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MILLS,L.M. Tennessee Valley Authority
RECIP.NAME RECIPIENT AFFILIATION
O'REILLY,J.P. Region 2, Atlanta, Office of the Director

SUBJECT: Final deficiency rept re tensile anchor capacities lower than assumed in design allowables,initially reported on 790212.Review of welded stud attachments conducted.Detailed study encl.

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TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401

400 Chestnut Street Tower II

April 1, 1981

RECEIVED APR 06 1981 U.S. NUCLEAR REGULATORY COMMISSION

Mr. James P. O'Reilly, Director
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Region II - Suite 3100
101 Marietta Street
Atlanta, Georgia 30303

Dear Mr. O'Reilly:

BELLEFONTE NUCLEAR PLANT UNITS 1 AND 2 - TENSILE ANCHOR CAPACITIES LOWER THAN ASSUMED IN DESIGN ALLOWABLES - NCR CEB 79-7 - FINAL REPORT

The subject nonconformance was initally reported to NRC-OIE Inspector T. Burdette on February 12, 1979, in accordance with 10 CFR 50.55(e). This was followed by our interim reports dated March 14, May 17, July 30, and December 17, 1979, and February 29, May 7, and September 8, 1980. Enclosed is our final report. This deficiency was also reported for Watts Bar, Sequoyah, Hartsville, and Phipps Bend Nuclear Plants.

If you have any questions concerning this matter, please get in touch with D. L. Lambert at FTS 857-2581.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills, Manager
Nuclear Regulation and Safety

Enclosure
cc: Mr. Victor Stello, Jr., Director (Enclosure)
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, DC 20555

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8104070525

TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN
THERMAL POWER ENGINEERING

Civil Engineering Branch
Research and Development Staff

WELDED STUD ANCHORS
EFFECT OF PLATE FLEXIBILITY
ON STUD CAPACITY

CEB Report No. 79-18

ENCLOSURE
BELLEFONTE NUCLEAR PLANT UNITS 1 AND 2
TENSILE ANCHOR CAPABILITIES LOWER THAN ASSUMED IN DESIGN ALLOWABLES
NCR CEB 79-7
10 CFR 50.55(e)
FINAL REPORT

Description of Condition

Progressive cracking of the heat-affected zone of welded stud anchors in flexible plate connections has occurred in TVA general research and development tests. This results in lower tensile anchor capacities than assumed in establishing design allowables.

Safety Implications

Based on the results and conclusions of the testing program, a review of welded anchorages found the anchorages were not adequate and would not have performed as designed under design loadings. This failure to perform as designed could have damaged safety systems supported by these plates and, consequently, could adversely affect the safe operation of the plant.

Corrective Action

A testing program was initiated to qualify the effect of plate flexibility on stud capacity as a guide for all TVA's nuclear plants. The results of the tests are contained in CEB Report 79-18 (Attachment 1).

A review of welded stud attachments for safety-related systems was conducted to verify the plant's compliance with Attachment 1. Listed below are the corrective actions required for each Category I building that contained attachments which did not qualify in accordance with the guidelines contained in Attachment 1.

Auxiliary and Control Buildings

Attachment Number	Number Anchorages Requiring Changes	Corrective Action
MKA, A'	119	Stiffeners
MK 2	1	Stiffeners
MK 19	12	Stiffeners
MK 36	11	Stiffeners

Reactor Building

H-110	1	Redesign
H-544	1	Redesign

Diesel Generator Building

Attachment Number	Number Anchorages Requiring Changes	Corrective Action
MK 6A	44	Bracing
MK 6B	24	Stiffeners
MK 6D	96	Stiffeners
MK 6E	102	Stiffeners
MK 6F	3	Bracing
MK 6P	2	Bracing
MK 6R	4	Bracing
MK 6W	14	Stiffeners
MK 6AA	2	Bracing
MK 7A	2	Surface Mounted Plate
MK 7B	2	Surface Mounted Plate
MK 8E	2	Stiffeners
MK 8G	2	Stiffeners

Bellefonte site work will be completed before fuel loading.

TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN
THERMAL POWER ENGINEERING

Civil Engineering Branch
Research and Development Staff

WELDED STUD ANCHORS EFFECT OF PLATE FLEXIBILITY ON STUD CAPACITY

CEB Report No. 79-18

Principal Investigator:	Robert W. Cannon	Issue Date:	7/10/79
Principal Engineer, Research and Development Staff:	Robert W. Cannon	Revision date:	
Chief, Civil Engineering Branch:	R. G. Domer		

WELDED STUD ANCHORS
EFFECT OF PLATE FLEXIBILITY ON STUD CAPACITY
CEB REPORT No. 79-18

In tests reported in Reference No. 1 welded stud anchors failed by pulling plugs out of the flexible attachment plates at capacities less than minimum stud material requirements. As a result of this, noncompliance reports were filed (see references) on all active TVA nuclear construction projects and a test program (Reference 2) was undertaken to quantify the effect of plate flexibility on stud capacity. This report describes the results of the test program.

The plug failures reported in Reference No. 1 were not experienced in any of the 24 tests reported herein, however reduced capacities were experienced which must be attributed to plate flexibility. A comparison of all test results to date is shown on Exhibit No. 5. As a result of this comparison it is our opinion that the reduced capacity is principally a function of plate flexibility rather than mode of failure. Plate failure occured in two of the tests. However TVA metalurgist Paul Guthrie described these failures as normal bending type failures and not lamellar tares. In his opinion the plates used in these tests were not susceptible to lamellar tearing. These tests do demonstrate that the mode of stress transfer alone is not responsible for plug failures. We must therefore conclude that a combination of material susceptibility and mode of stress transfer is necessary to duplicate plug failures. Since the test data from the plug failures fits the pattern of test data from stud failures we have concluded that the failure mode does not significantly effect capacity.

The effect of reduced stud capacity with increased eccentricity of load transfer and decreased thickness of plate is to restrict the effectiveness of studs to the first line of anchors beyond the face of the attachment. When the eccentricity "e" (representing the shortest distance from anchor to attachment) and plate thickness "t" exceed an e/t ratio of two, Exhibit 5 indicates that the tensile strength allowable for the anchor should be based on:

$$f_{SU} = 60 - 15\sqrt{e/t - 2} \text{ in ksi.}$$

When the overall spacing of exterior effective anchors exceeds the width of attachment or where the spacing is eccentric to the position of the attachment, then the effective capacity of a line of anchors must be weighed on the basis of the summation of the individual anchor capacities. This can be assumed since the same e/t relationship reducing anchor capacity also reduces or balances anchor displacements by the distribution of load to the anchors.

Description of Tests

Four 11 by 11 inch plates and four 3 by 11 inch plates, each of 1/2, 3/4, and 1 inch thickness were obtained from Watts Bar Project QA materials, and symetrically shop welded on the project with studs spaced eight inches on center. Five eighths inch studs by six inches long were welded to the 1/2 inch thick plates. Three-quarter inch studs by 7-1/2 inch long were welded to the other sizes. Inspection of the specimens prior to embedment in the test blocks revealed much working and grinding of the welds and all specimens were rejected. In securing the second batch of specimens it was requested that all ferrules be left in place. These ferrules were carefully removed at the laboratory during inspection prior to embedment. With the exception of one or two welds, which were repaired with normal procedures, all welds were judged acceptable.

Tensile tests were performed on half of the specimens. Pictures of the test rig are shown in Exhibit 1 and ultimate results are contained in Exhibit 3. Anchor displacements were measured at each loading increment by dial gages located directly above the anchors. Load displacement curves for the tensile tests are shown in Exhibits 6-8.

Since no plug failures occured in the tensile tests it was decided to test the remaining 12 specimens by applied moment to see if the manner of load application is the principal factor controlling the mechanism of failure. Pictures of the moment testing rig are shown in Exhibit 2 with moment capacities shown on Exhbit 4. Anchor displacement were measured and plots of applied moment vs anchor displacement are shown in Exhibits 9-14.

Anchor Displacement and Flexible Analysis

In general concrete failure did not occur around the peripher~~t~~y of the embedded plate at low loading nor did visible displacement of the plate edges occur with respect to the concrete until the tensile loading reached approximately 50 percent of the load capacity. Under direct tensile loading the upper surface of the outer edges of flexible plates tend to rotate outward due to the downward pull of the anchors. When the plate is embedded with its upper surface flush with the concrete surface the concrete will restrain this rotation creating a frictional force which supports directly the load in the anchors such that the actual net force in the anchors is the difference between the applied load and this frictional drag.

In the moment tests the tendency for the upper surface to rotate outward is offset by the counter rotation of the attachment. The differences can be seen by comparison of the load and moment-deflection curves (Exhibits 9 and 10). If the average load-deflection curve for the 3/4 inch anchors is assumed and moments-calculation on the basis of minimum moment arms of 7.5 inches for the 3/4 inch plates and 8 inches for the one inch plates the resulting moment deflection curves would be as shown. The increased stiffness in the low stress range for the assumed minimum moment arms substantiates the edge support discussed above. The same phenomenum does not occur with the 1/2 inch thick plates because the increased flexibility of these plates will allow for prying action to occur between the anchor and plate edge. This prying action offsets the edge support. This can be seen in Exhibit 11 which shows a close match up of theoretical and measured displacements when the input data is taken from the tensile tests.

The ability of any method of analysis to predict system deflections is dependent principally on the accuracy of predicted anchor displacements under load. The curves for the flexible analysis shown on Exhibits 9 and 10 are based on the adjusted average displacement curve shown on Exhibit 6 and 7. The effect of increasing anchor displacement in a flexible analysis, is to increase the effective moment arm of the anchorages to a maximum value dependent on the flexibility of the plate and the displacement capacity of the anchor. In the development of stud capacities for the moment tests of Exhibit No. 5 we have assumed a maximum displacement capacity of 0.25 inches at 60 ksi anchor stress. We also used the average load displacement data of the tensile tests (not adjusted average) as input to the flexible analysis. Varying this displacement data within reasonable results will not significantly effect the calculated anchor stress at ultimate moment capacities.

