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VICE PRESIDENT
NUCLEAR OPERATIONS

July 2, 1982 '82 JUL 8 A8:29

Mr. James P. O'Reilly, Director
U. S. Nuclear Regulatory Commission
Region II, Suite 3100
101 Marietta Street, N.W.
Atlanta, GA 30303

Subject: Virgil C. Summer Nuclear Station
Docket No. 50/395
IEB 79-02

Dear Mr. O'Reilly:

As indicated in our response to IEB 79-02, Revision 3, dated February, 1982, base plate analyses for the Virgil C. Summer Nuclear Station have been performed by two separate contractors, Teledyne Engineering Services and Gilbert Associates, Inc. By our letter of June 22, 1982, South Carolina Electric and Gas Company (SCE&G) submitted responses (for Teledyne & Gilbert) to several questions concerning base plate analyses and noted that an additional question remained to be answered for Gilbert. SCE&G hereby submits the additional response for Gilbert.

If you have additional questions, please let us know.

Very truly yours,

O. W. Dixon, Jr.

NEC:OWD,jr:lkb
Attachment

cc: V. C. Summer	(w/o attach.)	C. L. Ligon (NSRC)
G. H. Fischer	(w/o attach.)	G. J. Braddick
T. C. Nichols, Jr.	(w/o attach.)	J. L. Skolds
O. W. Dixon, Jr.	(w/o attach.)	J. B. Knotts, Jr.
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IE11

Question: Item 3

The short direction prying factor shown in the submittal of January 7, 1980 does not include the effect of flexibility of the angle. Show by analysis and by a numerical example that this effect is indeed negligible, or conversely, show how it is taken into account in the design of these angles.

Response

The short direction prying factor for a single angle attached to concrete with expansion bolts as given in the January 7, 1980 submittal equation is based on satisfying vertical and moment equilibrium on the cross section model of the angle and bolt. Inherent in this derivation is the need to assume a location of the concrete compressive reaction on the angle. This concrete compressive reaction produces a moment about the bolt line to resist the applied moment. Considering this moment loading to be similar to a working stress analysis of a singly reinforced concrete beam where the bolt represents the rebar, the resultant of the compressive force was assumed to be located at a distance from the bolt equal to 7/8 of the distance between the bolt and the edge of the angle. It can possibly be argued that the thickness (i.e. stiffness) of the angle leg in contact with the concrete could influence the location of this compressive force. However, once this location is established, the stiffness of the angle leg or bolt has no influence on the outcome of the structural analysis for the bolt force because the model is statically determinate. Hence, using the two-step approach of defining the location of the concrete force and then solving for all forces, the prying factor as calculated by the formula will account for the effects of component stiffnesses.

To address the issue of whether the resultant compressive concrete force is at a distance of 7/8 ℓ , where ℓ is the distance from the bolt to the edge of the angle, a planar finite element model was made of the angle cross section and concrete interface. This model is shown in Figure 16 and is for a 4" x 4" x 3/8" angle with a 5/8" Ø x 6" long Hilti bolt. The horizontal and vertical legs of the angle

are modeled by beam elements with many more elements being used in the horizontal leg which is the area of prime interest. The expansion bolt nut is modeled by five beam elements which can transmit only axial forces from the angle to the top of the bolt. The 5/8" Ø x 6" long Hilti bolt is modeled by one beam element which has a hinge support at the bottom to simulate the transfer of the expansion bolt force to the concrete. The concrete surface is modeled by gap-spring elements which can resist a compressive force but which possess no stiffness in tension. The length of angle in the third dimension used to calculate the beam element stiffness properties for the angle is taken to be a distance equal to the horizontal leg dimension. This is used because in the submittal of January 7, 1980, in Figure 17, it was observed that a longitudinal distance of approximately the horizontal leg dimension is effective in resisting the applied load even when the angle applied load is far from the embedded bolt. The model described herein was executed using the ANSYS finite element program by applying increments of load to the outstanding leg of the angle.

Cases of a 4 x 4 angle with three different leg thicknesses were run for the case of no bolt preload. Varying loads (P) in five load steps from 0.0 to 1.0 kips were applied to the centerline of the outstanding leg. Using the equation given in the submittal of January 7, 1980, for the 4 x 4 angle with a distance from bolt centerline to the angle edge of 1.5 inches and with a Hilti allowable load of 1.5 kips, the permissible applied load was back-calculated and found to be .52 kips. This 0.52 kip bolt force was therefore included as one of the load steps and equates to a prying factor of 2.9.

