safety
SWH-220	5/8	19.3
CCH-474 Vert. Leg	5/8	10.7
CCH-474 Dia. Leg	5/8	7.7
CSH-185	5/8	10.2
SPH-291	5/8	8.0
CCH-475	5/8	10.1
SWH-203	5/8	11.9
FWH-225	5/8	11.2
CCH-773	3/4	6.2
CSH-196	3/4	14.3
SWH-204	3/4	3.28*
CCH-297	3/4	22.4
SWH-207	3/4	5.67
CCH-473	3/4	12.3
SWH-114 Vert. Leg	3/4	5.7
SWH-114 Dia. Leg	3/4	6.5
FWH-253	1	13.4
FWH-218	1	9.0
SWH-218	1	3.52*
FWH-262	1	3.57*
FWH-255	1	5.10
SWH-138 Vert. Leg	1	5.20
SWH-138 Dia. Leg	1	6.00
RHH-263 Vert. Leg	1-1/4	12.5
RHH-263 Dia. Leg	1-1/4	9.2
MSH-226	5/8	23.92
MSH-244	5/8	38.27
MSH-207	5/8	21.99
MSH-216	5/8	27.17
MSH-167	5/8	15.53
MSH-272	5/8	5.89
MSH-218	3/4	27.25
MSH-057	3/4	5.82
MSH-062	3/4	2.98*
MSH-246 Vert. Leg	1	70.42
MSH-246 Dia. Leg	1	39.5
MSH-158 Vert. Leg	1	47.15
MSH-158 Dia. Leg	1	26.53
MSH-250 Vert. Leg	1	7.75
MSH-250 Dia. Leg	1	6.53
MSH-183 Vert. Leg	1	6.17
MSH-183 Dia. Leg	1	4.58
RHH-102 Vert. Leg	5/8	53.6
RHH-102 Dia. Leg	5/8	39.5
RHH-269	5/8	11.0
RHH-173 Vert. Leg	3/4	13.8
RHH-215 Vert. Leg	3/4	7.78
RHH-215 Dia. Leg	3/4	4.25
RHH-233	3/4	10.28
RHH-125	3/4	35.9
SWH-116 Vert. Leg	3/4	15.84
SWH-116 Dia. Leg	3/4	9.00
SWH-139	3/4	10.9
SWH-078	3/4	24.43
SWH-067	3/4	5.7
SWH-065	3/4	11.13
RHH-281	3/4	7.6
RHH-105	3/4	12.2
RHH-108 Vert. Leg	1	9.14
RHH-108 Dia. Leg	1	4.96
RHH-216 Vert. Leg	1	7.47
RHH-216 Dia. Leg	1	4.39
RHH-267	1	21.6
RHH-280	1	33.6
SWH-138 Vert. Leg	1	4.05
SWH-138 Dia. Leg	1	4.19
SWH-124	1	6.5
RHH-283 Vert. Leg	1	35.11
RHH-283 Dia. Leg	1	52.66
RHH-185 Vert. Leg	1	7.12
RHH-185 Dia. Leg	1	3.79*
RHH-268	1	9.56
RHH-263 Vert. Leg	1-1/4	11.97
RHH-263 Dia. Leg	1-1/4	9.18
RHH-204 Vert. Leg	1-1/4	9.1
RHH-204 Dia. Leg	1-1/4	4.95
RHH-173	1-1/4	5.07

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*Factor of Safety less than 4.0 as noted in IE Bulletin 79-02

TABLE 2
RESULTS OF BASE PLATE ANCHOR REANALYSIS

FAULTED LOAD COMBINATION

Mark	Anchor Size Ø	Factor of Safety
RHH-263 Vert. Leg	1-1/4	4.00
RHH-263 Dia. Leg	1-1/4	3.7 *
MSH-246 Vert. Leg	1	6.04
MSH-246 Dia. Leg	1	3.39*
MSH-158 Vert. Leg	1	6.04
MSH-158 Dia. Leg	1	3.39*
RHH-269	5/8	6.99
RHH-173 Vert. Leg	3/4	9.9
RHH-281	3/4	5.54
RHH-267	1	5.6
RHH-280	1	17.6
RHH-283 Vert. Leg	1	28.43
RHH-283 Dia. Leg	1	42.66
RHH-185 Vert. Leg	1	7.73
RHH-185 Dia. Leg	1	4.11
RHH-268	1	4.1
RHH-263 Vert. Leg	1-1/4	4.01
RHH-263 Dia. Leg	1-1/4	3.7 *
RHH-173 Dia. Leg	1-1/4	3.64*