Comparison With CEB Report No. 78-210

A comparison of this moment vs anchor displacement is shown on Exhibit 9-11. The curves from CEB Report No. 78-210 (listed as 77-17, 78-11, 78-12, 78-13, 78-14) have been adjusted to account for the difference in deflections measured from a point half way between the anchors to a direct anchor displacement. In all cases the anchor displacement from the 78-210 tests exceed the displacement of the 79-18 tests over the full range of measurements. With the exception of Test No. 78-12 the failure mode for the remaining 78-210 tests was by pullout of plugs from the plate. In our opinion this increased displacement confirms our original assumption of progressive cracking in the 78-210 test report.

A comparison of the moment capacities of the two sets of tests indicate the 78-210 tests had higher capacities with the 1 inch thick plates, approx equal capacities in the 3/4 inch plate tests, and lower capacities in the 1/2 inch plate tests. There appears to be no consistent correlation between the load displacement curves and ultimate capacity in any of the tests. Apparently the variation in residual stress due to welding influences displacements in the lower load ranges but reduces in effect as yielding propogates over a larger proportion of area as loading approaches ultimate.

Load Distribution Beyond The First Line Of Anchors

The distribution of load beyond the first line of anchors depends on: (1) the displacement of the first line of anchors, (2) the thickness of plate, (3) the size and location of the attachment with respect to the anchors, and (4) the reduced capacity of the second line of anchors due to plate flexibility. The distribution of load for a typical 3/4 inch thick strip plate is shown in Exhibit No. 15.

Exhibit 15 indicates a limited eccentricity of load transfer to the first line of anchors of approx 3 inches for any load distribution to the second line of anchors witnout exceeding the stud capacity of the first line of anchors. The limit shown for the second lines of anchors is based on the e/t relationships developed here-in and may not be a valid limit for multiple lines of anchors. If the limit is valid the graph indicates that the second line of anchors will generally fail before the first line of anchors reach their limit. If so then failure of the second anchor line generally occurs at an applied moment less than the capacity of the first line of anchors acting independently. This is generally true (by analysis) for thicker plates as well. Thus, until more specific information can be obtained on the capacities of the second line of anchors beyond the attachment they should be discounted and not be considered available for support of an adjacent attachment.

Design Recommendations

1. Effective Anchors

   (a) Consider as effective only those anchors immediately beyond the attachment. (The first line of anchors.) If the tensile flange of the attachment is directly over an anchor or is in direct line with a line of anchors then the next line of anchors is effective.

   (b) Except as outlined in 1(a) disregard the second line of anchors beyond an attachment for utilization by any other attachment.

2. Design Allowables

   (a) Consider the e/t relationship of each tensile anchor beyond the attachment and establish the ultimate stress capacity of each anchor by:

   $$f_{SU} = 60 - 15\sqrt{e/t - 2}$$

   (b) For service load conditions apply a minimum factor of safety of 2.5 to the tensile capacities determined in 2(a).

   (c) For factored load conditions apply a minimum factor of safety of 1.5 to the tensile capacities determined in 2(a).

   (d) For the effectiveness of a line of anchors use the summation of the individual anchor design allowables.

   (e) In the transmission of shear, disregard all tensile anchors whose capacity is effected by plate flexibility and transmit the entire shear through the remaining anchors.

3. Unless a flexible analysis is used assume the center of gravity of the compressive force in an anchorage is located at a point 2 plate thicknesses beyond the compression elements of the attachment.

Criteria For Qualification Of Designs

Minimum Spacing of Studs. For a given size stud of fixed length there is a minimum stud spacing which is required for a given strength of concrete to fully assure the development of the stud capacity. (See Civil Design Standard DSC6.1 for embeddment requirements.) For Exhibits 16-21 we have assumed a minimum spacing of seven inches on center for 3/4 inch studs and six inches on centers for 5/8 inch studs. This spacing requires a concrete strength in excess of 5000 psi for full development. Since the long range strength of all TVA structural concrete (containing fly ash) exceeds this, the spacing should be an acceptable minimum particularly with flexible plate connections because of the reduced stud capacities.

Plate flexibility and reduced stud capacity have been accounted for in the development of the anchorage capacities shown in Exhibits 16-21. The uniaxial capacities are based on location of the attachment anywhere within the configuration of the anchors such that minimum capacities are given. If the spacing of anchors is taken as "S" then a minimum edge distance for the attachment should be maintained as (S-1)/2. Note: A lesser edge distance from stud to plate may be utilized to reduce plate size without reducing capacity as long as the above minimum edge distance to attachment is maintained.

Basic Criteria: No failure of anchorage will occur in flexure as long as the uniaxial moment capacity of the anchorage exceeds the strong axis moment capacity of the attachment or exceeds the capacity of the welds connecting the attachment to the anchor plate providing: (1) None of the effective anchors are closer than two anchor spaces from anchors utilized by another attachment, (2) a minimum edge distance for the attachment of (S-1)/2 is observed.

In general the controlling element in the effect of increased anchor spacing on moment capacity is the effect of increased eccentricity on stud capacity. The charts can be used to conservatively qualify larger anchor spacing by altering the effective width of the attachment with larger anchor spacing. This is done by reducing the actual width of attachment by an amount equal to approximately 2/3 of the difference between the overall spacing of the actual attachment anchors and the overall spacing of the anchors in the charts. As an example: (1) Assume a six inch tube section and a 1 inch thick by 16 inch wide plate with 4-3/4 inch anchors at 10 inches on center. The difference in anchor spacing is 3 inches therefore read a capacity for a "w" of 4 inches from Exhibit No. 16 of 400 inch kips. (By analysis the minimum capacity is 419 inch kips.) (2) Assume a 21 inch attachment width on a 1 inch thick plate 36 inches wide with 16-3/4 inch anchors at 10 inch on center. From Exhibit No. 18 read 2350 inch kips from W = 21 - (30-21)2/3 = 15 inches. (By analysis the minimum capacity is 2580 inch-kips.)

Conclusions

1. The tensile capacity of welded stud anchors is effected by the flexibility of the attachment plate transmitting stress to the anchors. Considering

"e" as the minimum distance from anchor to attachment and "t" as the thickness of plate; the effect of plate flexibility on minimum tensile stress capacity " f_{SU}" can be estimated by:

$$f_{SU} = 60 - 15 \sqrt{e/t - 2} \text{ in ksi.}$$

2. The mode of failure does not appear to be a governing factor in establishing stud capacity. For identical plate flexibilities there appears to be little difference in the ultimate capacities of the stud failures in the test series compared with the plug failures of the plate from the 78-210 series.

3. The effect of reduced stud capacity with increased eccentricity is to restrict anchor effectiveness to the first line of anchors beyond the attachment.

4. For moment type connections the second line of anchors beyond any attachment should be discounted completely because of uncertainties related to capacities. The second line of anchors may be subject to failure at applied moments less than the moment capacity excluding those anchors.

5. When the location of attachment with respect to anchors is known the ultimate moment capacity of the anchorage about any axis can be reasonably estimated by using the above reduced tensile stress allowables for each tensle anchor beyond the attachment and by assuming the center of gravity of the compression is located 2 plate thicknesses beyond the compression elements of the attachment. Anchors located between the CG of the compression and the tension anchors exterior to the attachment may be assumed to have stresses in proportion to their distances from the location of the CG.

6. When the location of the attachment with respect to the anchors is <u>not</u> known then minimum capacities can be obtained from Exhibits No. 16-21 as described here-in under "Qualification of Designs".

REFERENCES

1. CEB Report No. 78-210 - Anchorage Tests of Load Transfer Through Flexible Plates - Interim Report

2. Ray H. Dunham's memorandum to Gene Farmer dated February 27, 1979 (CEB 790227 028) entitled - Testing of Welded Stud Anchors in Flexible Plate Connections.

3. List of NCR's Filed on the Subject.

   NCR CEB - 79-5 - Sequoyah Nuclear Plant
   NCR CEB - 79-6 - Watts Bar Nuclear Plant
   NCR CEB - 79-7 - Bellefonte Nuclear Plant
   NCR CEB - 79-16 - Hartsville Nuclear Plant
   NCR CEB - 79-12 - Phipps Bend Nuclear Plant

EXHIBITS

No.

1 Pictures of Tensile Test Rig

2 Summary of Tensile Test Results

3 Pictures of Moment Test Rig

4 Summary of Moment Test Results

5 Plot of Welded Stud Capacities vs Plate Flexibility

6 Tensile Tests - Stress vs Anchor Displacement - 1" Plate

7 Tensile Tests - Stress vs Anchor Displacement - 3/4" Plate

8 Tensile Tests - Stress vs Anchor Displacement - 1/2" Plate

9 Moment vs Anchor Displacement - 1" Plate - 4 Anchors

10 Moment vs Anchor Displacement - 3/4" Plate - 4 Anchors

11 Moment vs Anchor Displacement - 1/2" Plate - 4 Anchors

12 Moment vs Anchor Displacment - 1" Plate - 2 Anchors

13 Moment vs Anchor Displacement - 3/4" Plate - 2 Anchors

14 Moment vs Anchor Displacement - 1/2" Plte - 2 Anchors

15 Distribution of Load to Anchors

16 Moment Capacity vs Attachment Width - 4-3/4" Anchor

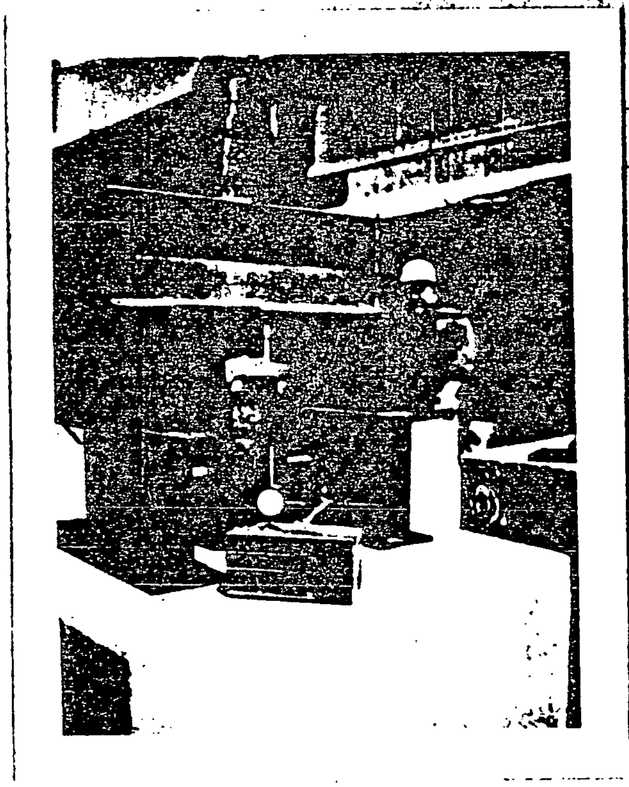
17 Moment Capacity vs Attachment Width - 9-3/4" Anchor

