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O. W. DIXON, JR.
VICE PRESIDENT
NUCLEAR OPERATIONS

82 JUN 25 A 9 : 39

June 22, 1982

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

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

Dear Mr. O'Reilly:

The following information is being submitted on the basis of additional questions received from Mr. Mark Hartzman of NRR. As indicated in our response to IEB 79-02, Revision 3, dated February, 1982, base plate analyses have been performed by two separate contractors. The responses to questions 1, 2, and 3 for Teledyne Engineering Services are contained in Attachment I. Responses to questions 1 and 2 for Gilbert Associates, Inc. are included in Attachment II.

We are in the process of performing comparitive analyses and obtaining examples which will address question 3 for Gilbert. We will transmit this information to you as soon as it becomes available.

If you require additional information, please advise.

Very truly yours,

O. W. Dixon, Jr.

GDM:OWD:glb

Attachments

cc: Page 2

IE11

cc: V. C. Summer w/o atts.
T. C. Nichols, Jr. w/o atts.
G. H. Fischer w/o atts.
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ATTACHMENT I

Request for Additional Information on IEB 79-02
Teledyne Response

The Teledyne program for base plate flexibility anchor bolt analysis is based on the generic program contained in report TR-3501-2 which was previously reviewed and accepted by the NRC. To facilitate analysis for the Summer Project, a curve was developed which conservatively incorporates the results of the generic program (see attached figure). The amplification factor, ϕ, is multiplied by the no-prying or rigid plate bolt load as a conservative estimate of the actual bolt load. The attached 4 examples are intended to provide answers to your questions.

TELEDYNE ENGINEERING SERVICES

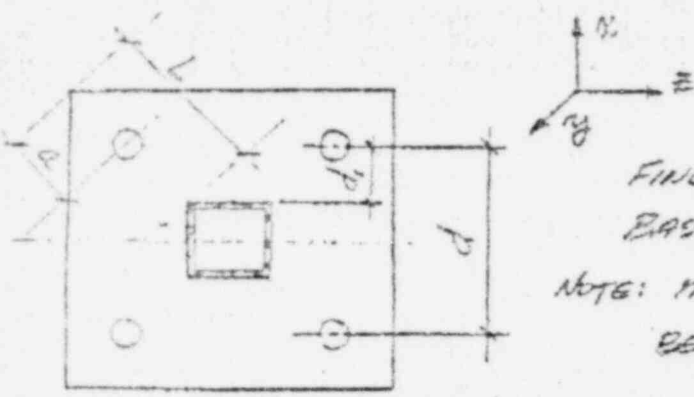
TYPICAL BASE PLATE CALCULATIONS

BY TMB DATE 6.1.82
CHKD. BY MEM DATE 6/3/82

South Carolina Electric & Gas Company
P.O. 025B258-0003
V.C. Summer Unit-1

PROJECT NO.	PAGE NO.
4813	1 of 4

SERVICE 4-BOLT PLATE W/ TENSILE LOAD & BENDING



FY, MZ ACTING

USING TES EP-2-010, FIND AMPLIFICATION FACTOR, ϕ BASED ON a/L RATIO.

NOTE: MOMENTS ARE REACTED BETWEEN BOLT CENTERLINES.

$$T_{BOLT} = \phi\left(\frac{FY}{4} + \frac{MZ}{2d}\right)$$

TO CHECK BOLT INTERACTION $\frac{T_B}{T_A} + \frac{V_B}{V_A} \leq 1.0$

WHERE T_A = BOLT TENSION ALLOWABLE

V_A = BOLT SHEAR ALLOWABLE

NOTE: TES ASSUMES ONLY 1/2 THE BOLTS ACTING IN SHEAR.

FOR THIS CASE,

$$\frac{T_{BOLT}}{T_{ALLOW}} \leq 1.0^{*}$$

TO CHECK BASEPLATE STRESS (S_Z = SECTION MODULUS OF BASEPLATE)

PLATE STRESS, $f_b = 2 \times T_{BOLT} \times d_1 / S_Z$

$f_b \leq 0.75\ F_Y^{*}$ OF BASEPLATE MATERIAL

* NOTE: IF EITHER OF THESE ALLOWABLES ARE EXCEEDED, A MODIFICATION WOULD BE REQUIRED, IE GUSSET PLATES, OR REPLACEMENT OF BOLTS.

TELEDYNE ENGINEERING SERVICES

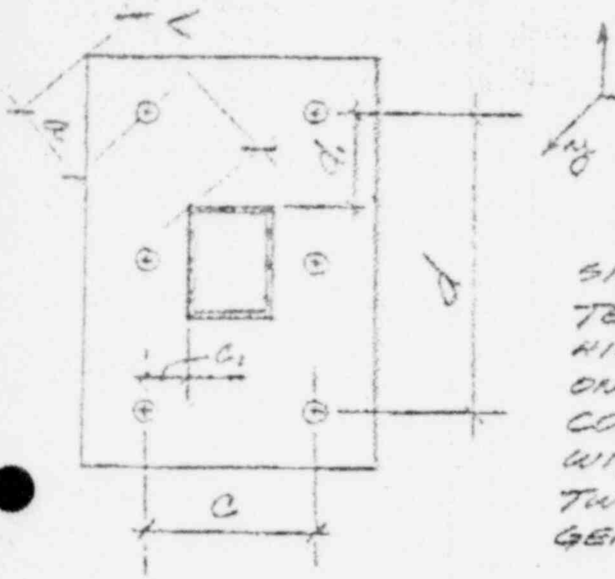
TYPICAL BASEPLATE CALCULATIONS

BY TMB DATE 6-1-82
CHKD. BY MEM DATE 6/3/82

South Carolina Electric & Gas Company
P.O. Q258258-0003
V.C. Sumner Unit-I

PROJECT NO.	PAGE NO.
4813	

RECTANGULAR 6-BOLT PLATE W/ TENSILE LOAD & BIAXIAL BENDING



FY, MX, MZ ACTING

INITIAL CALCULATION TRIAL MAY BE USING 4-BOLTS ACTING. GENERALLY, GUSSET PLATES ARE NEEDED TO BETTER UTILYZE THE BOLT CONFIGURATION CAPACITY SINCE THE PRYING FACTOR IN TES EP-2-010 BECOMES PROHIBITIVELY LARGE WHEN CONSIDERING ONLY FOUR BOLTS IN THIS CASE. CONSIDERING THE LOAD DISTRIBUTION, WITHOUT GUSSET PLATES, THE TWO MIDDLE BOLTS WOULD GENERALLY BE OVER LOADED

FROM TES EP-2-010, DETERMINE ϕ FROM e/L

$$T_B = \phi\left(\frac{FY}{6} + \frac{MX}{3C} + \frac{MZ}{2d}\right)$$

$\phi = 1.0$ FOR RIGID PLATE CONSERVATIVE

INTERACTION $T_{BOLT} / T_{ALLOW} \leq 1.0$

PLATE STRESS: SX, SZ B.P. SECTION MODULUS

$$f_b = \left(\left(\frac{2 \times T_B \times d_1}{SZ}\right)^2 + \left(\frac{3 \times T_B \times C_1}{SX}\right)^2\right)^{1/2}$$

$$f_b \leq 0.75\ FY \text{ BASEPLATE MATERIAL}$$

NOTE: IF THE ESTIMATE FOR f_b IS TOO CONSERVATIVE, A FINITE ELEMENT PROGRAM CAN BE RUN FOR A BETTER APPROXIMATION.

TELEDYNE ENGINEERING SERVICES

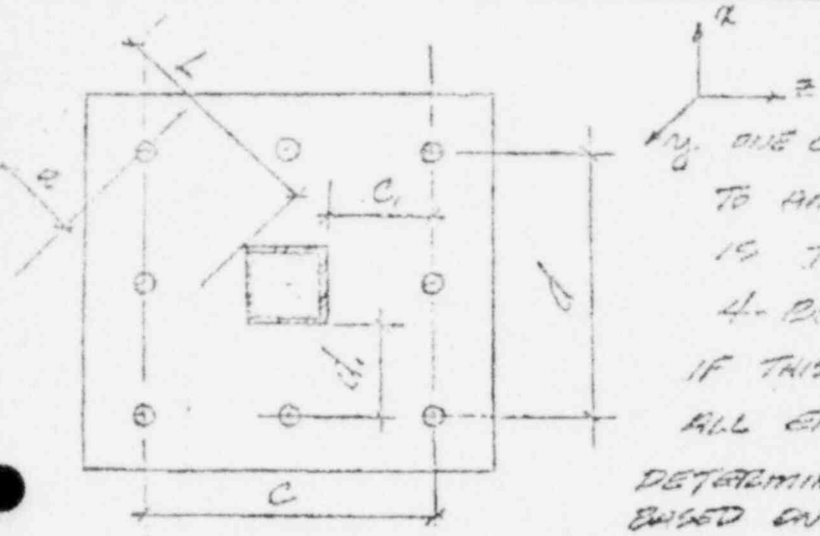
TYPICAL BASE PLATE CALCULATIONS

BY TAB DATE 6-1-82
CHKD. BY MEM DATE 6/3/82

South Carolina Electric & Gas Company
P.O. 025B25B-0003
V.C. Summer Unit-1

PROJECT NO.	PAGE NO.
4813	

SQUARE 8-BOLT PLATE W/ BIAXIAL BENDING



MX, MZ ACTING

ONE CONSERVATIVE APPROACH TO ANALYZE 8-BOLT PLATES IS TO ASSUME ONLY 4-BOLTS ACTING.

IF THIS PROVES TOO CONSERVATIVE, ALL EIGHT BOLTS ARE UTILIZED.

DETERMINE AMPLIFICATION FACTOR ϕ BASED ON a/L RATIO.

$$T_{BOLT} = \phi\left(\frac{MX}{3C} + \frac{MZ}{3d}\right) \quad \text{(MAXIMUM)}$$

CHECK $T_{BOLT}/T_{ALLOW} \leq 1.0$ BOLT INTERACTION

BASEPLATE STRESS SX = SZ = SECTION MODULUS OF B. PL.