*Factor of Safety less than 4.0 as noted in IE Bulletin 79-02

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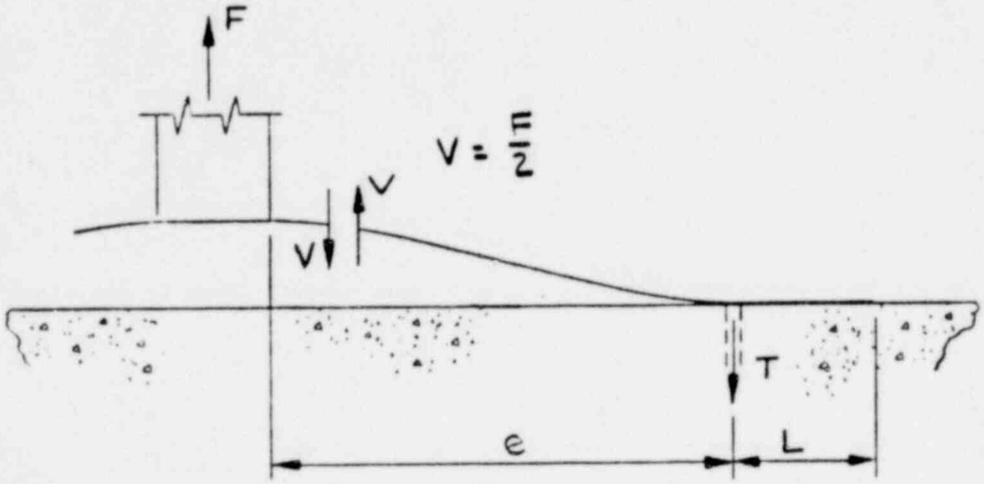
CONDITION 1



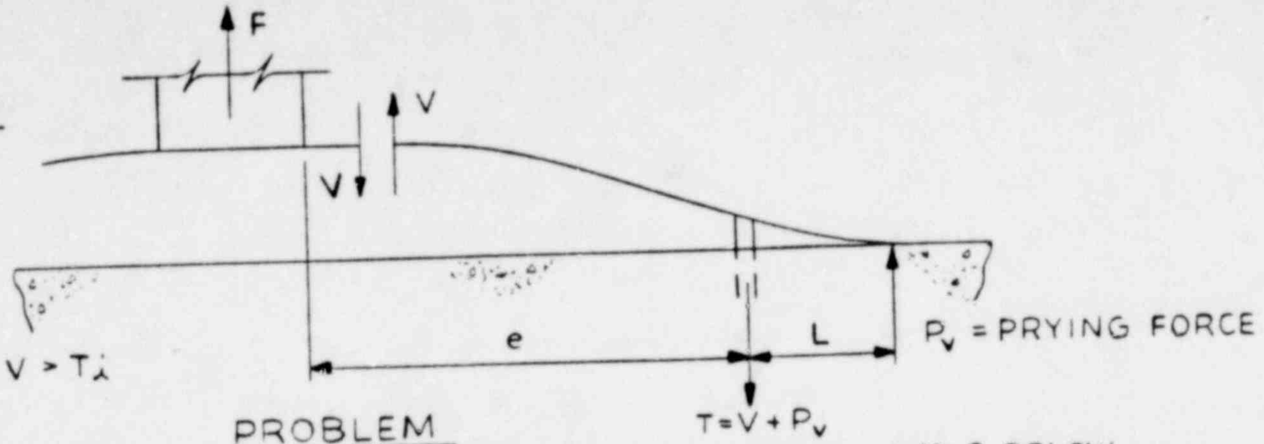
WHEN $(T_i - V)L = V\frac{e}{2}$, ANCHOR LOAD $T = T_i$ = PRELOAD IN THE ANCHOR.