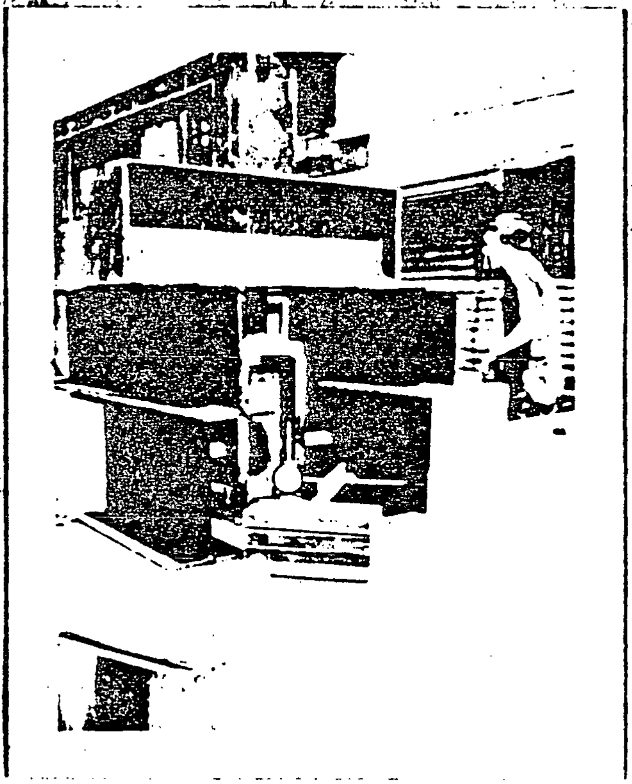
18 Moment Capacity vs Attachment Width - 16-3/4" Anchor

19 Moment Capacity vs Attachment Width - 4-5/8" Anchor

20 Moment Capacity vs Attachment Width - 9-5/8" Anchor

21 Moment Capacity vs Attachment Width - 16-5/8" Anchor





WELDED STUD [redacted] TEST 1 4-19-79

2 - 3/4" ϕ STUDS ON 1" PLATE

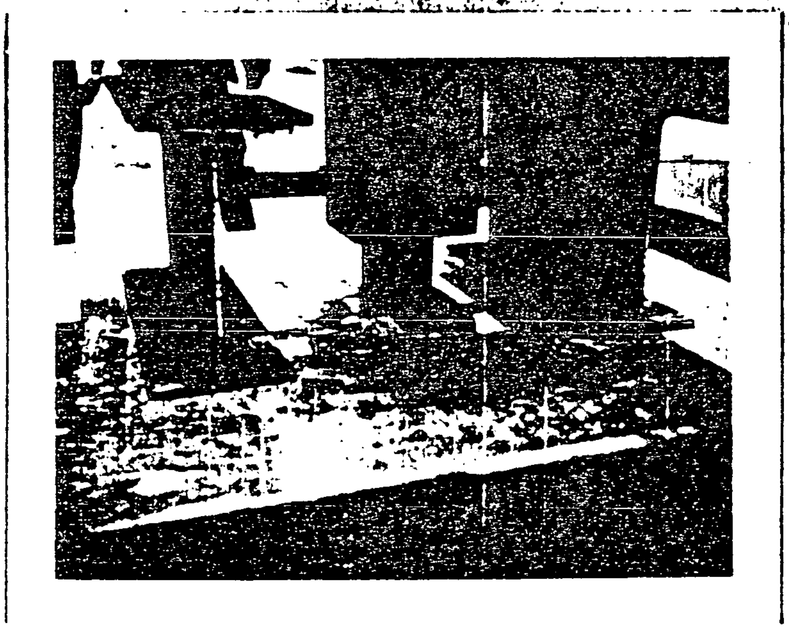


Exhibit #1

		SHEET
WELDED STUD TENSILE TESTS		
SINGLETON LAB		CEB RED
	COMPUTED	DATE 4-26-79
	CHECKED	DATE

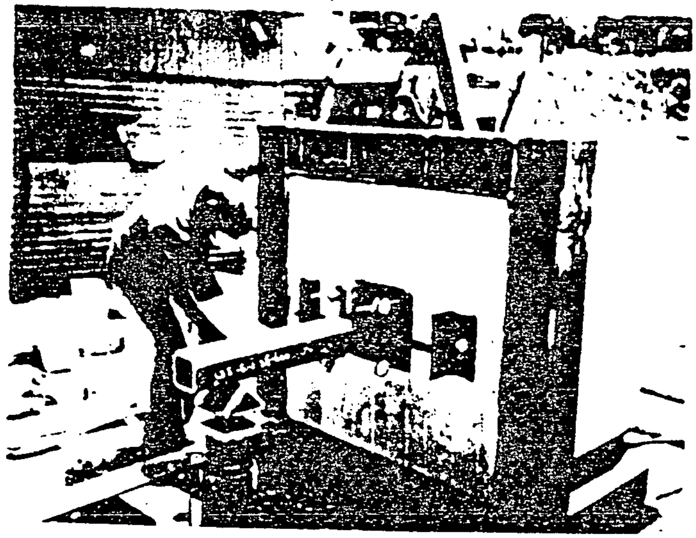
TEST DESIG T79-	DATE OF TEST 1979	# ANCH PER PL	PL THICK (IN)	BOLT DIA (IN)	ULT LOAD (K)	ULT LOAD PER BOLT (K)
1	4-19	2	1	3/4	58.43	29.21
2	4-20	2	1	3/4	55.97	27.98
3	4-20	2	3/4	3/4	47.97	23.99
4	4-20	2	1/2	5/8	28.91	14.45
5	4-20	2	1/2	5/8	28.29	14.15
6	4-20	2	3/4	3/4	46.13	23.06
7	4-23	4	1	3/4	118.13	29.53
8	4-25	4	1	3/4	116.25	29.06
9	4-25	4	3/4	3/4	112.5	28.13
10	4-25	4	1/2	5/8	63.75	15.94
11	4-25	4	1/2	5/8	61.25	15.31
12	4-25	4	3/4	3/4	110.63	27.66

PLATE PROPERTIES

PL THICK (IN)	YIELD STRENGTH	TENSILE STRENGTH
1/2	38400 PSI	52400 PSI
3/4	42400	71700
1	38000	69800

TVA 11030 (WM-7-75)

Exhibit #2



WELDED STUD MOMENT

TEST 2 5-16-79

4 - ¾" ϕ STUDS ON
1" PLATE

LAMELLAR TEARING

Exhibit #3

WELDED STUD MOMENT TESTS

SINGLETON LAB

CEB R&D

COMPUTED ______ DATE 6-15-79

CHECKED ______ DATE ______

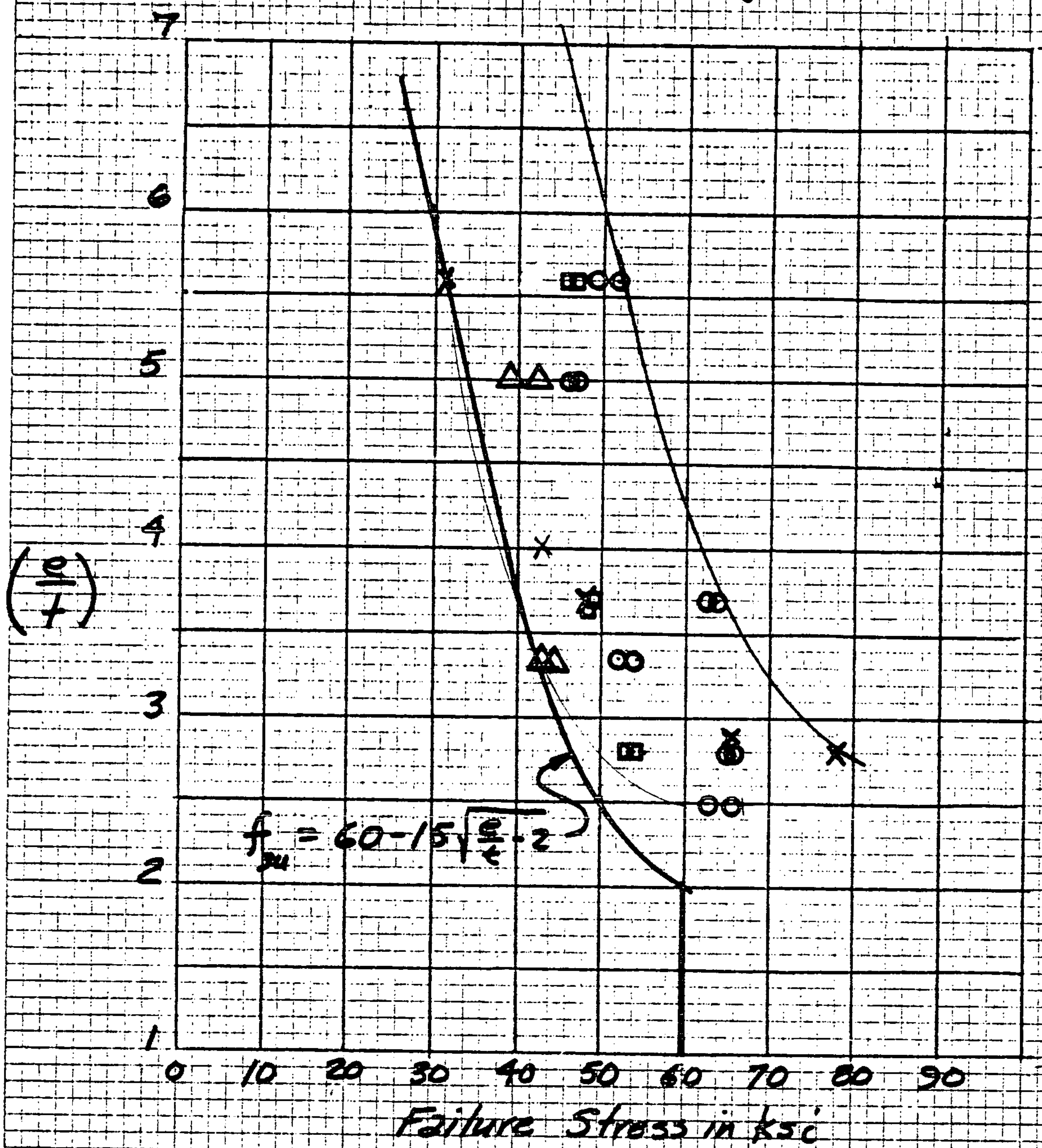
TEST DESIG M79-	DATE 1979	# ANCH PER PL	PL THICK (IN)	BOLT DIA (IN)	ULT LOAD (K)	MODE OF FAILURE	ULT MOM (K-FT)	ULT STRESS* (KSI)
1	5-15	2	1	.75	7995	TUBE YIELDED	16.0	58.2
2	5-16	4	1	.75	18172	STUD FAILURE	36.4	54.0
3	5-17	4	1/2	.625	9440	STUD FAILURE	18.8	47.0
4	5-17	4	1/2	.625	9204	STUD FAILURE	18.4	46.0
5	5-18	4	3/4	.75	15812	STUD FAILURE	31.6	49.6
6	5-18	4	3/4	.75	15576	STUD FAILURE	31.2	49.0
7	5-18	4	1	.75	18408	LAMELLAR TEAR AROUND WELD	36.8	54.8
8	5-18	2	1/2	.625	3540	STUD FAILURE	7.1	39.1
9	5-25	2	1/2	.625	3955	STUD FAILURE	7.9	42.8
10	5-25	2	3/4	.75	6215	PLATE FAILURE	12.4	43.0
11	5-25	2	3/4	.75	6328	STUD FAILURE	12.7	43.2
12	5-29	2	1	.75	8475	TUBE FAILURE	17.0	50.9