The results of the ANSYS analysis for the case of non-preloaded anchors are plotted in Figures 17 through 19 for angle thicknesses of 1/4", 3/8", and 1/2" respectively. The results show the resultant bolt force and a plot of the pressure at the interface of the angle with the concrete. The interesting observation is that as the angle becomes thicker, the resultant compressive concrete force moves toward the

tip of the angle indicating an effect of stiffness on the force distribution. Also, it can be seen that the magnitude of the load for each angle thickness has no effect on the location of the compressive force. Only the magnitude of the compressive force increases with increasing load. This leads to the very important conclusion for non-preloaded anchors that the prying factor (bolt load divided by applied load) is constant for all load levels for a particular angle and bolt geometry.

For the 1/4" thick angle, the compressive force is located at approximately 1.06 inches from the bolt or .71 times the bolt edge distance. This is smaller than the .875 factor used in the prying factor formula. With this smaller moment arm, it would be expected that the prying factor equal to the bolt force (F) divided by the applied load (P) would be higher than the theoretical value of 2.9 predicted by the prying factor equation. Actually taking the ANSYS produced bolt tension and dividing it by the applied load, the factor is 2.82 based upon an applied load of .52 kips producing a bolt force of 1.46 kips. The factor is lower than the theoretical because for this angle thickness, 18% of the applied moment at the bolt line is resisted by the bending stiffness of the bolt. This leaves only 82% of the applied moment to be resisted by the concrete compressive force times 1.06 inches. The bending stiffness of the bolt and its influence on resisting the applied bending moment are ignored by the prying factor equation.

For thicker angles, the concrete compressive force moves closer to the edge of the angle producing a longer moment arm for the resisting moment. Also, as the angle becomes thicker, its stiffness relative to the bolt stiffness becomes greater and less moment is taken by the bolt and more is taken by the concrete resisting moment. For example, in the 4" x 4" x 1/2" angle, only 9% of the applied moment is taken by the bolt. Therefore, the more influential effect of the concrete compressive force moving toward the edge of the angle versus the opposing effect of reduced moment resisting capacity of the bolt produces a net result of a decreasing prying factor

as the angle thickness increases.

Shown in Figure 20 is a plot of the prying factors for the range of angle thicknesses used at V. C. Summer for the 4 x 4 angle. All these factors from the ANSYS runs are lower than the 2.9 factor produced using the prying factor equation. Hence, it appears that the prying factor derived from the equation in the January 7, 1980 submittal is conservatively high and, therefore, overpredicts the bolt force compared to the finite element analysis for identical applied loads with similar angle and bolt geometries.

Although the plots of the concrete force distributions are not enclosed herein, similar results were obtained when looking at 3" x 3" angles. Here also, as the angle thickness increases, the prying factor became smaller. The largest prying factor for the range of angle thickness utilized in the field was 2.28 for the 1/4" thick angle, which is less than the value of 2.60 predicted for the 3" angle by the prying factor formula. Prying factors for both the 3/8" and 1/2" angle thicknesses are both 2.06. The prying factors obtained for the 3" x 3" angle for three different thicknesses are also plotted on Figure 20.

It was decided also to look at the case of the same angles but with the Hilti bolt being preloaded. The preload was applied to the model by means of a temperature reduction on only the bolt element. The magnitude of the preload selected was 3.4 kips (based on the existing field torquing requirements) for the 5/8" Ø Hilti. This was considered to be the preload after allowing for some preload loss occurring soon after installation.

This model was again loaded in increments by a vertical load on the centerline of the outstanding angle leg. The results of this analysis for the concrete pressures are also plotted on Figures 17 through 19 for the 4" x 4" angle. For the preloaded bolt case, it is apparent that the behavior is significantly different from the

non-preloaded case. For the case of no applied load, the concrete stresses are localized symmetrically around the bolt in reaction to the preload applied through the nut. As the applied load is increased, the resultant of the compressive forces moves toward the edge of the angle. Since the preload force is present in the bolt and not overcome until high levels of load are applied, the concept of calculating a prying factor by dividing the bolt force by the applied load is meaningless.