CONSERVATIVE ESTIMATE –

$$f_b = \left(\left(\frac{3 \times T_{BOLT} \times C_1}{SX}\right)^2 + \left(\frac{3 \times T_{BOLT} \times d_1}{SZ}\right)^2\right)^{1/2}$$

$f_b \leq 0.75\ F_y$ OF BASEPLATE MATERIAL

NOTE: IF THE ESTIMATE FOR f_b IS TOO CONSERVATIVE A MORE DETAILED HAND CALCULATION CAN BE MADE TO DETERMINE INDIVIDUAL BOLT LOADS, OR A FINITE ELEMENT PROGRAM CAN BE RUN TO ANALYZE THE BOLT LAYOUT.

TYPICAL BASEPLATE CALCULATIONS

BY TAIB DATE 6-3-82
CHKD. BY [illegible] DATE 6/4/82

South Carolina Electric & Gas Company
P.O. Q258258-0003
V.C. Summer Unit-1

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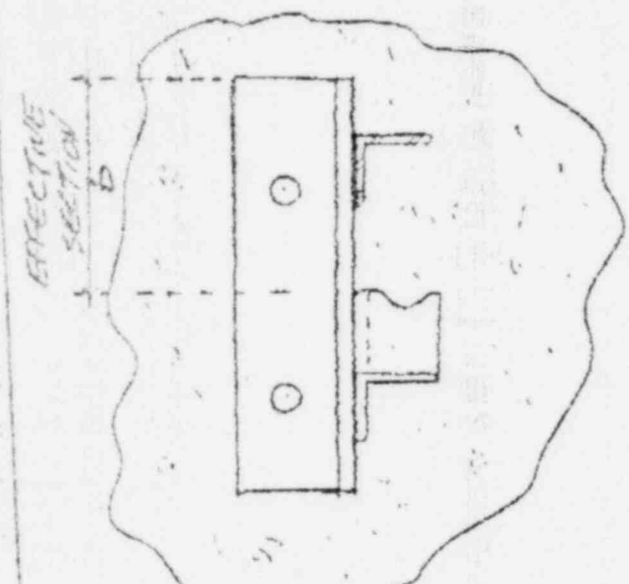
* SHORT DIRECTION PRYING FACTOR FOR ANGLE BASEPLATES
TES DID NOT HAVE ANY ANGLE BASEPLATES IN WORK SCOPE.



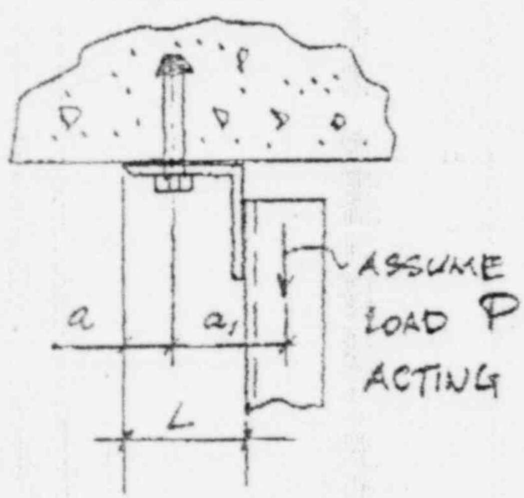
THE AMPLIFICATION FACTOR, ϕ, SHOWN IN TES PROCEDURE EP-2-010 INCLUDES THE EFFECT OF THE FLEXIBILITY OF THE ANGLE WHOSE INSIDE ATTACHED LEG BEHAVES LIKE A BASEPLATE.

FIND THE AMPLIFICATION FACTOR, ϕ BASED ON a/L.

$$T_{BOLT} = \phi P$$

INTERACTION ~

$$T_{BOLT} / T_{ALLOW} \leq 1.0$$



CHECK ANGLE LEG BENDING

$$f_b = \frac{T_{BOLT} \times a_1}{\text{SECTION MODULUS BASED ON EFFECTIVE SECTION}}$$

CHECK BENDING STRESS...

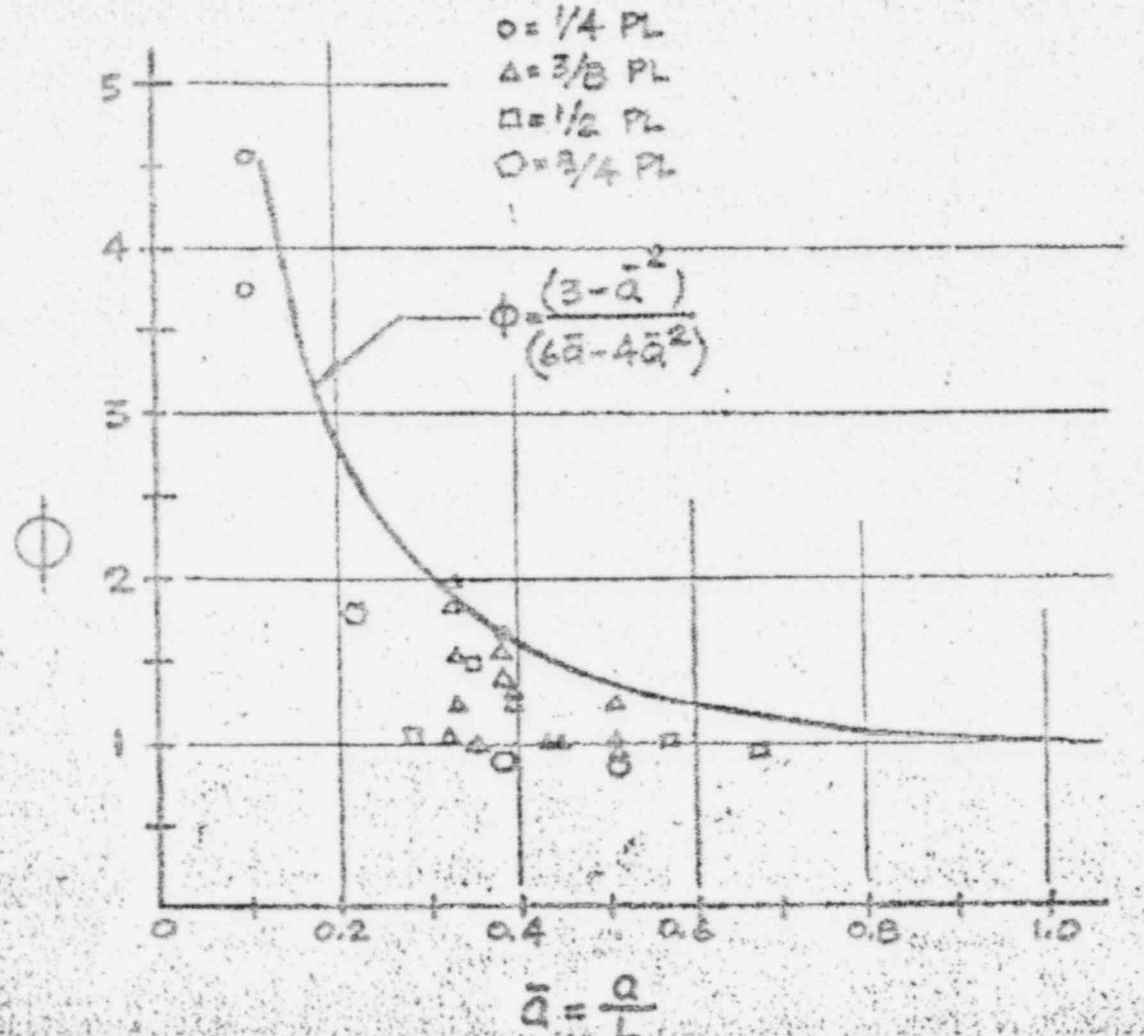
$$f_b \leq 0.75\ F_y \text{ OF ANGLE MATERIAL}$$

* NOTE: THIS IS HOW TES WOULD ADDRESS ANGLE BASEPLATES IF THERE WERE ANY IN OUR SCOPE.

Amplification Factor, ϕ

Comparison with Results

from the Generic Program



AMPLIFICATION FACTOR ϕ

ATTACHMENT II

Request for Additional Information on IEB 79-02
Gilbert Response

Question: Item 1

The flexibility analyses shown in your submittal of July 5, 1979 are applicable to plates subjected to a central tensile load or a bending moment. Show the extention of these analyses to plates subjected to the following load combination:

a. Tensile load and bending.
b. Biaxial bending.
c. Tensile load and biaxial bending.

Response

Figures 1, 2, 3, and 4 which were included with the original response dated July 5, 1979, showed the formulation for flexible plate analysis for tension loads and bending moments separately. When a flexible plate analyses is required, a computer program which accepts a tension load and a bending moment in the same run is utilized. The program first generates the anchor forces due the applied tension load including prying forces if they exist. These forces are then internally subtracted from the anchor residual preload. This reduced preload is then used by the computer in calculating anchor forces, due to the applied bending moment, including any additional prying force. The output lists all forces and the sum of these forces.

The methods of analysis used for Items a, b, and c of the NRC question are as follows:

a. Tension and Bending:

The anchor tension force is the sum of the forces due to the applied tension load and the applied bending moment.

$$T = F_T + F_{PT} + F_{Mn} + F_{PMn}$$

where:

T = tension force induced into an anchor.

F_T = anchor force due to applied tension load.

F_{PT} = prying force due to F_T.

F_{Mn} = F_{Mx} or F_{My} = anchor force due to applied bending moment.