* STRESS BASED ON FLEXIBLE ANALYSIS

TVA 11030 (WM-7-75)

Exhibit #4

Welded Studs
Anchor Capacity



e = Shortest distance from anchor to attachment

t = Plate thickness

× = Test Data from CEB Report # 78-210

○ = Test Data from tension tests at Singleton

□ = Test Data from 4 anchor moment tests at Singleton

△ = Test Data from 2 anchor moment tests at Singleton

Note: Failure stress based on flexible analysis.

Exhibit #5

WELDED STUD TENSILE TESTS

1" Plate 3/4" Studs

(ULT LOAD, K)

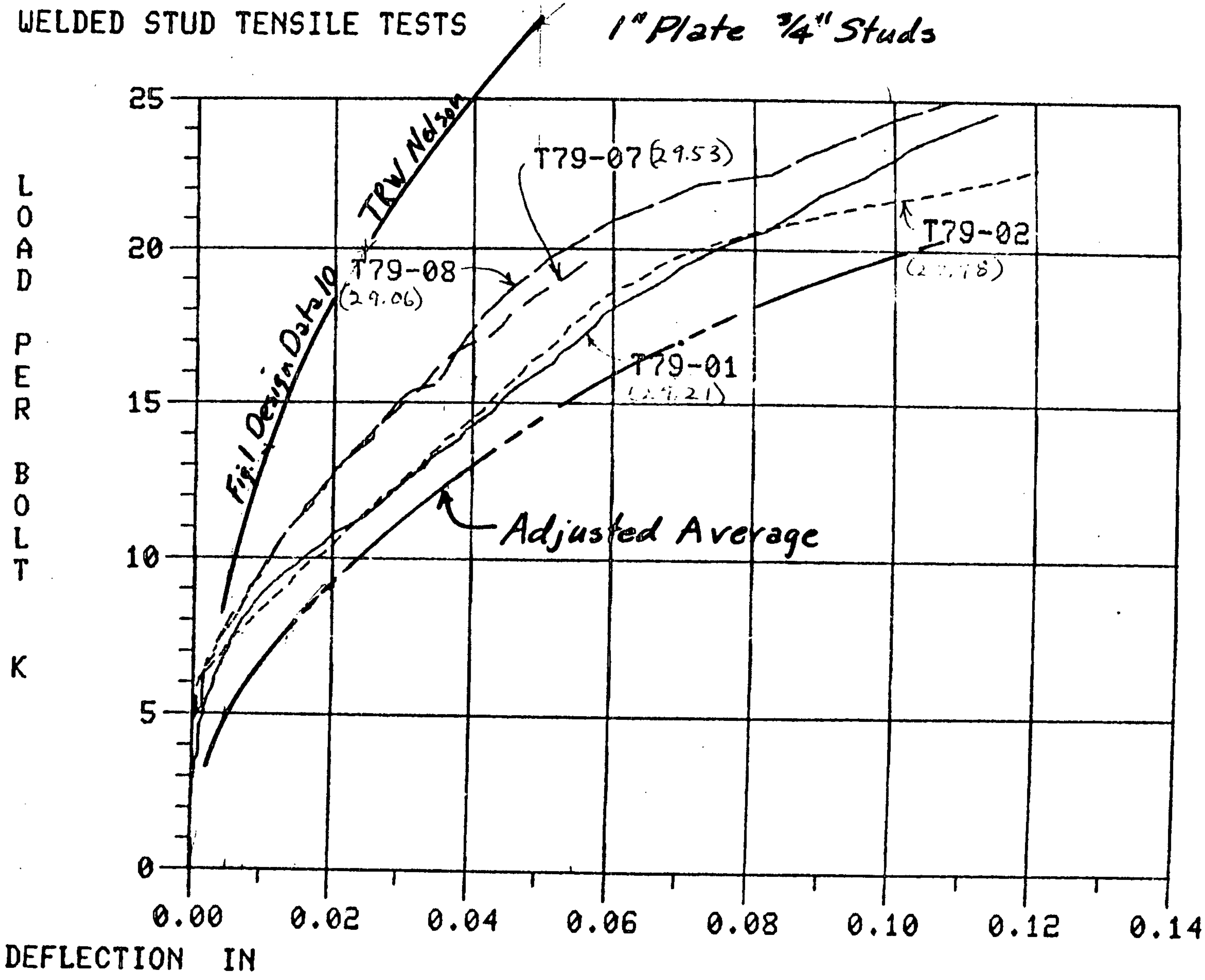
℞ THICNESS = 1" TYP

1 2 STUDS/℞

2 2 STUDS/℞

7 4 STUDS/℞

8 4 STUDS/℞



NOTE: POSITION OF S.G.'s FOR TEST T7901 WAS 1" FROM EDGE OF PLATE INSTEAD OF 1.