What can be examined, however, is the bolt force at the applied load level equal to .52 kips. This is the maximum load, for all thicknesses of 4" x 4" angles, which is permitted to be applied to this angle and bolt system, based on the prying factor formula. For this applied load level, the bolt forces are 3.499 kips, 3.468 kips, and 3.442 kips respectively for the cases of 1/4", 3/8", and 1/2" thick angles. The highest of these is only 3% in excess of the preload value of 3.4 kips. This small increase above the preload value is insignificant leading to the conclusion that for the load level predicted by the prying factor formula, the bolt is essentially still only experiencing its initial preload.

In conclusion, it is apparent that angle flexibility does influence the prying factor slightly by affecting the location of the resultant concrete force. This is evidenced by the differing prying factors for the three different angle thicknesses analyzed in this study. Although the factors vary as a function of angle thickness, the factors from the finite element analysis are less than those computed using the prying formula (considering the concrete resultant force to be at 7/8 of the angle edge distance), making all analyses conducted using the formula conservative. For the case of the preloaded anchor, when an external load equal to that predicted by the prying factor formula is applied, the bolt force is only slightly in excess of the preload. This is true for all thicknesses indicating a negligible influence of angle stiffness at this load level. For higher load levels, the same trends of increasing bolt force for decreasing angle thicknesses, as observed for the non-preloaded bolt system, are evident for the preloaded bolt system.

FIGURE 16

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	DEPARTMENT NAME: STRUCTURAL	DEPT. NO.: 0412	FILING CODE
	PROJECT NAME: V. C. SUMMER UNIT 1	W.O. NUMBER: 04-4461-020	PAGE