F_{PMn} = F_{PMx} or F_{PMy} = prying force due to FM_n.

b. Biaxial Bending:

The anchor tension force is determined by summing the bending moments, if the plate/attachment is symmetrical, and a single run made. If unsymmetrical (plate/attachment), two separate runs are made and the results summed with:

$$T = F_{Mx} + F_{PMx} + F_{My} + F_{PMy}$$

c. Tension plus Biaxial Bending:

The anchor tension force is determined by running the program with the tension load combined with the most critical bending moment. The program is then run again with the other moment in the other direction. The results are summed directly with:

$$T = F_T + F_{PT} + F_{Mx} + F_{PMx} + F_{My} + F_{PMy}$$

Question: Item 2

Provide a numerical example for each of the following flexible plate and bolt configurations which was used to determine allowable axial loads and bending moments.

a. square plate/four bolts, eight bolts
b. rectangular plate/six bolts

Provide the load-displacement curves for the anchored bolts on which the allowable bolt loads were based.

Response

The design approach used was not to determine "allowable axial loads and bending moments". For every plate and bolt configuration the actual loads and bending moments were used to determine an anchor tension force, assuming a rigid plate. This force was then doubled to conservatively account for potential prying action of a flexible plate. The factor of safety for the anchor was then calculated using the following equation.

$$FP_C = \frac{1}{\frac{2P_T}{T_O} + \frac{V}{V_O}}$$

where:

FP_C = factor of safety assuming flexible plate

P_T = calculated anchor tension assuming a rigid plate analysis

T_o = allowable anchor tension = $\frac{T_U}{4}$ where T_U = ultimate anchor tension capacity

V = calculated anchor shear

V_O = allowable anchor shear = $\frac{V_u}{4}$ where V_u = ultimate anchor shear capacity

if $FP_C > 1.0$ Design is acceptable

if $FP_C < 1.0$ Redesign or run flexible plate program

From the flexible plate computer analysis an anchor tension force is calculated and the factor of safety is checked as shown:

$$F_{Pa} = \frac{1}{\frac{T}{T_O} + \frac{V}{V_O}}$$

where:

F_{Pa} = factor of safety using prying analysis

T = actual anchor tension force including any prying forces

$F_{Pa} < 1.0$ Design is acceptable

$F_{Pa} > 1.0$ Redesign is required

Note: The program accepts only anchors on a single row, therefore, anchors on the centerline are ignored in calculating anchor forces for bending moments and tension loads.

Numerical examples of base plate and anchor configurations are shown in attached Figures 1, 2, and 3.

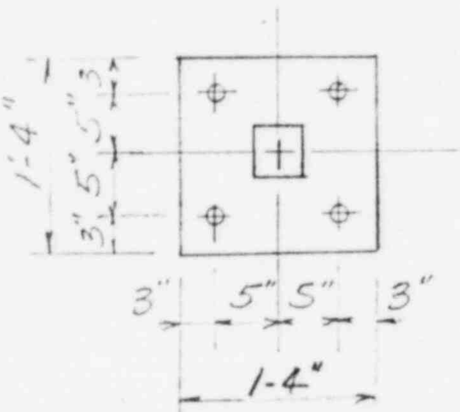
It should be noted that for these examples, shear forces have been omitted. In actual design case the inclusion of the Shear Force in the interaction formula for Factor of Safety would require a larger anchor size to be used. Using the larger anchor size results in the majority of cases showing no prying in the flexible plate computer analysis output.

The load displacement curves for the Hilti "Kwik Bolts" used on V. C. Summer Unit #1 are shown in Figures 4 thru 15. Curves for Tension vs. Displacement and Shear vs. Displacement are shown for each Kwik Bolt size used. These curves were developed by the HILTI Company.

FIGURE 1

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	DEPARTMENT NAME: STRUCT' ENG.	DEPT. NO. 0412	FILING CODE 0.13.11
	PROJECT NAME: V.C. SUMMER NUC' STN. UNIT #1	W.O. NUMBER 02-2461-020	PAGE 2
SUBJECT: RESPONSE TO QUESTION 2 - NRC DOCKET No. 50-395			ORIGINATOR [signature] DATE 5.26.82 VERIFIER R.M. [signature] DATE 5-27-82

EXAMPLE: SQUARE PLATE W/ FOUR ANCHORS.



GIVEN:

BASE PLATE = 16" × 3/4" × 1'-4"

ATTACH. SIZE = 4" × 4"

ANCHOR = 1"ϕ Hilti "Kwik Bolt"

TENSION LOAD = 4.5K = F_z

BEND. MOMENT = 38.0K-in. = M

T_o = 3.75K

CALCULATE ANCHOR TENSION LOAD:

$$P_T = \frac{F_z}{4} + \frac{M}{2(10)} = \frac{4.5}{4} + \frac{38}{20} = 1.125 + 1.9 = 3.025^K$$

CHECK FACTOR of SAFETY:

$$FP_c = \frac{1}{\frac{2P_T}{T_o} + \frac{V_{10}}{V_o}} = \frac{1}{\frac{2(3.025)}{3.75}} = 0.62 < 1.0 \quad \underline{\text{No Good}}$$

RUN FLEXIBLE PLATE PROGRAM:

OUTPUT:

$F_T = 1.125^K$ $\quad FP_T = 0.0$ (No Pry)

$F_M = 2.517^K$

$FP_M = 0.064^K$

$T = 3.706^K$

FACTOR OF SAFETY

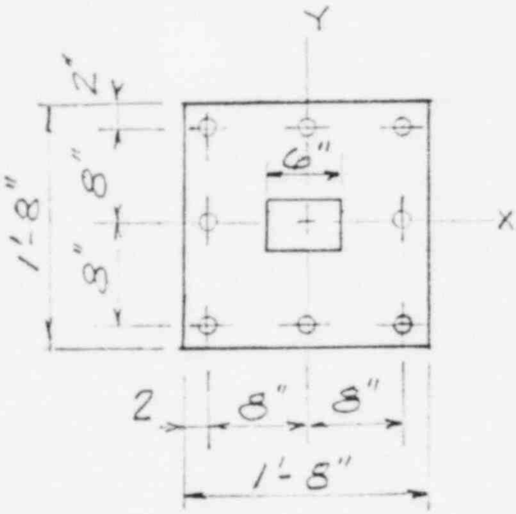
$$FP_a = \frac{1}{3.706/3.75} = 1.01 > 1.0 \therefore \underline{OK}$$

FILING CODE

FIGURE 2

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	DEPARTMENT NAME: STRUCT. ENG'.	DEPT. NO.: 0212	FILING CODE: 0.13.11
	PROJECT NAME: V.C. SUMMER NUC'. STN. UNIT #1	W.O. NUMBER: 04-4261-020	PAGE: 3
SUBJECT: RESPONSE TO QUESTION 2 - NRC DOCKET No. 50-395			ORIGINATOR: [signature] DATE 5-26-82
			VERIFIER: [signature] DATE 5-27-82

EXAMPLE: SQUARE PLATE w/ EIGHT BOLTS



GIVEN:

BASE PLATE = 20" × 3/4" × 1'-8"

ATTACH. SIZE: 6" × 4"

ANCHOR: 3/4"Φ HILTI "KWIK BOLT"

TENSION LOAD = F_Z = 3.0^K

MOMENT M_X = 46.0 in-K

MOMENT M_Y = 10.0 in-K.

T_O = 2.28 K

CALCULATE ANCHOR TENSION LOAD

$$P_T = \frac{F_Z}{8} + \frac{M_X(c)}{I_X} + \frac{M_Y(c)}{I_Y} \quad \text{AND } I_X = I_Y = 2(8)^2 + 3(16)^2 = 896 \text{ in}^2$$

$$= \frac{3.0}{8} + \frac{46(16)}{896} + \frac{10(16)}{896} = 1.374^K \quad c = 16''$$

CHECK FACTOR OF SAFETY

$$FP_C = \frac{1}{2P_T/T_O} = \frac{1}{2(1.374)/2.28} = 0.83 < 1.0 \ \underline{\text{No Good}}$$

RUN FLEXIBLE PLATE PROGRAM

OUTPUT:

$F_T = 0.500^K$ $\quad FP_T = 0.0$ (No Pry)

$F_{M_X} = 1.387^K$

$FP_{M_X} = 0.062^K$

$F_{M_Y} = 0.281^K$ $\quad FP_{M_Y} = 0.0$ (No Pry)

$T = 2.230$

FACTOR OF SAFETY

$$FP_a = \frac{1}{2.230/2.280} = 1.02 > 1.0 \ \therefore \ \underline{\text{OK}}$$

FILING CODE

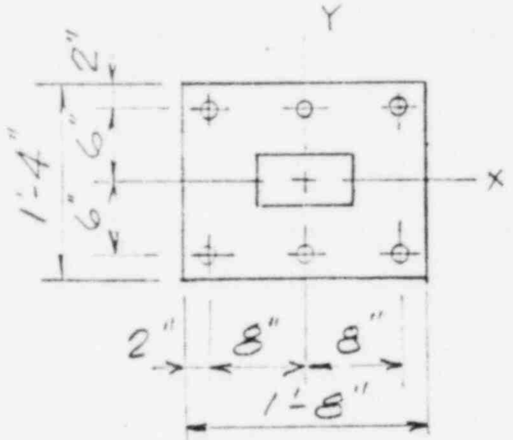
FIGURE 3

GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PA.	DEPARTMENT NAME: STRUC. ENG.	DEPT. NO.: 0412	FILING CODE: 0.13.11
	PROJECT NAME: V.C. SUMMER NUC. STN. UNIT #1	W.O. NUMBER: 02.44W-020	PAGE: 4

SUBJECT: RESPONSE TO QUESTION 2 – NRC DOCKET NO. 50-395

ORIGINATOR: [illegible] DATE: 5-[illegible]-82
VERIFIER: R.M. [illegible] DATE: 5-27-82

EXAMPLE: RECTANGULAR PLATE w/ SIX BOLTS



GIVEN:
BASE PLATE = 16" × 3/4" × 1'-8"
ATTACH. SIZE = 8" × 4"
ANCHOR = 3/4"Φ Hilti "Kwik Bolt"
TENSION LOAD = $F_Z = 3.0^K$
MOMENT = $M_X = 45.0$ in·K
$T_O = 2.28^K$