Exhibit #6

WELDED STUD TENSILE TESTS 3/4" Plate 3/4" Studs

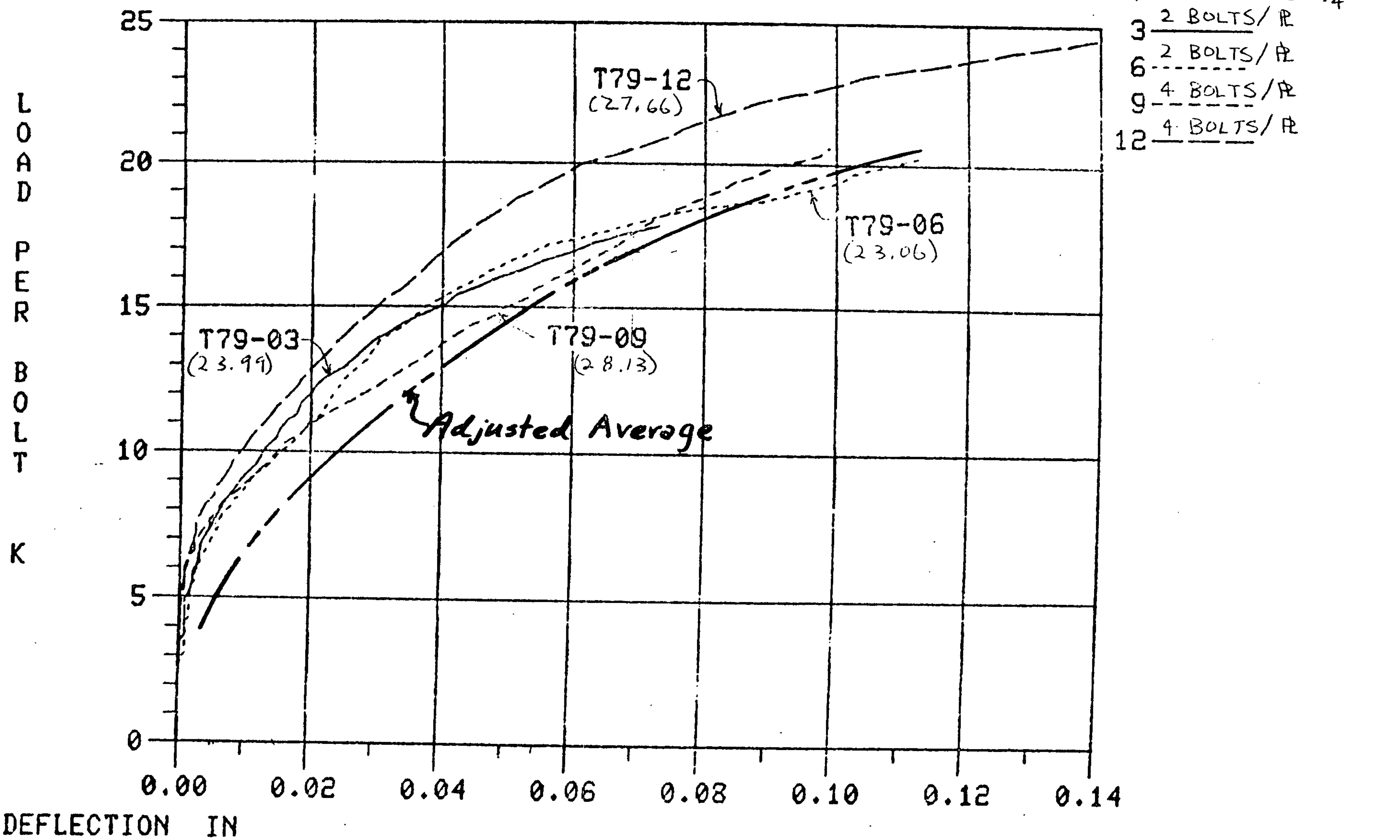


Exhibit # 7

WELDED STUD TENSILE TESTS ½" Plate ⅝" Studs

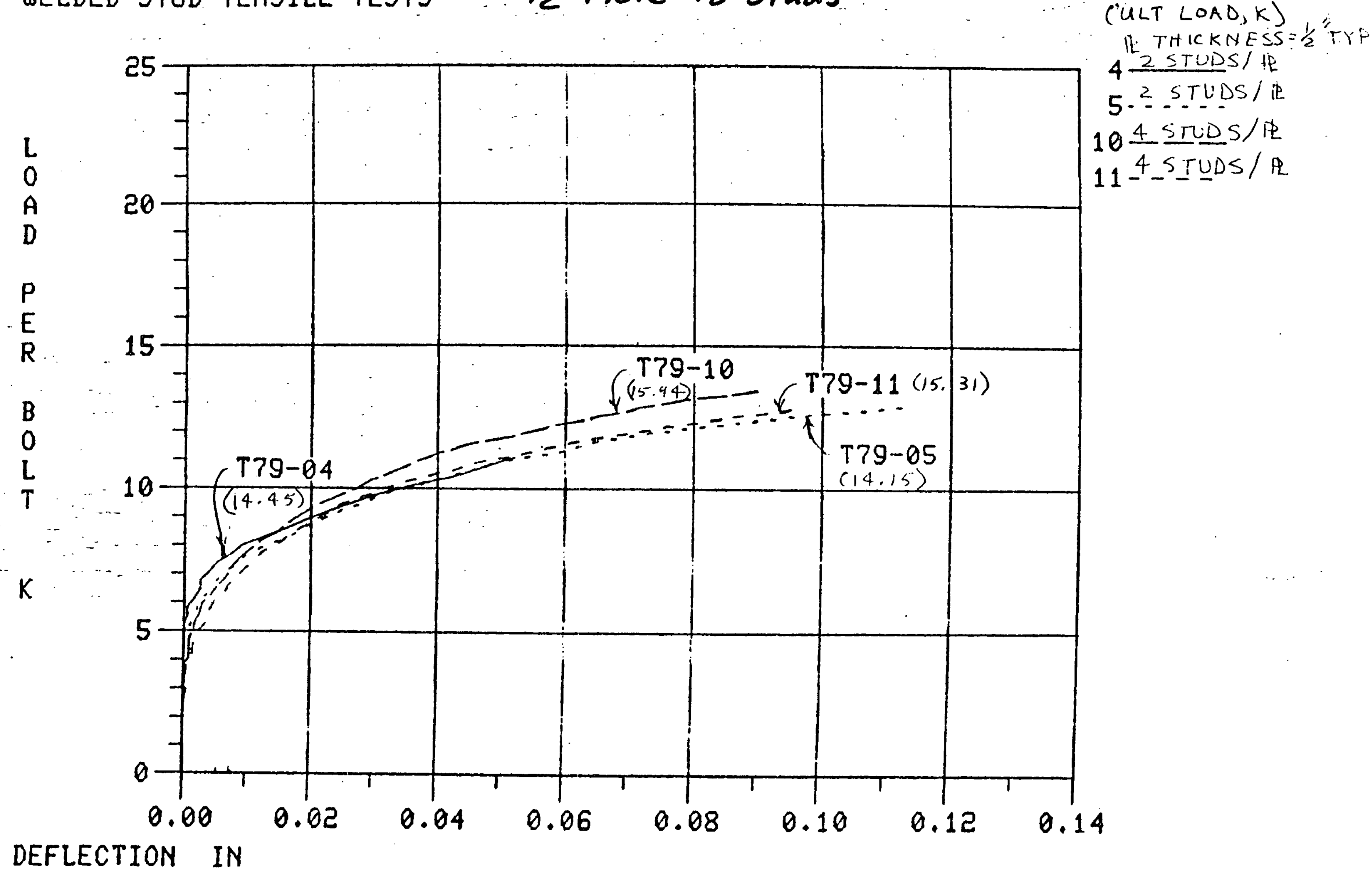
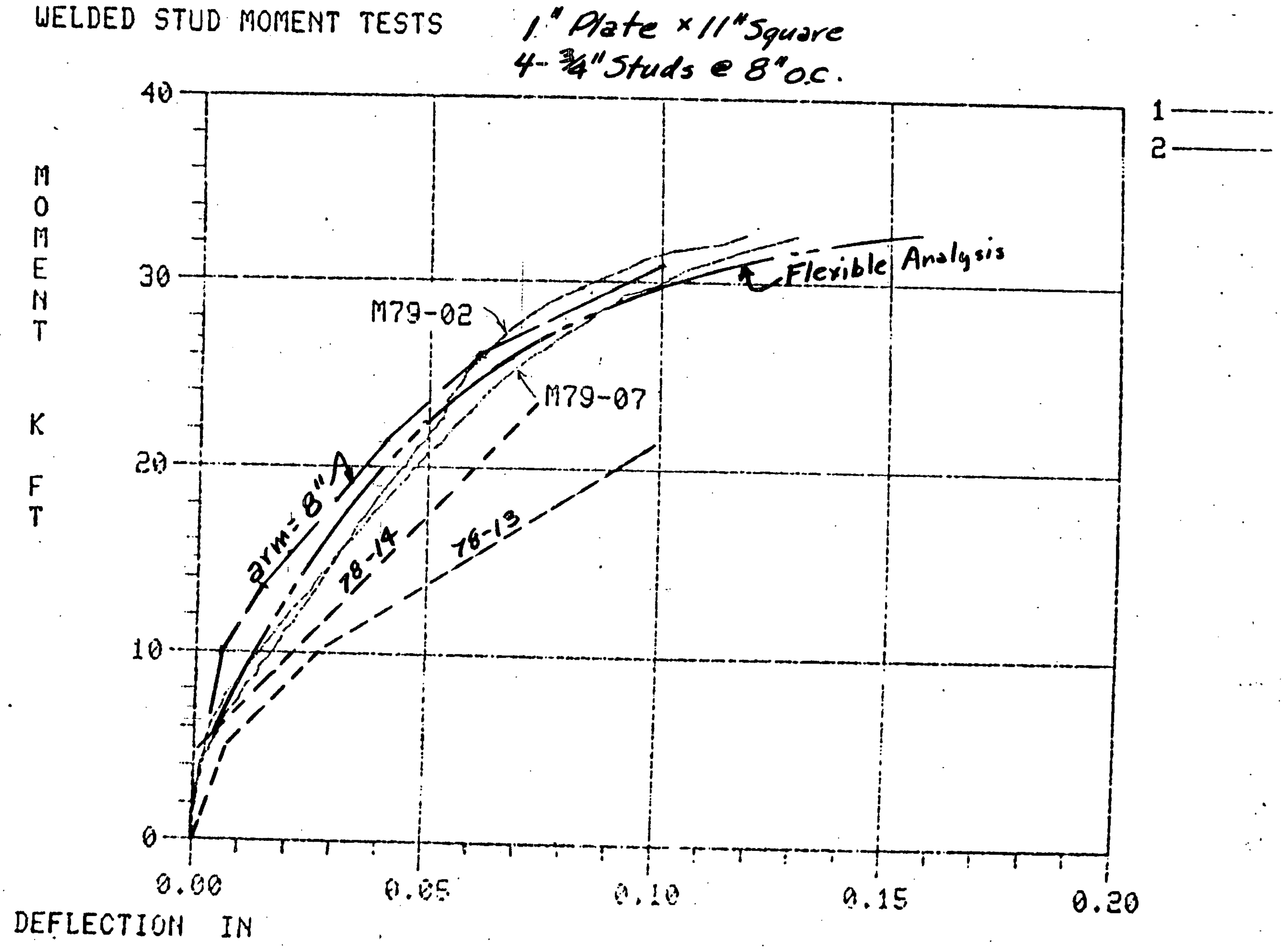


Exhibit #8



WELDED STUD MOMENT TESTS
1" Plate × 11" Square
4-¾" Studs @ 8" o.c.
MOMENT K FT
DEFLECTION IN
0
10
20
30
40
0.00
0.05
0.10
0.15
0.20
1
2
M79-02
M79-07
Flexible Analysis
arm=8"
78-14
78-13

Exhibit #9

WELDED STUD MOMENT TESTS 3/4" Plate × 11" Square
4 - 3/4" Studs @ 8" o.c.