T = TOTAL LOAD IN ANCHOR

T_i = PRELOAD IN ANCHOR

FIGURE 1

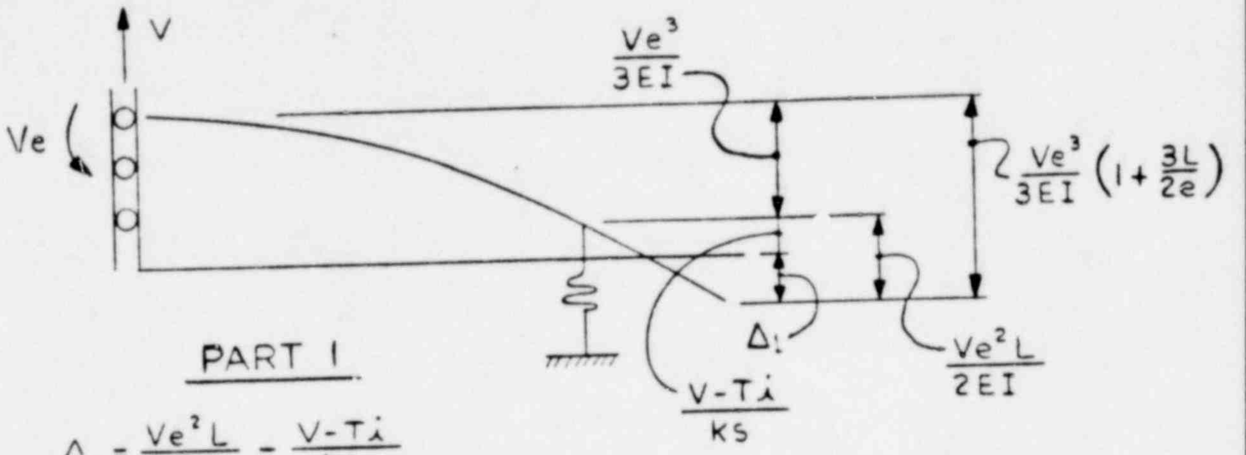
CONDITION 2



WHEN $V > T_i$

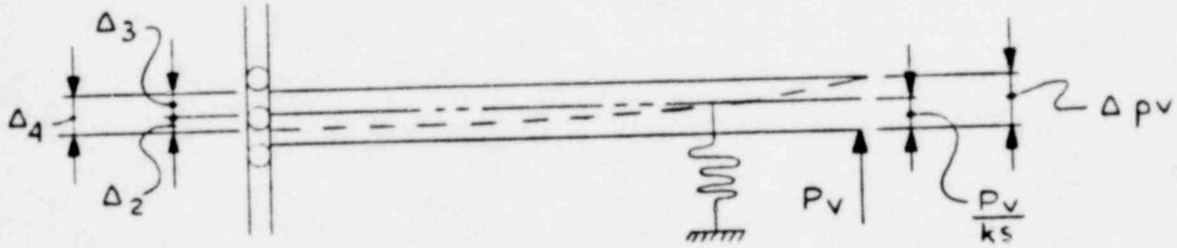
PROBLEM

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

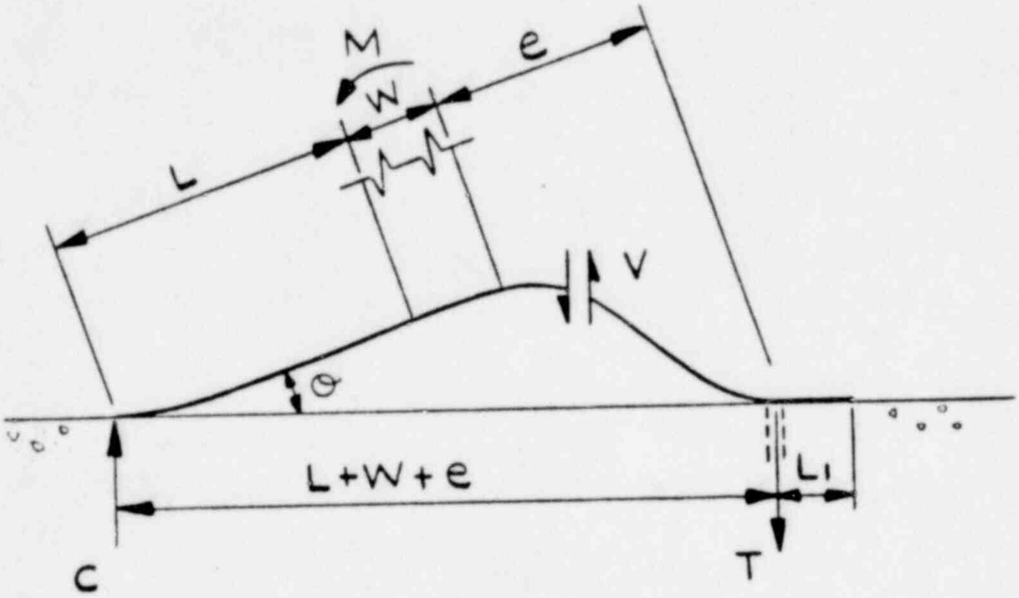
IF $\frac{Ve^2L}{2EI} < \frac{V-T_i}{ks}$ NO PRYING EXISTS AND $T = V$