CALCULATE ANCHOR TENSION LOAD:

$$P_T = \frac{F_Z}{6} + \frac{M_X}{3(12)} = \frac{3}{6} + \frac{45}{36} = 0.50 + 1.25 = 1.75^K$$

CHECK FACTOR OF SAFETY

$$FP_C = \frac{1}{2P_T/2.28} = \frac{1}{2(1.75)/2.28} = 0.65 < 1.0 \text{ NO GOOD}$$

RUN FLEXIBLE PLATE PROGRAM

OUTPUT:

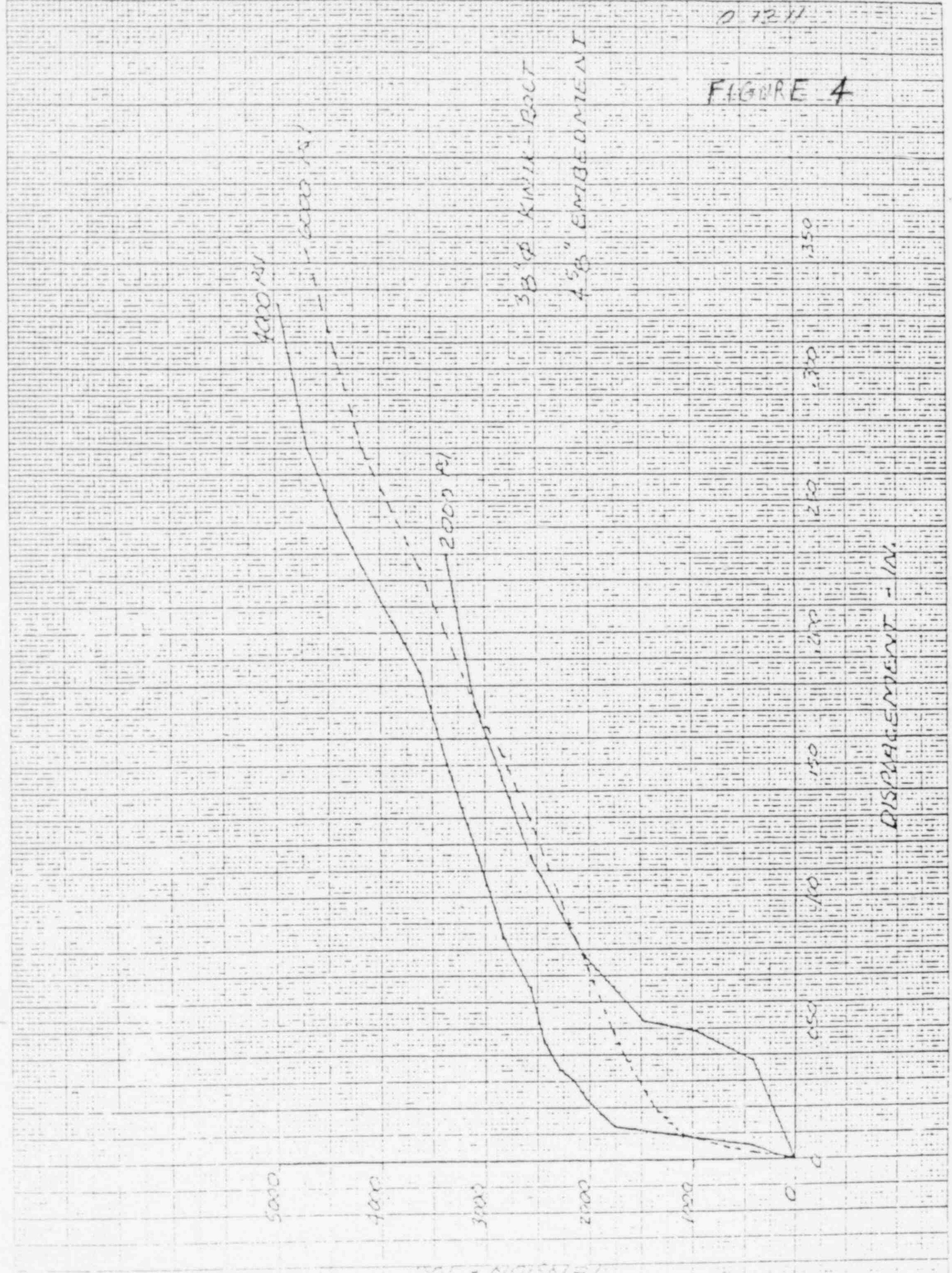
$F_T = 0.500^K$ $FP_T = 0.0$ (No Pry)
$F_{M_X} = 1.690^K$
$FP_{M_X} = 0.015^K$
$T = 2.205^K$