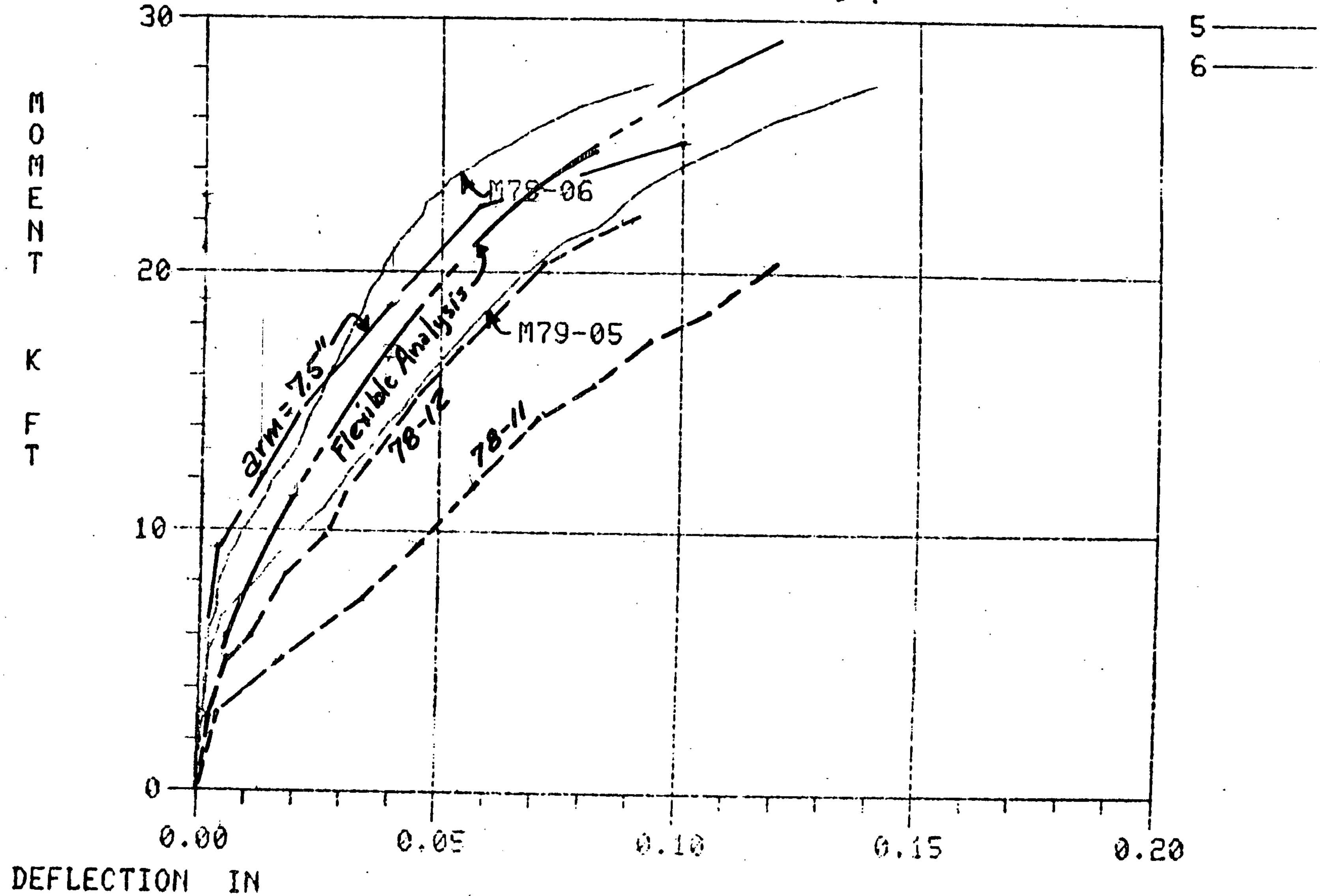
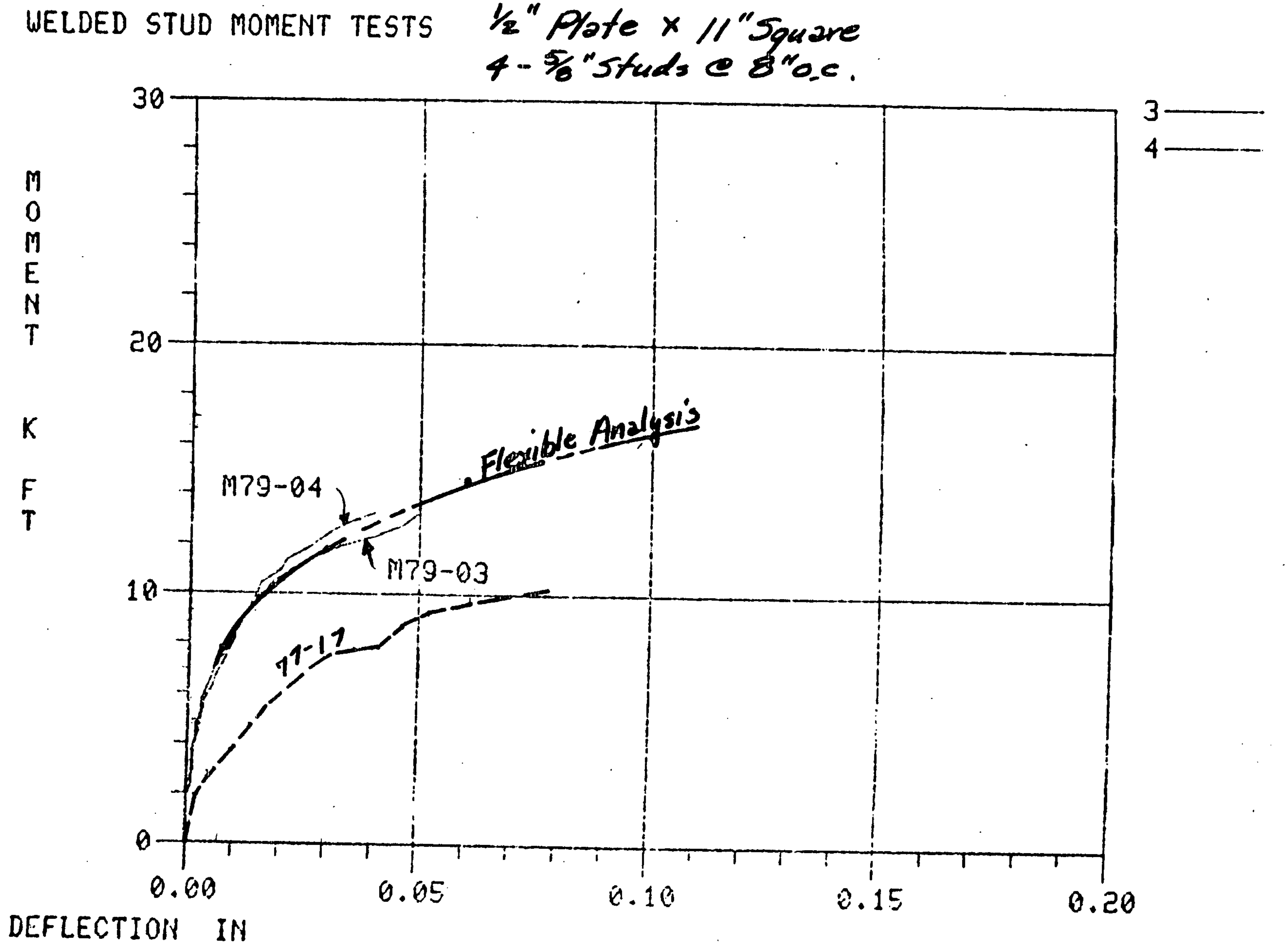


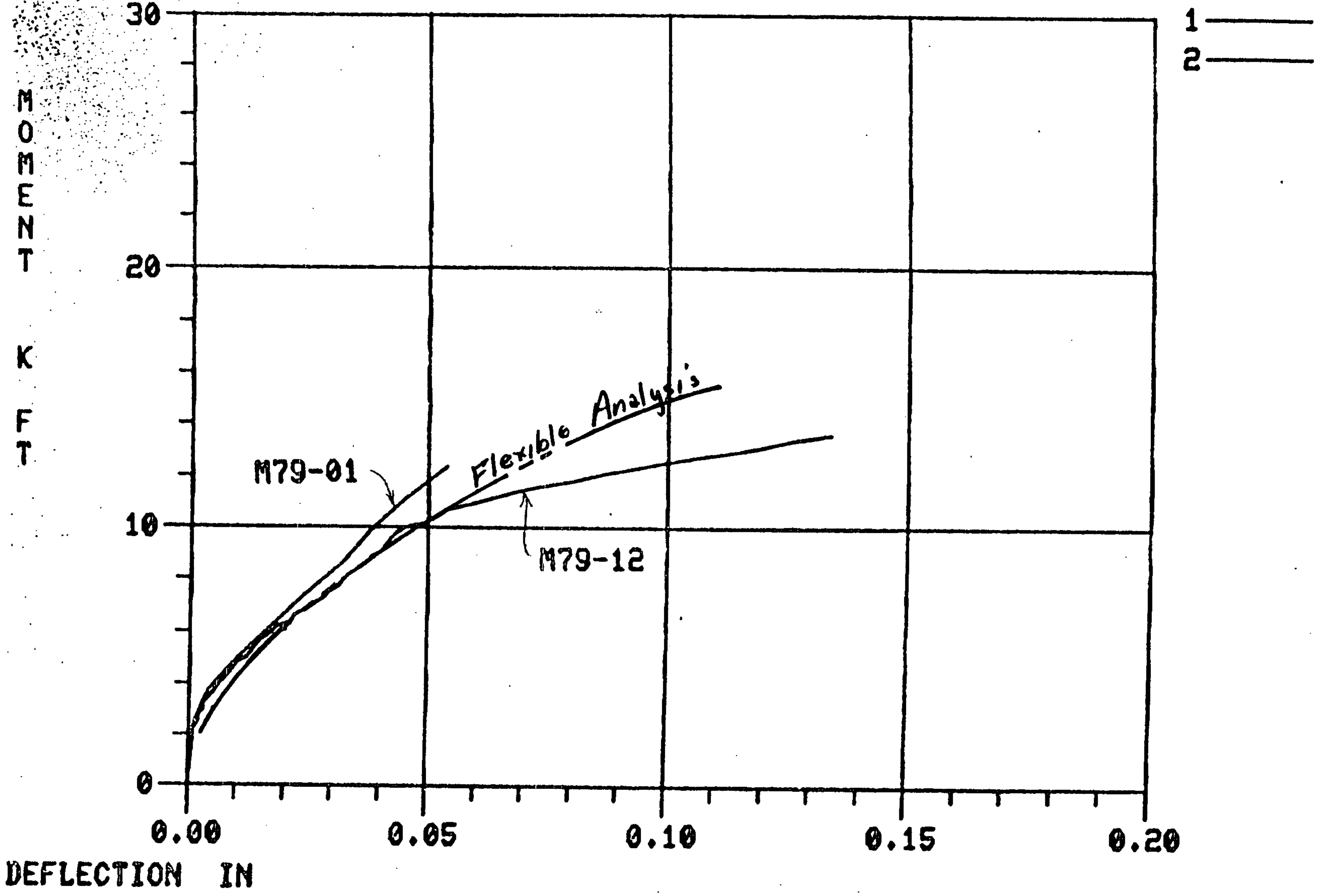
Exhibit #10



WELDED STUD MOMENT TESTS
½" Plate × 11" Square
4 - ⅝" Studs @ 8" o.c.
MOMENT K FT
30
20
10
0
DEFLECTION IN
0.00
0.05
0.10
0.15
0.20
3
4
Flexible Analysis
M79-04
M79-03
77-17

Exhibit #11

WELDED STUD MOMENT TESTS 1" Plate 3"x 11"
2- 3/4" Studs @ 8"oc



Exbibit # 12

WELDED STUD MOMENT TESTS   3/4" Plate 3×11
2 - 3/4" Studs @ 8" o.c.