SUBJECT: ANALYSIS OF EXPANSION BOLTED ANGLE IN SHORT DIRECTION PRYING

ORIGINATOR: S H HSU

DATE: 6-2-82

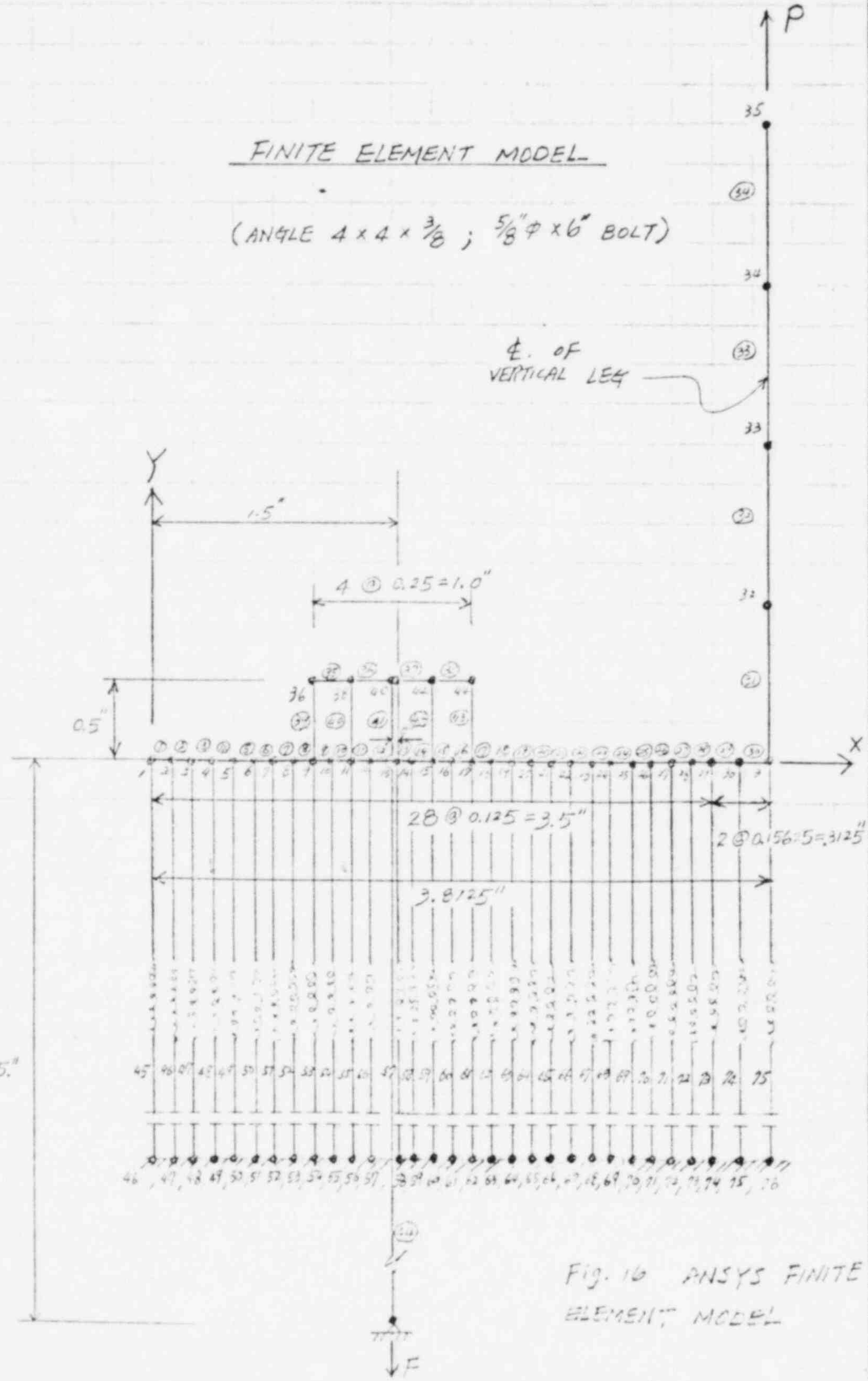


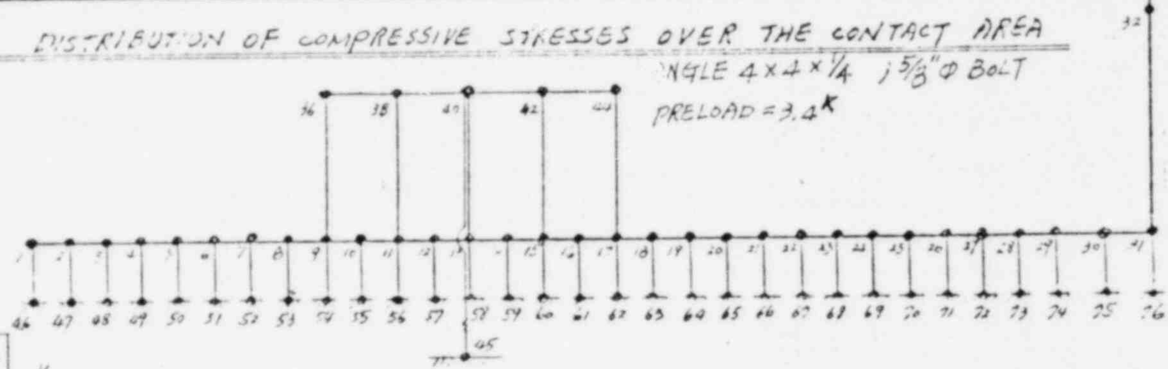
Fig. 16 ANSYS FINITE ELEMENT MODEL

Gilbert Associates, Inc. Reading, Pennsylvania CALCULATION	SUBJECT Figure 17 - 4"x4"x1/4" Angle			CISID	PAGE ___ OF ___ PAGES
	REV. 0	1	2	3	
	MICROFILMED				
	ORIGINATOR S. H. HSU				
	DATE 6-17-82				