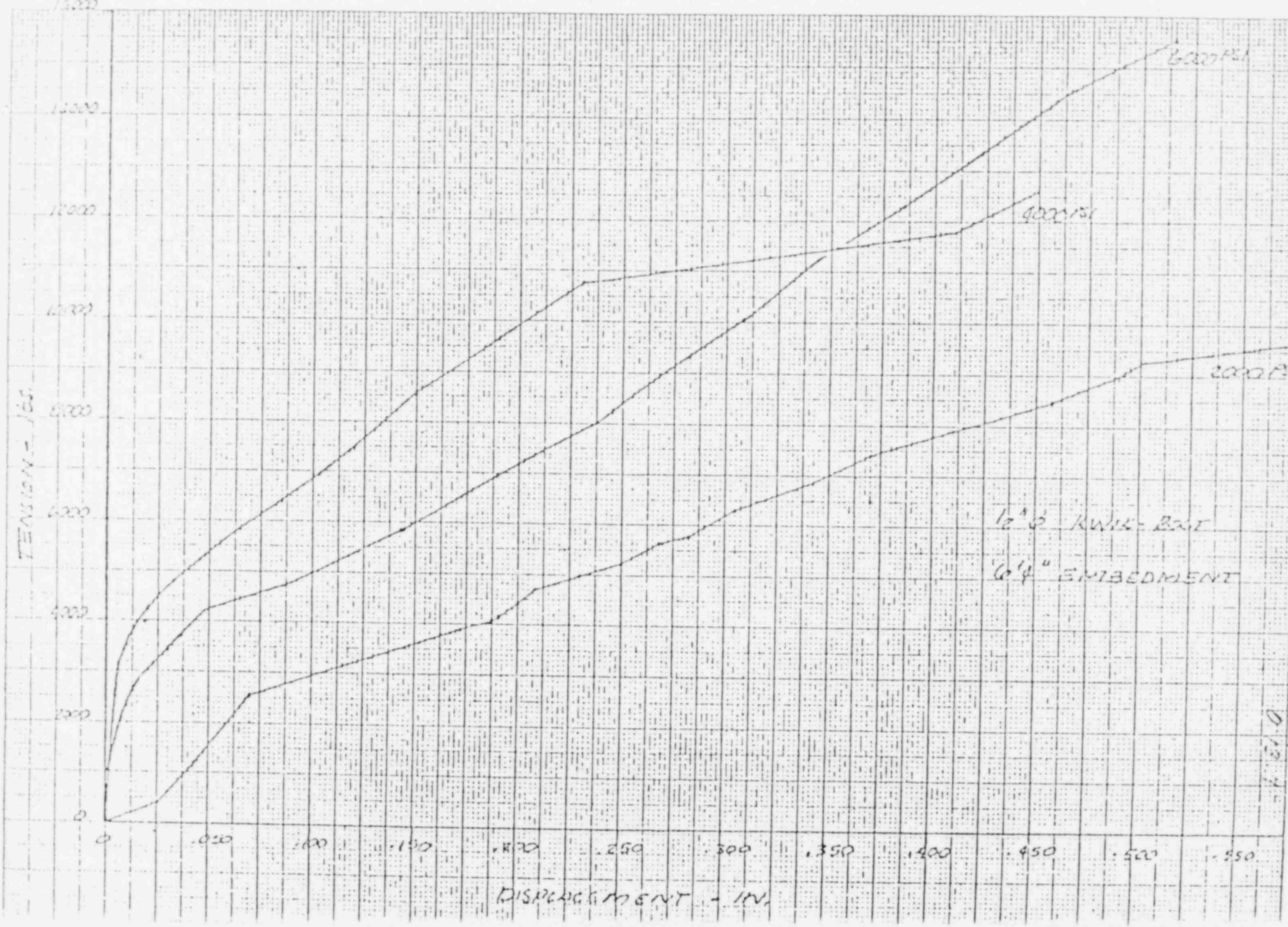
FACTOR OF SAFETY

$$FP_a = \frac{1}{2.205/2.28} = 1.03 > 1.0 \therefore \text{OK}$$

FIGURE 4

FIGURE 4

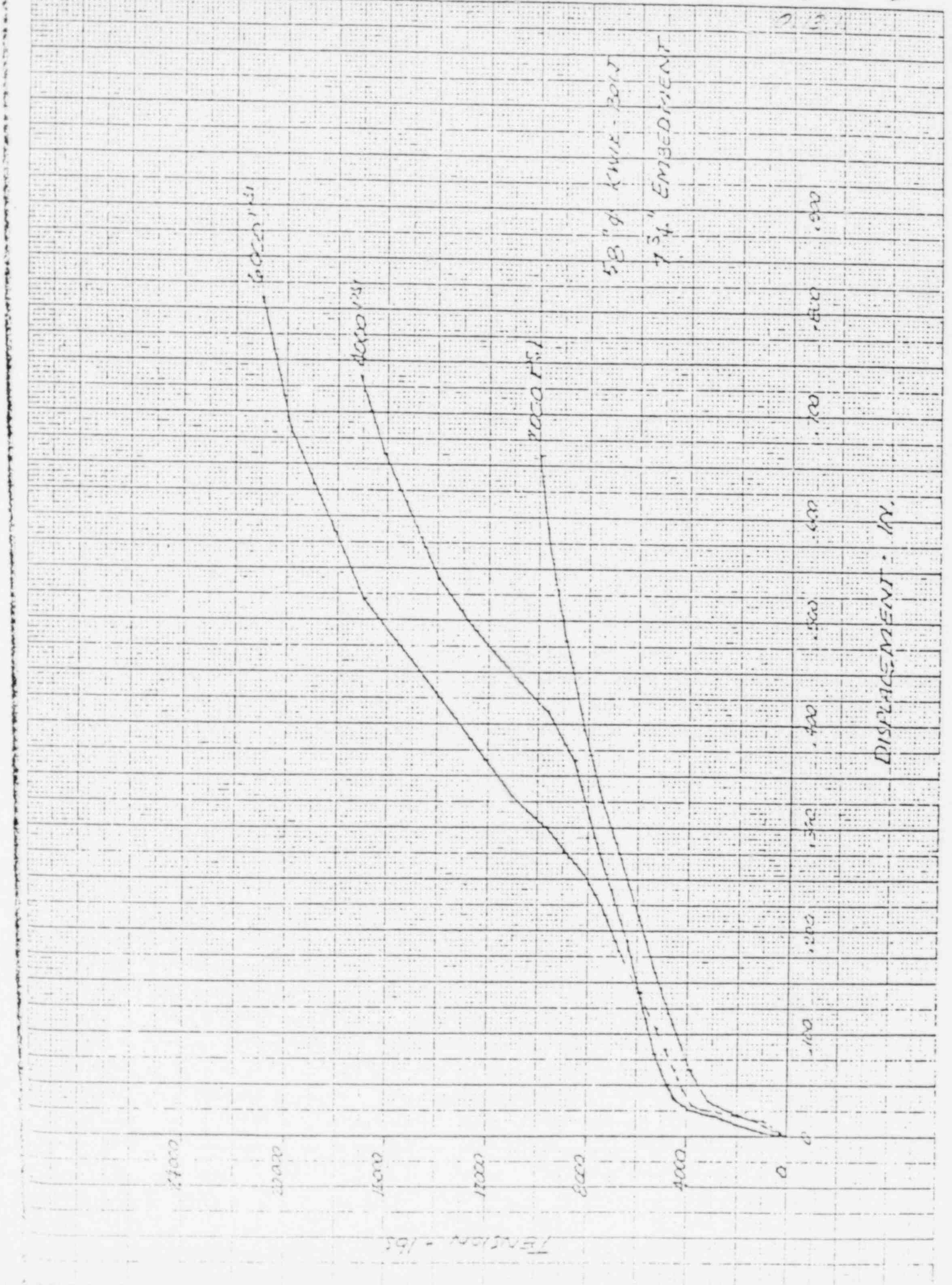




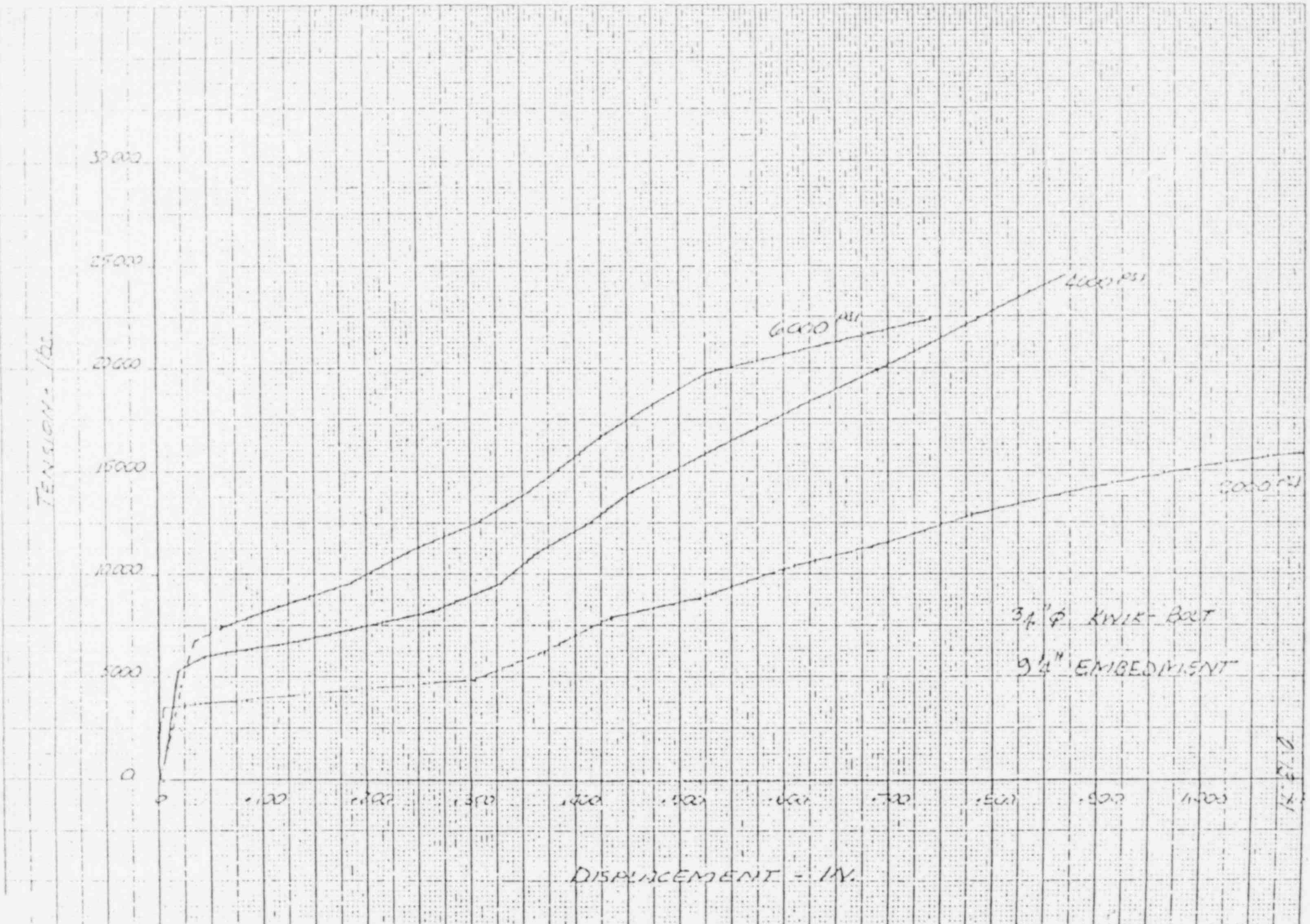
TENSION - LBS.
DISPLACEMENT - IN.
6000 PSI
4000 PSI
2000 PSI
EMBEDMENT
.250
.300
.350
.400
.450
.550