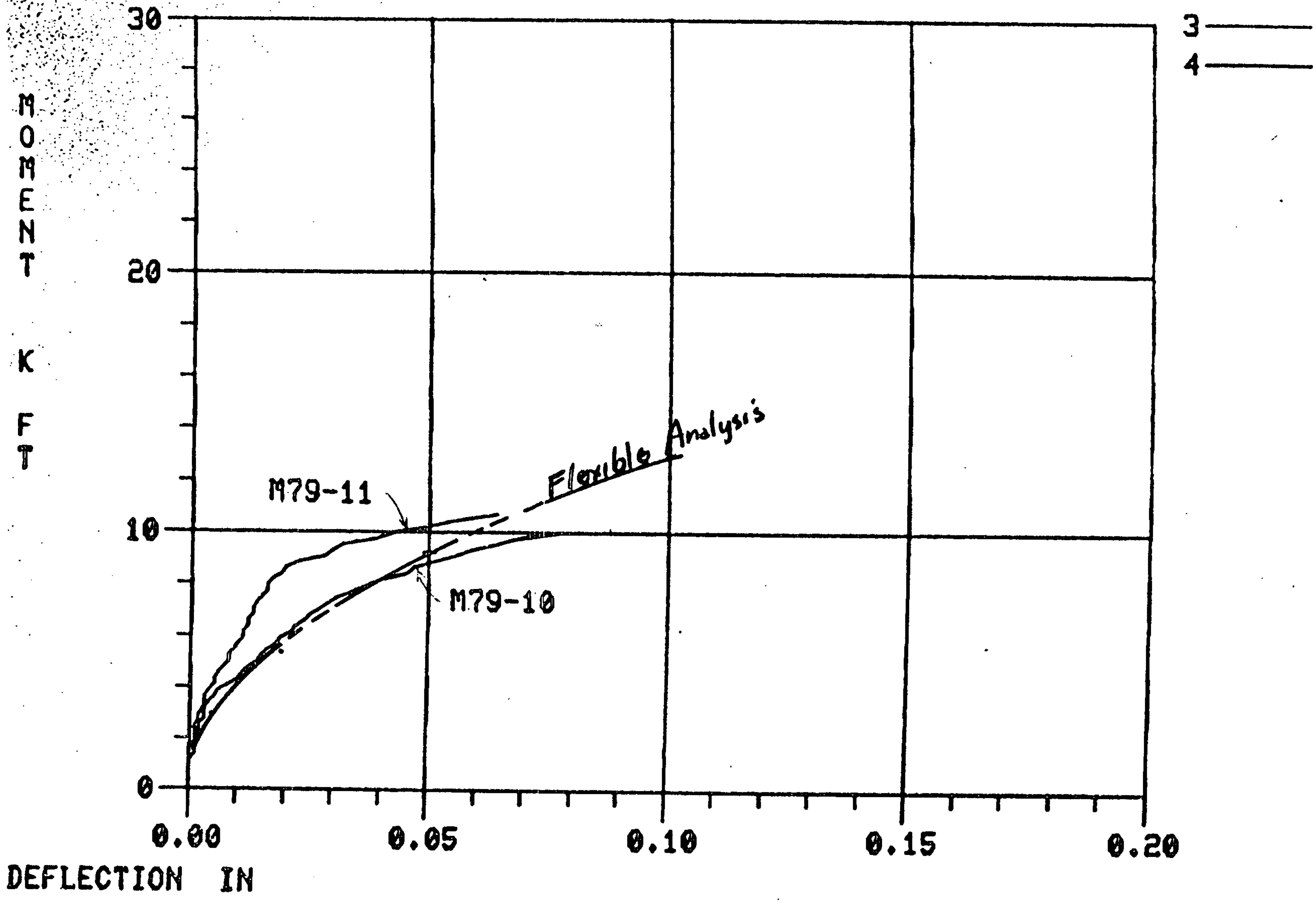
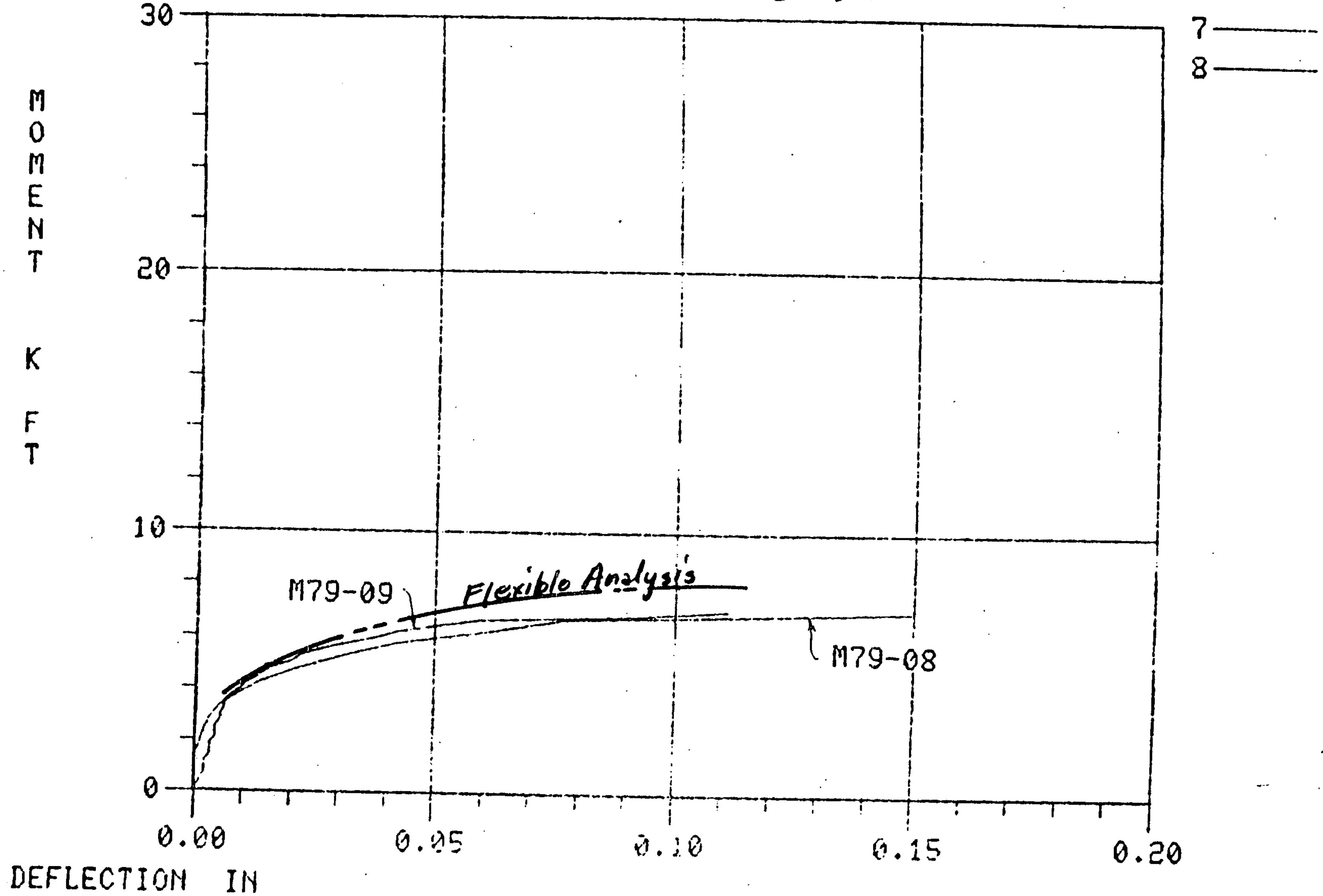


Exhibit # 13

WELDED STUD MOMENT TESTS ½" Plate 3×11
2-⅝" Studs @ 8" o.c.