DISTRIBUTION OF COMPRESSIVE STRESSES OVER THE CONTACT AREA

ANGLE 4×4×1/4 ; 5/8" Φ BOLT

PRELOAD = 3.4^K



	APPLIED FORCE (P^K)	BOLT FORCE (F^K)	F/P
PRELOAD	0.0	3.399	N/A
NO PRELOAD	0.0	0.0	N/A
PRELOAD	0.25	3.411	N/A
NO PRELOAD	0.25	0.7063	2.825
PRELOAD	0.5164	3.499	N/A
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PRELOAD	1.0	3.651	N/A
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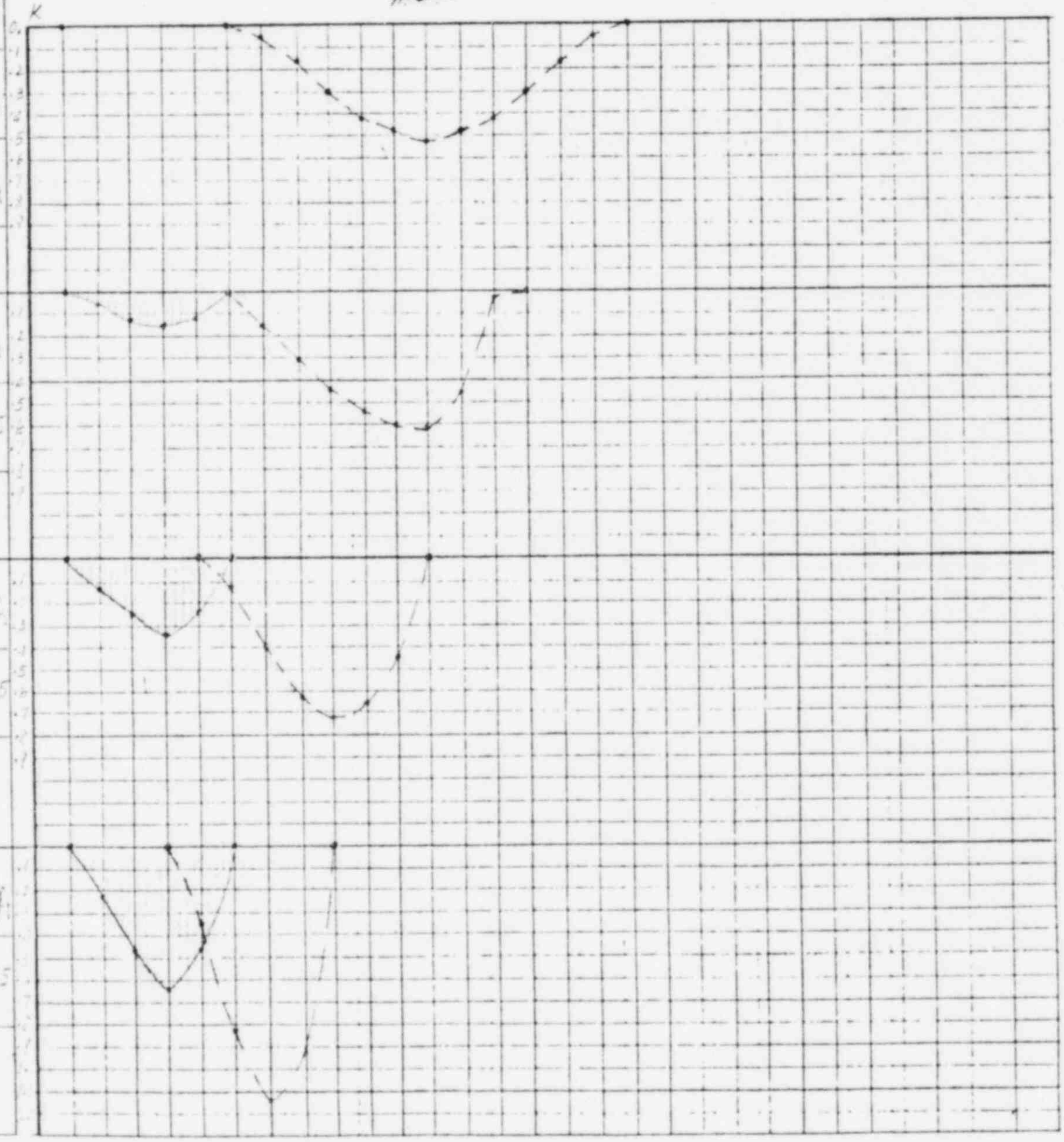

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* USING 1.5^K AS ALLOWABLE FORCE FOR 5/8" HILTI BOLT