FIGURE 5

FIGURE 6

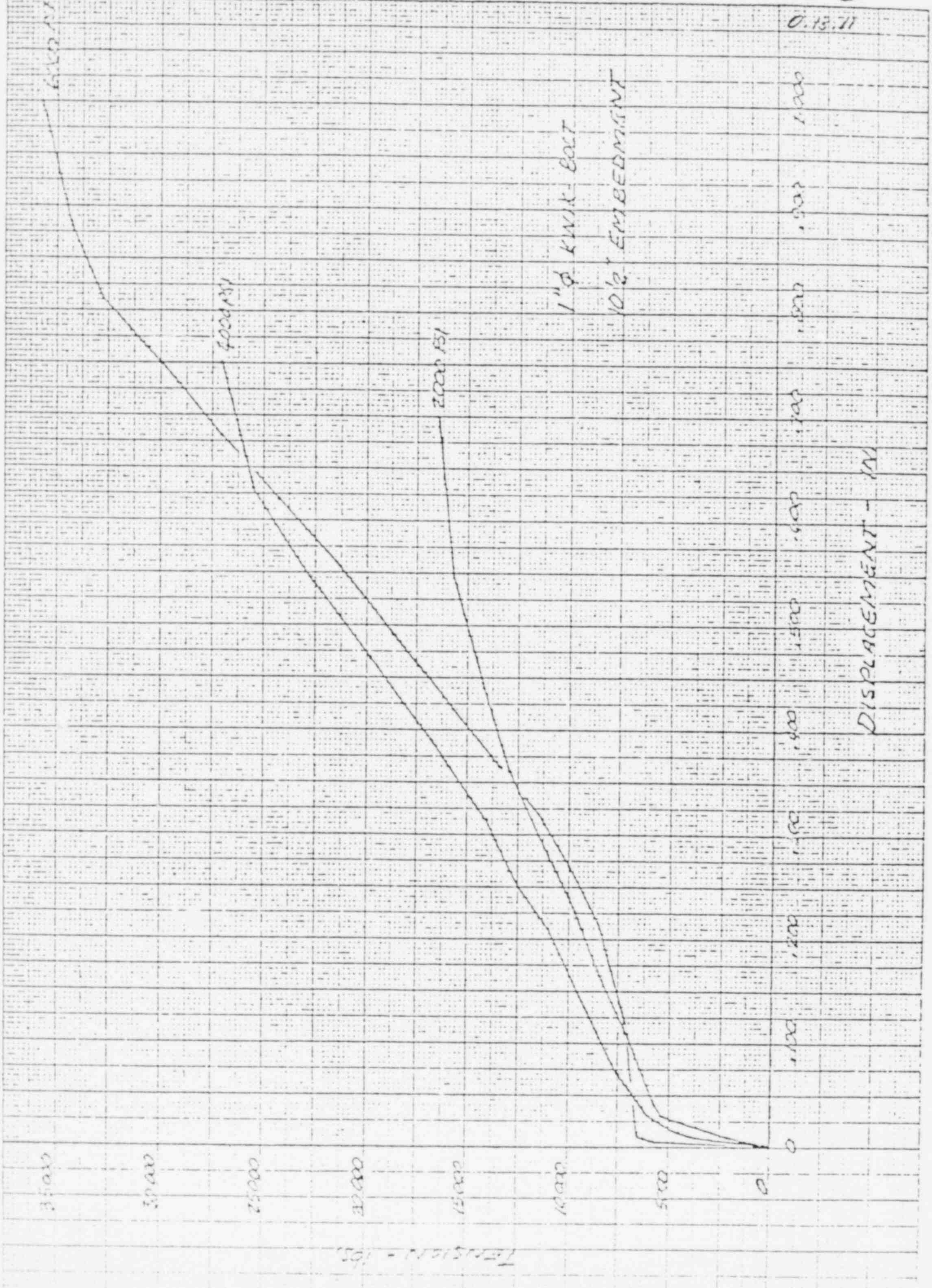


5/8" φ KWIK-BOLT
7 3/4" EMBEDMENT
DISPLACEMENT : IN.
TENSION - lbs
6000 PSI
4000 PSI
2000 PSI



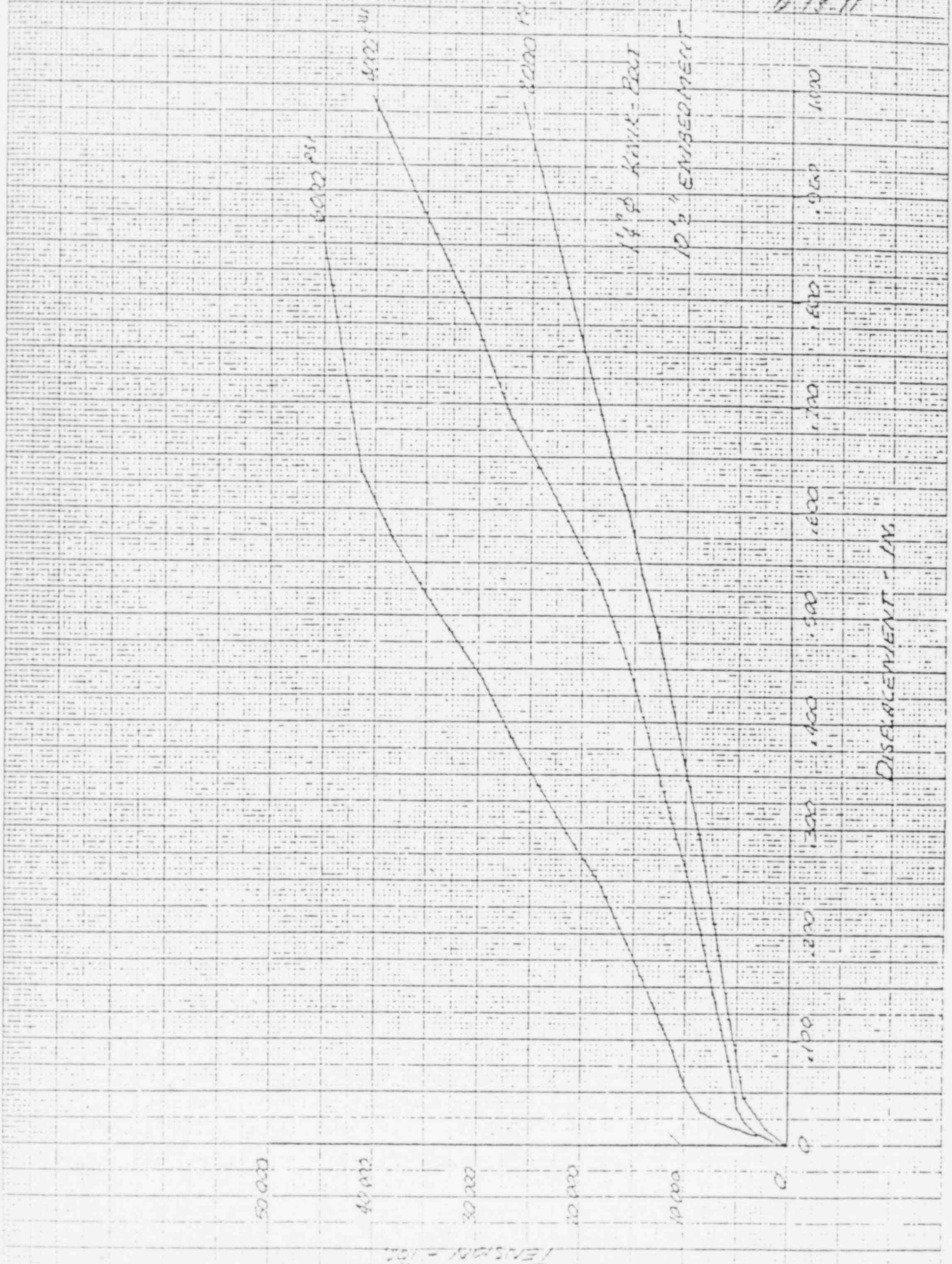
TENSION - lbs
30 000
25 000
20 000
15000
10000
5000
0
0
.100
.200
.300
.400
.500
.600
.700
.800
.900
1.000
DISPLACEMENT - IN.
6000 PSI
4000 PSI
2000 PSI
3/4" φ KWIK-BOLT
9 1/4" EMBEDMENT

FIGURE 8



1"Ø KWIK-BOLT
10½" EMBEDMENT
DISPLACEMENT - IN
6000 PSI
4000 PSI
2000 PSI
0
500
1000
1500
2000
2500
3000
3500

FIGURE 9



1 1/4" ø KWIK-BOLT
10 1/2" EMBEDMENT
DISPLACEMENT - IN.
TENSION - LBS.
0
10000
20000
30000
40000
50000
.100
.200
.300
.400
.500
.600
.700
.800
.900
1.000

FIGURE 10

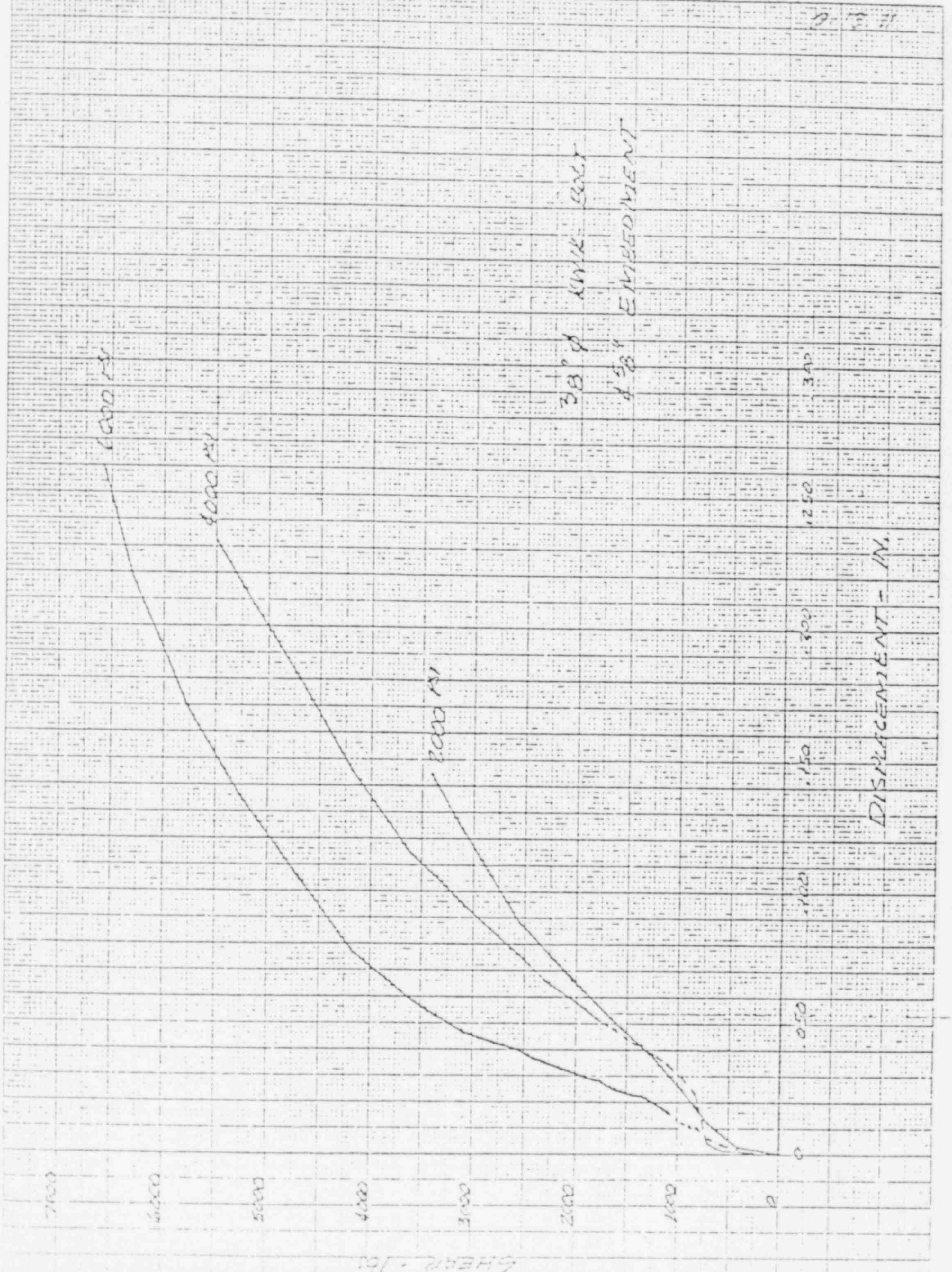

6000 PSI
4000 PSI
2000 PSI
3/8" Ø KWIK-BOLT
4 5/8" EMBEDMENT
DISPLACEMENT - IN.
0
.050
.100
.150
.200
.250
.300
0
1000
2000
3000
4000
5000
6000
7000
SHEAR - LBS