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

TOTAL BOLT FORCE IS $V + P_v$

FIGURE 2

CONDITION I: NO TENSION ANCHOR ROTATION OR DISPLACEMENT



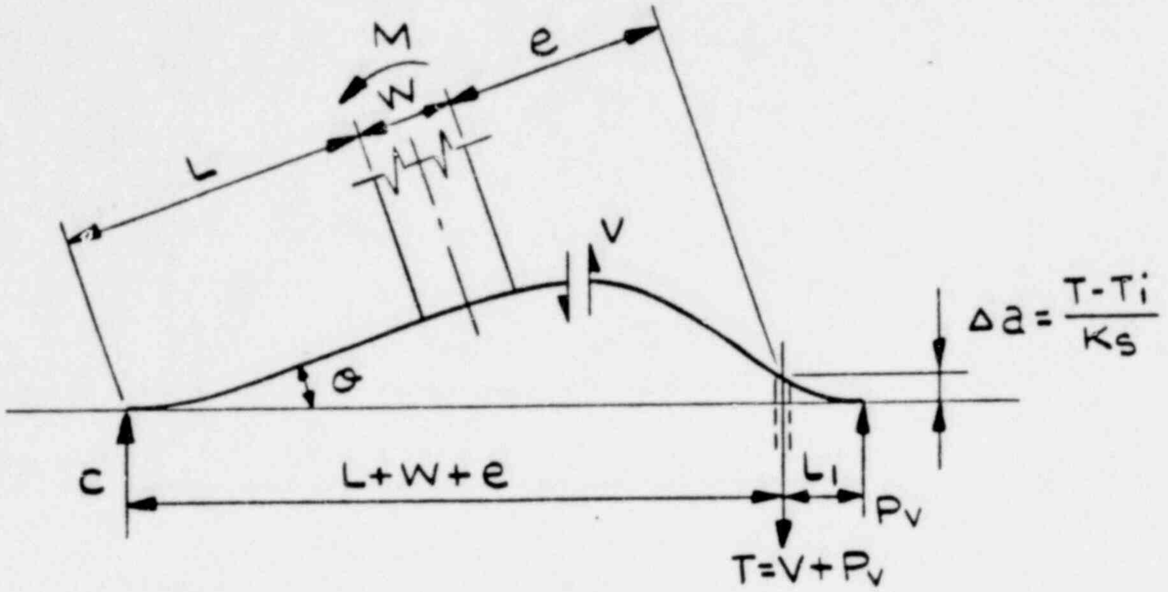
T = TOTAL LOAD IN ANCHOR
T_i = PRELOAD IN ANCHOR

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

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