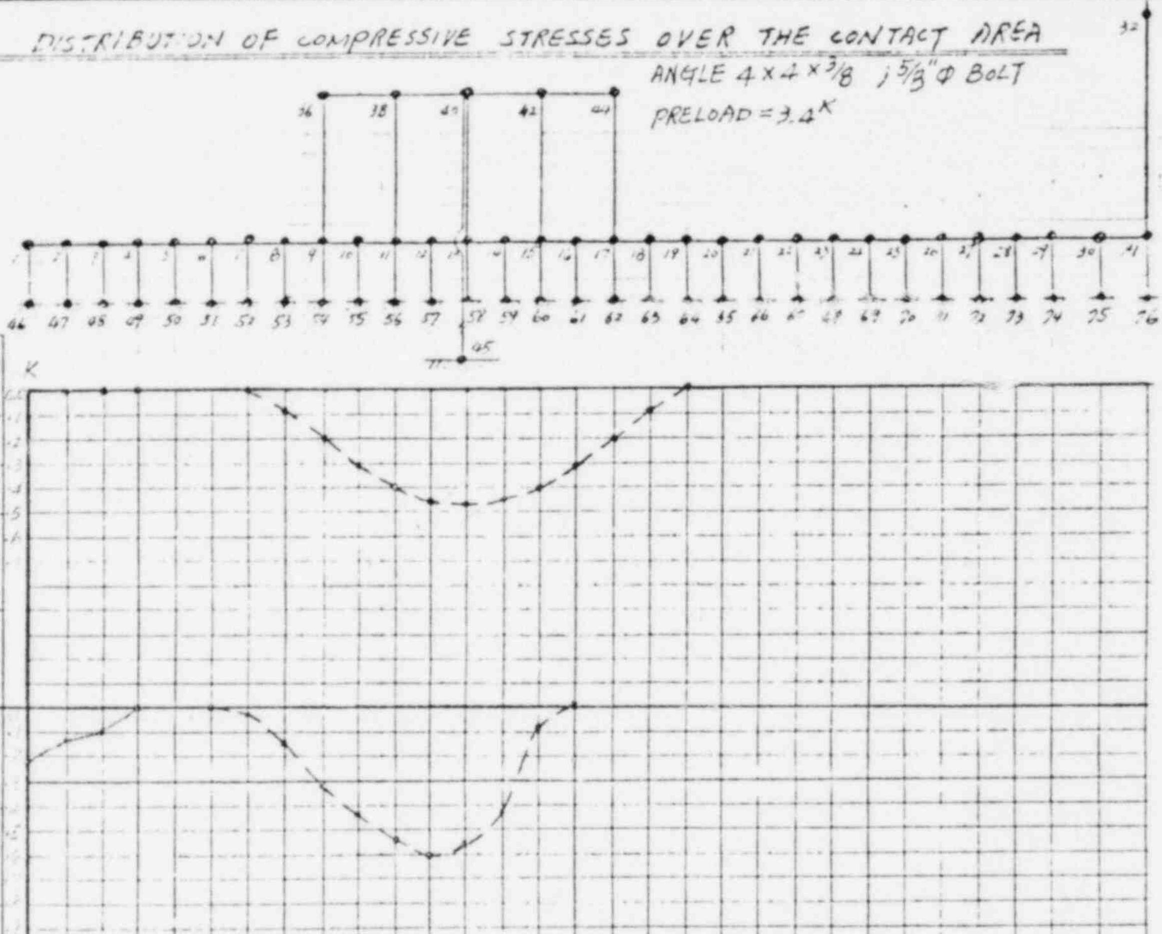
$\therefore F = \left(\frac{8l}{7?l}(b - 9/8)\right)P$, WHERE b = 4" ; l = 1.5"

P = 0.516^K F/P = 1.5/0.516 = 2.9

Gilbert Associates, Inc.
Reading, Pennsylvania
CALCULATION

SUBJECT	Figure 18 – 4"x4"x3/8" Angle
CISID	C4-4461-020
PAGE	OF PAGES
REV.	0
MICROFILMED	
ORIGINATOR	S. H HSU
DATE	6-17-82

DISTRIBUTION OF COMPRESSIVE STRESSES OVER THE CONTACT AREA



	APPLIED FORCE $(P)^K$	BOLT FORCE $(F)^K$	F/P
PRELOAD	0.0	3.4	N/A
NO PRELOAD	0.0	0.0	N/A
PRELOAD	0.25	3.465	N/A
NO PRELOAD	0.25	0.5993	2.397
PRELOAD	0.5164	3.468	N/A
NO PRELOAD	0.5164	1.2378	2.397
PRELOAD	1.0	3.744	N/A
NO PRELOAD	1.0	2.3971	2.397

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———— NO PRELOAD

* USING 1.5^K AS ALLOWABLE FORCE PER 5/8" HILTI BOLT

$\therefore F = \left(\frac{8}{7l}\right)\left(b - \frac{9}{8}\right)P$, WHERE b = 4", l = 1.5"