FIGURE 11

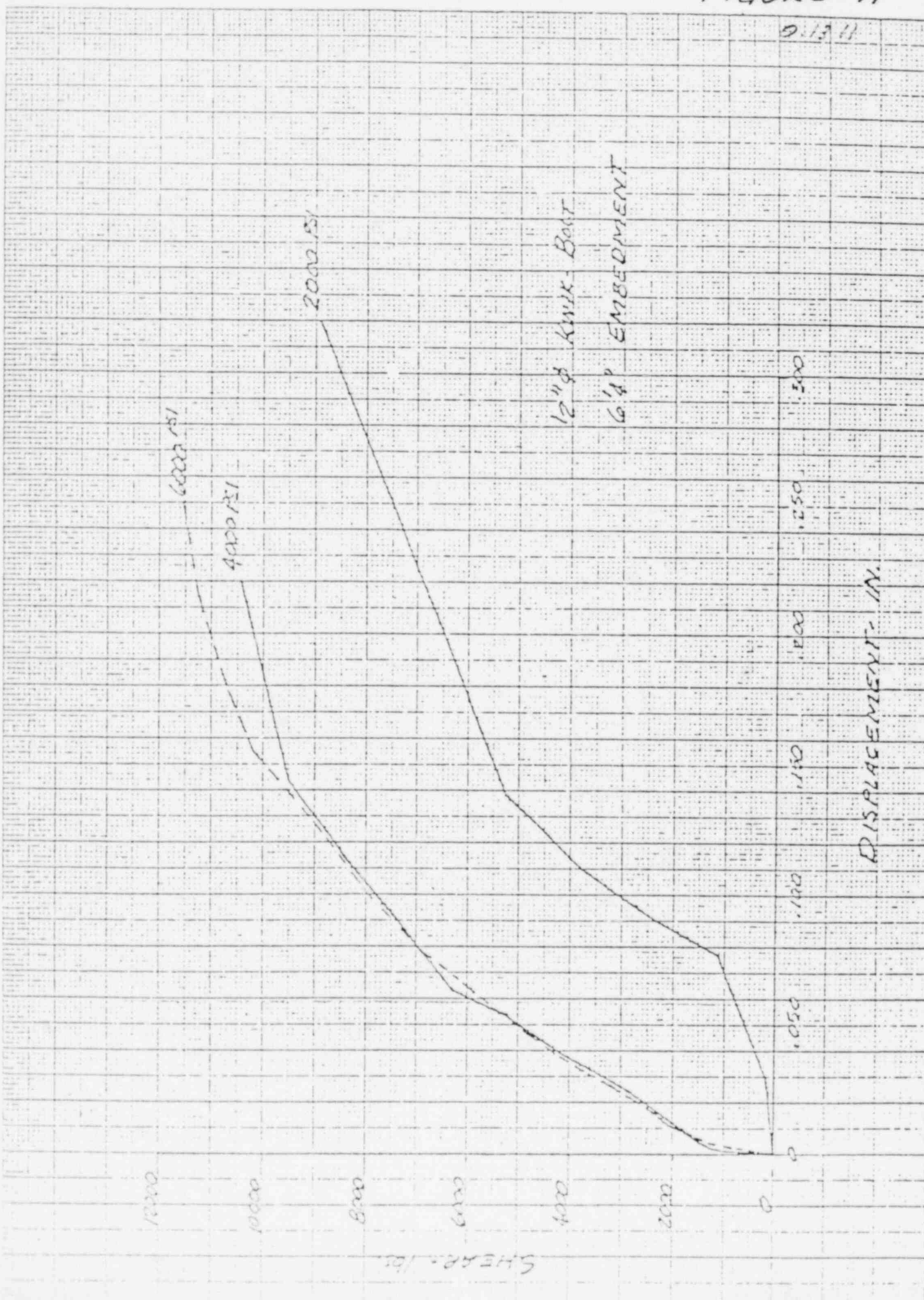

2000 PSI
4000 PSI
6000 PSI
EMBEDMENT
DISPLACEMENT - IN.
.050
.100
.150
.200
.250
.300
0
2000
4000
6000
8000
10000
12000
SHEAR - LBS

FIGURE 12

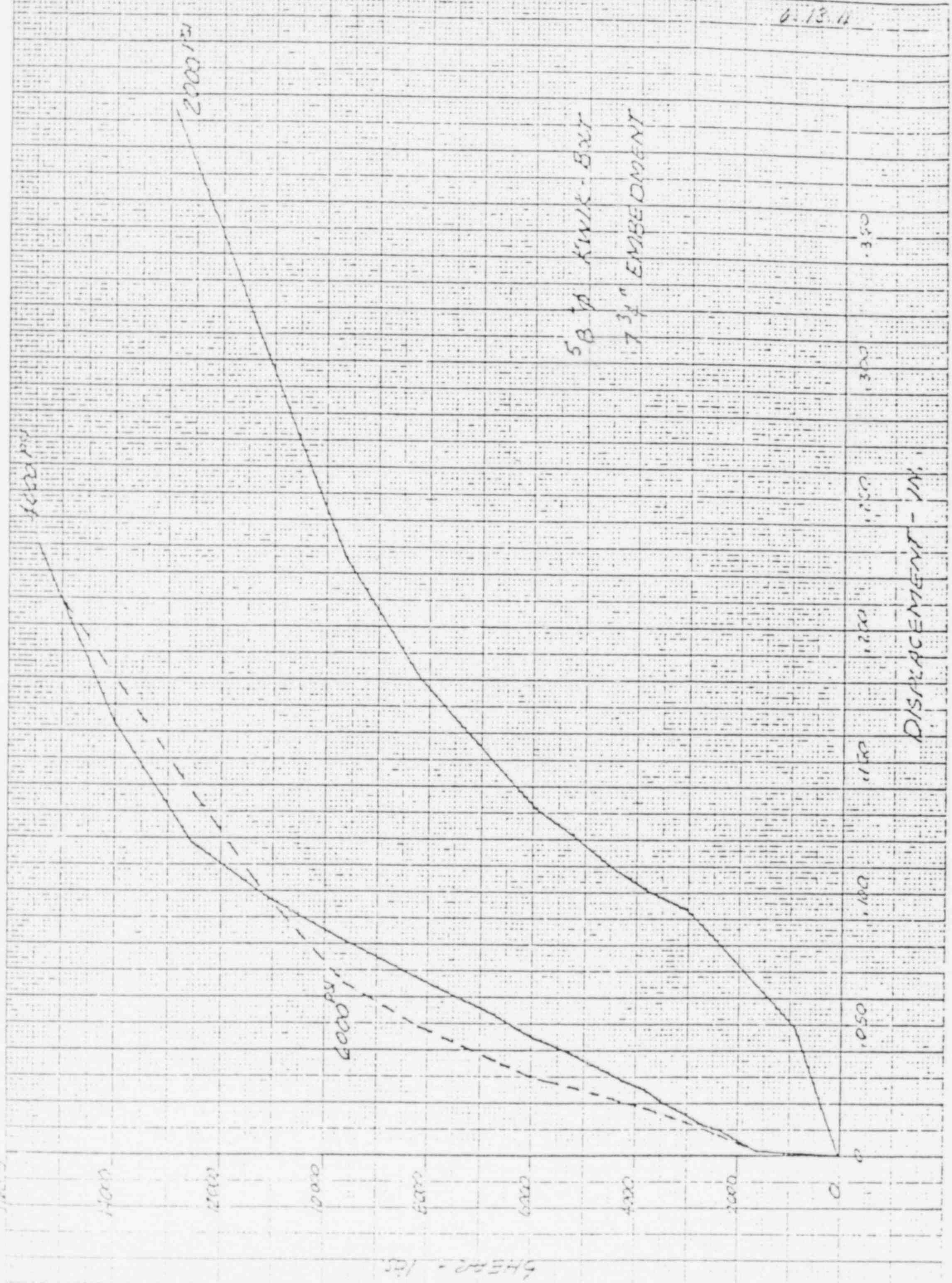
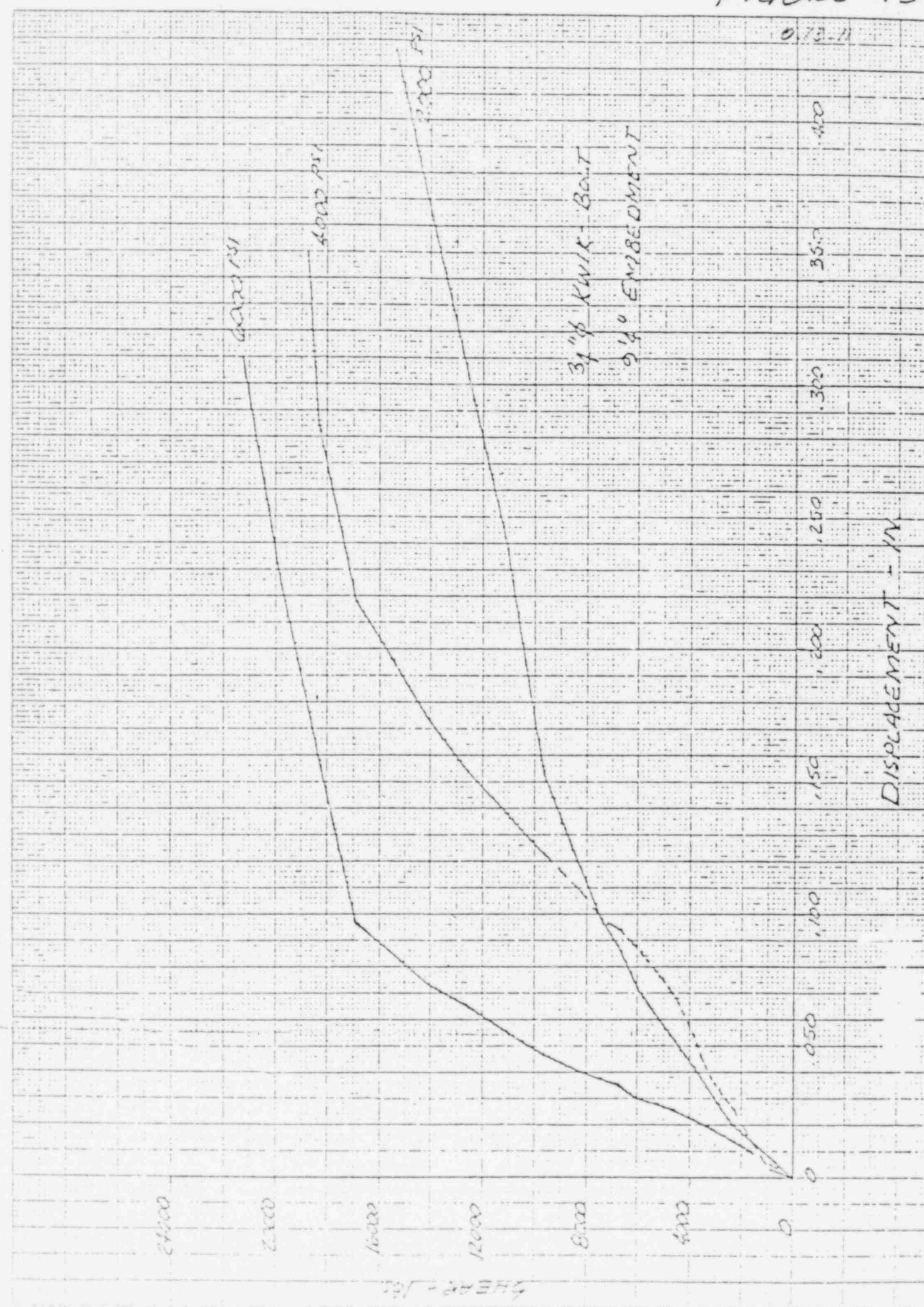