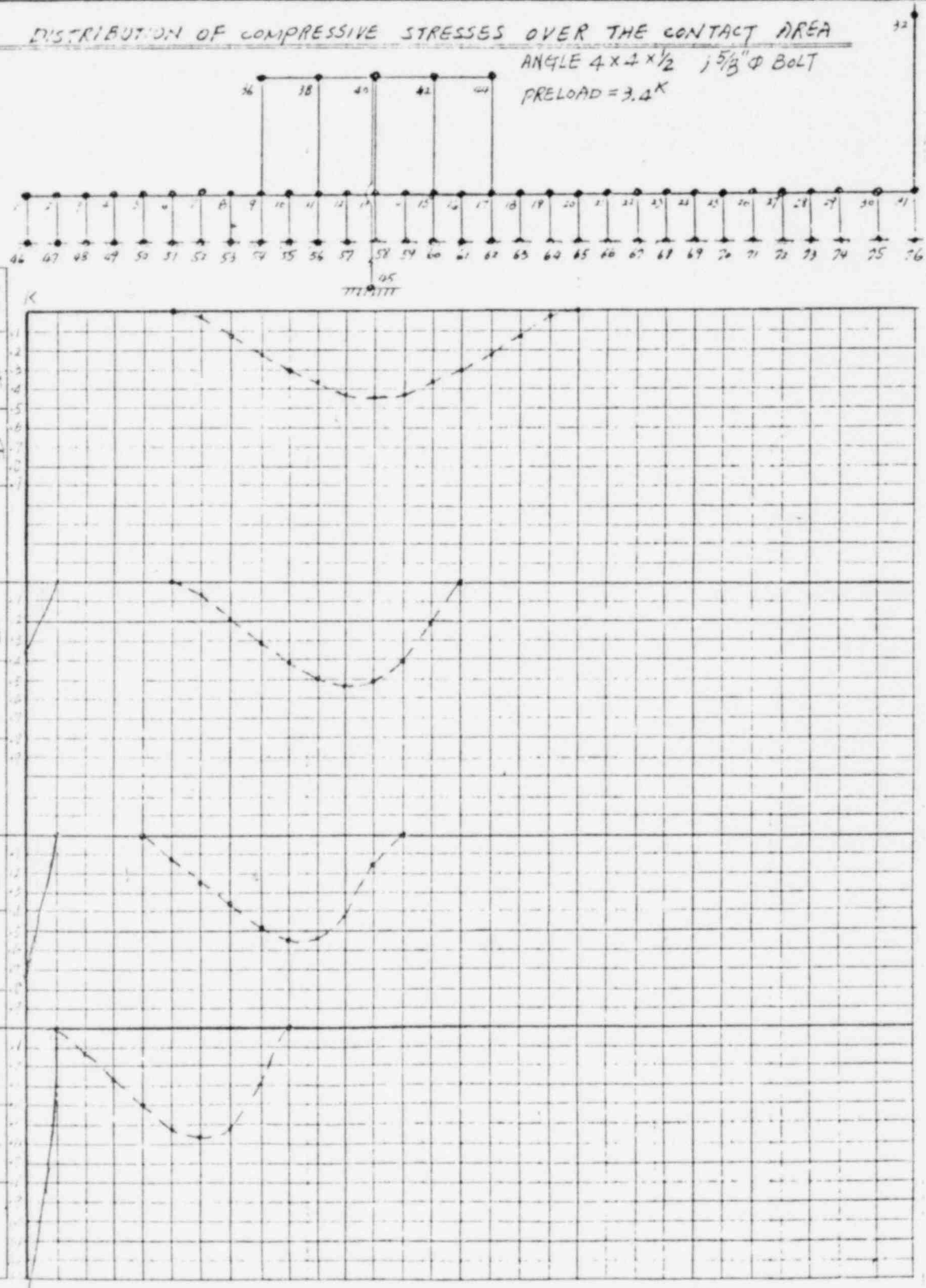
$P = 0.516^K$; $F/P = 1.5/0.5164 = 2.9$

Gilbert Associates, Inc. Reading, Pennsylvania	SUBJECT: Figure 19 - 4"x4"x½" Angle			CISID	PAGE ___ OF ___ PAGES
CALCULATION	REV. 0	1	2	3	
	MICROFILMED				
	ORIGINATOR S. H. HSU				
	DATE 6-18-82				

DISTRIBUTION OF COMPRESSIVE STRESSES OVER THE CONTACT AREA

ANGLE 4 x 4 x ½ ; 5/8" Φ BOLT

PRELOAD = 3.4^K



	APPLIED FORCE $(P)^K$	BOLT FORCE $(F)^K$	F/P
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NO PRELOAD	0.0	0.0	N/A
PRELOAD	0.25	3.403	N/A
NO PRELOAD	0.25	0.6008	2.4
PRELOAD	0.5164	3.442	N/A
NO PRELOAD	0.5164	1.241	2.4
PRELOAD	1.0	3.933	N/A
NO PRELOAD	1.0	2.433	2.4

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* USING 1.5^K AS ALLOWABLE FORCE FOR 5/8" HILTI BOLT