FIGURE 13



3/4" φ KWIK-BOLT
3 1/4" EMBEDMENT
6000 PSI
4000 PSI
2000 PSI
0
.050
.100
.150
.200
.250
.300
.350
.400
DISPLACEMENT - IN.
0
4000
8000
12000
16000
20000
24000

FIGURE 14

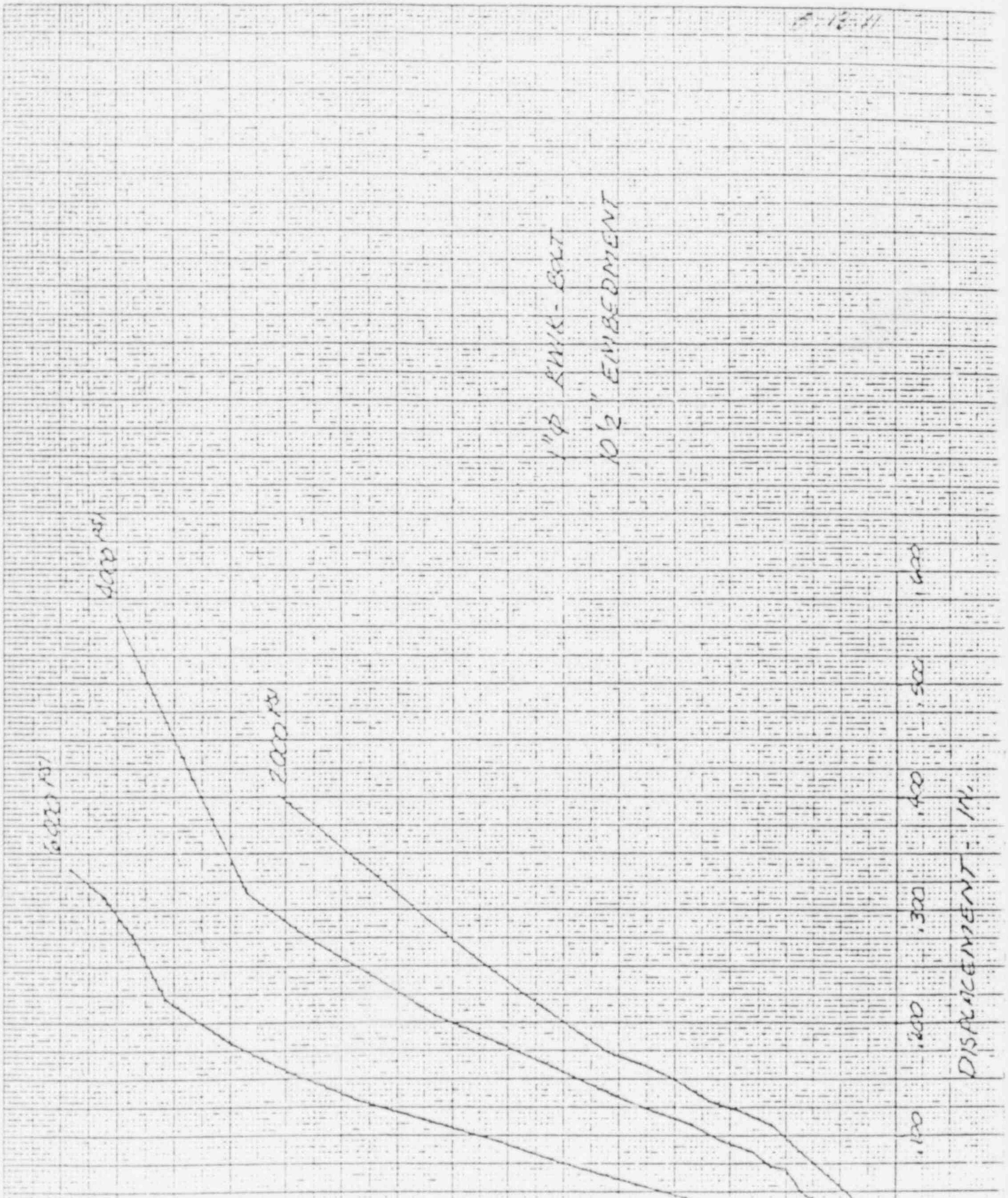
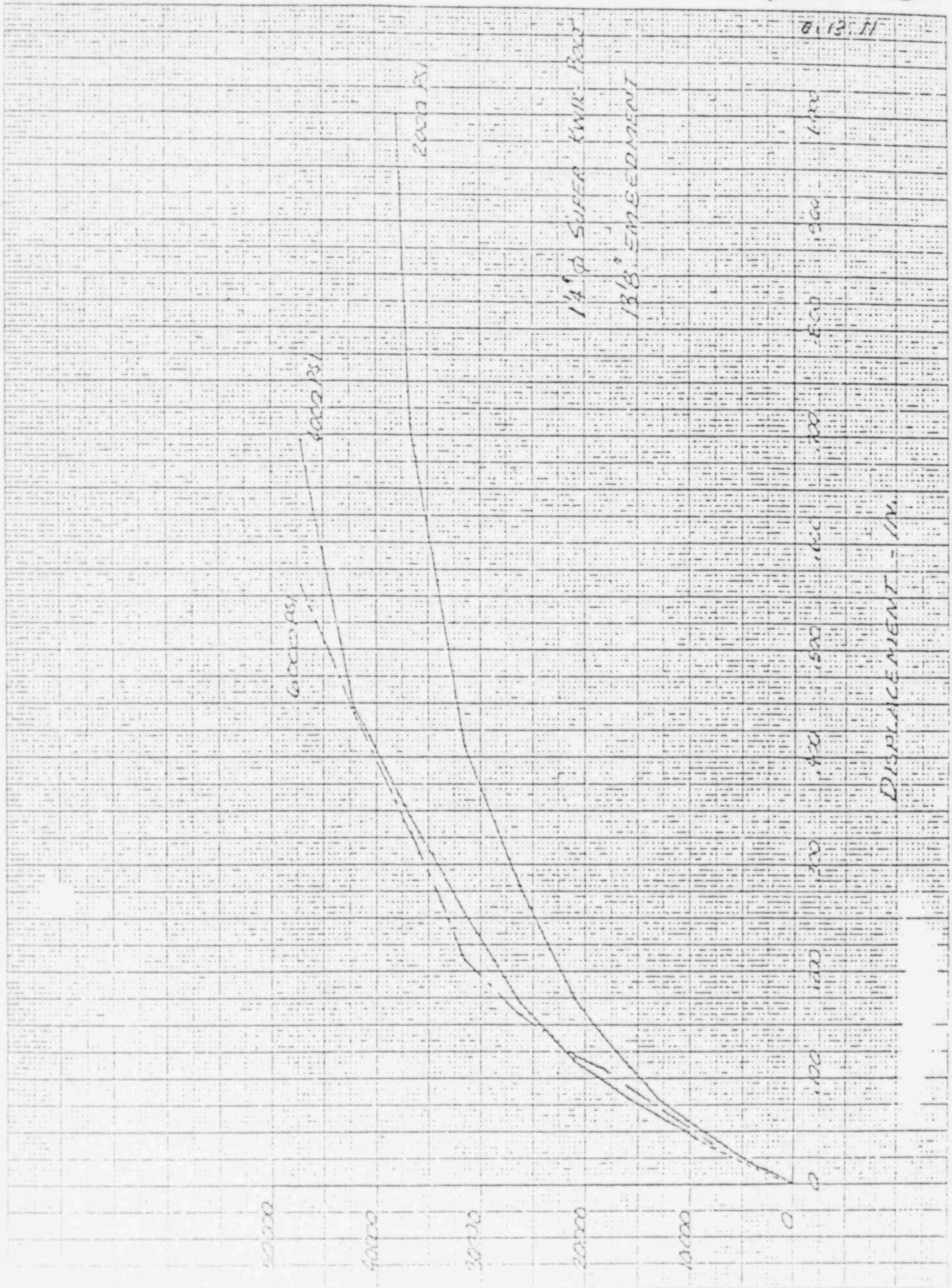

1"φ KWIK-BOLT
10½" EMBEDMENT
6000 PSI
4000 PSI
2000 PSI
DISPLACEMENT - IN.
0
.100
.200
.300
.400
.500
.600

FIGURE 15



1¼" ⌀ SUPER KWIK-BAR
13 1/8" EMBEDMENT
2000 PSI
4000 PSI
6000 PSI
DISPLACEMENT - IN.
SHEAR - LB.
0
10000
20000
30000
40000
50000