∴ $F = \left(\frac{8}{7l}\right)(b - \frac{l}{8})P$, WHERE b = 4", l = 1.5"

$P = 0.516^K$ $F/P = \frac{1.5}{.516} = 2.9$

FIGURE 20

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	DEPARTMENT NAME: Structural	DEPT. NO.: 0412	FILING CODE
	PROJECT NAME: V.C. Summer Unit #1	W.O. NUMBER	PAGE

SUBJECT

ORIGINATOR: G. Rentschler

DATE: 6/22/82

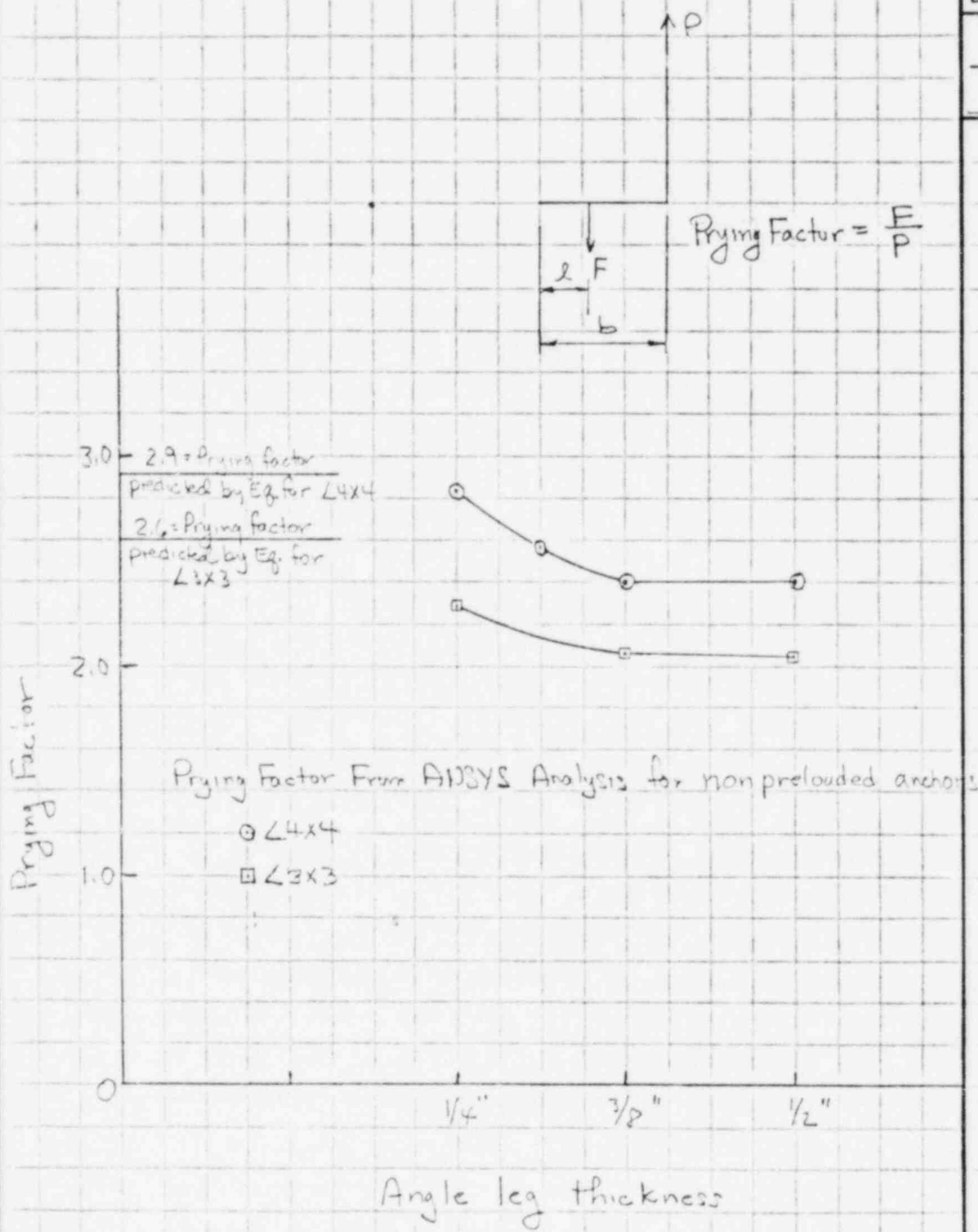

Figure 20 Prying Factor Vs Angle Thickness

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