Exbibit #14

3/4" × 12" Wide Plate
3/4" Studs @ 8" oc
Distribution of Load to Anchors

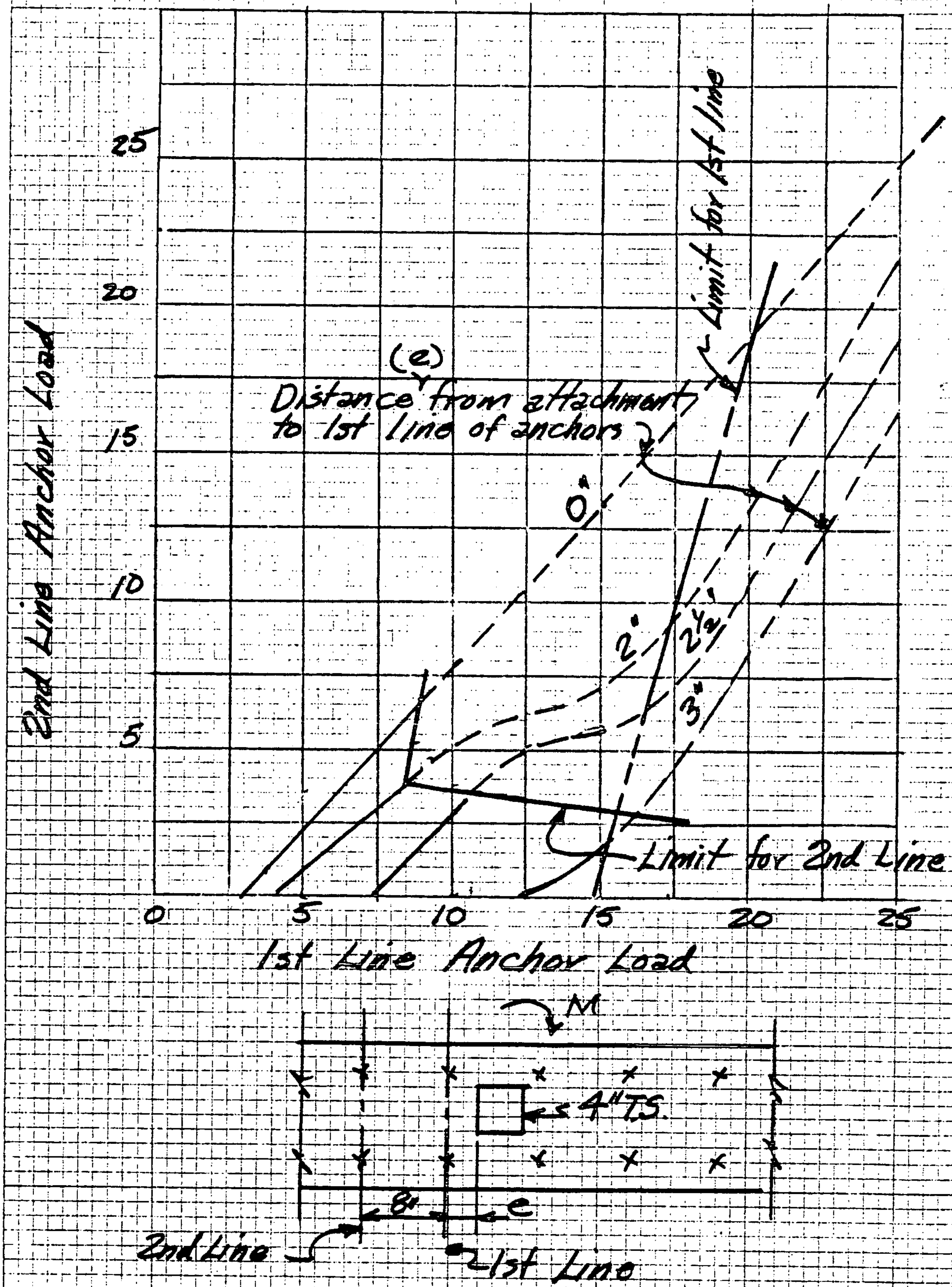
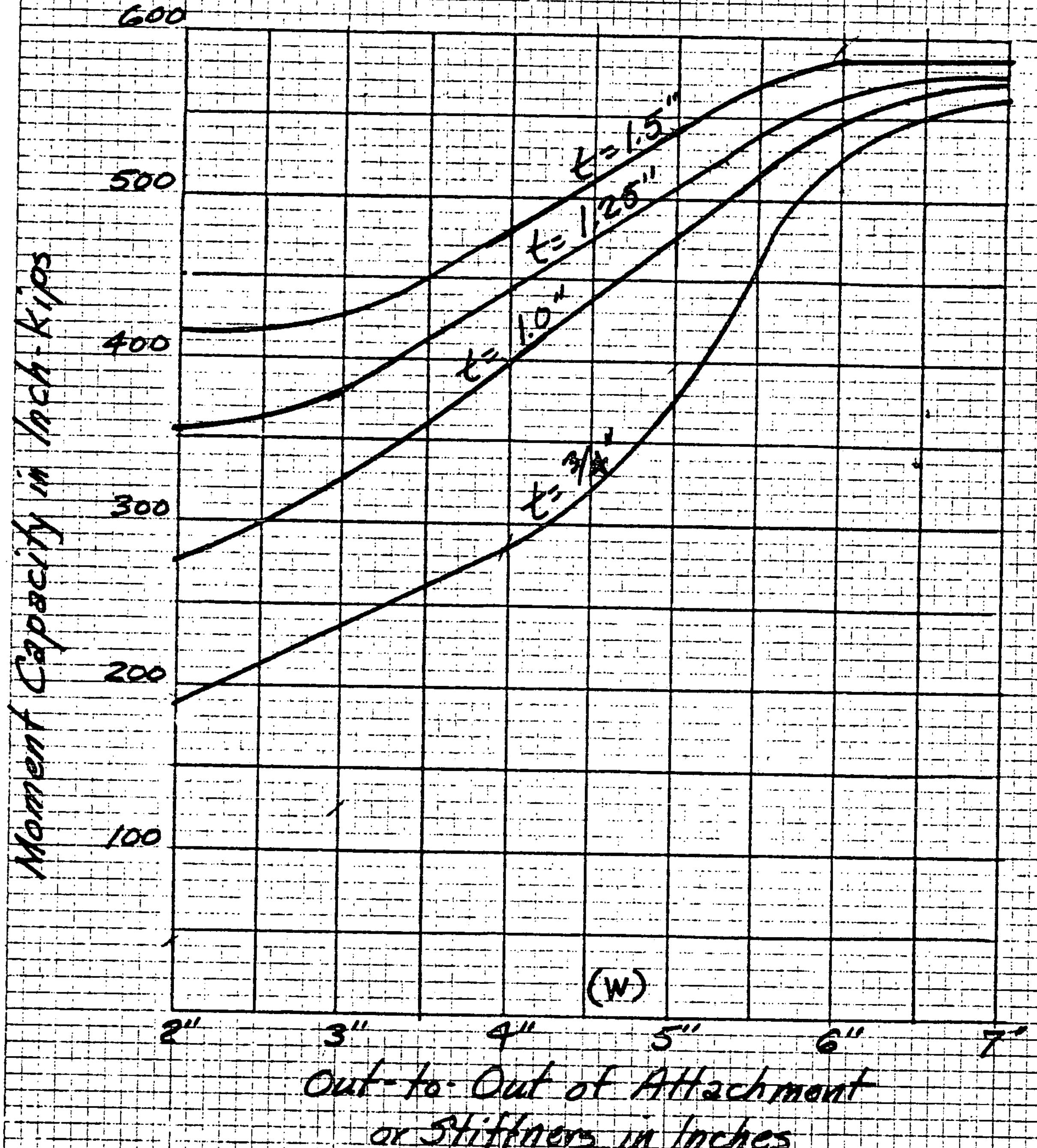
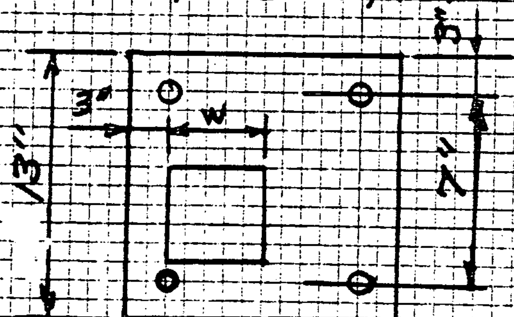


Exhibit #15

Welded Stud Anchors
3/4" @ 7" oc.

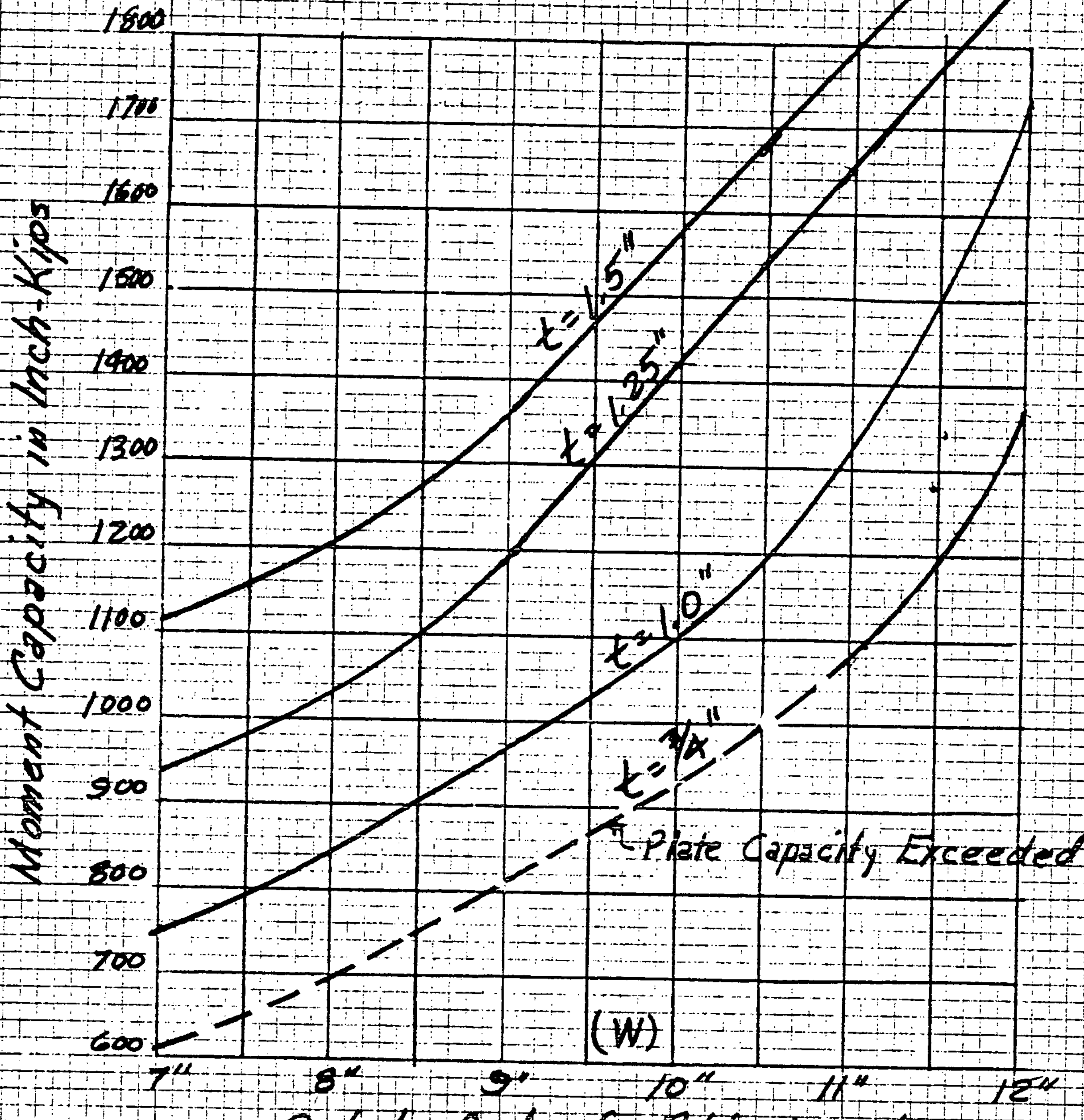


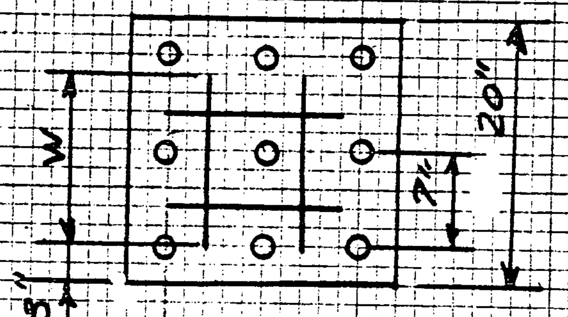


Minimum Plate Requirements

Exhibit #16

Welded Stud Anchors
3/4" @ 7" oc

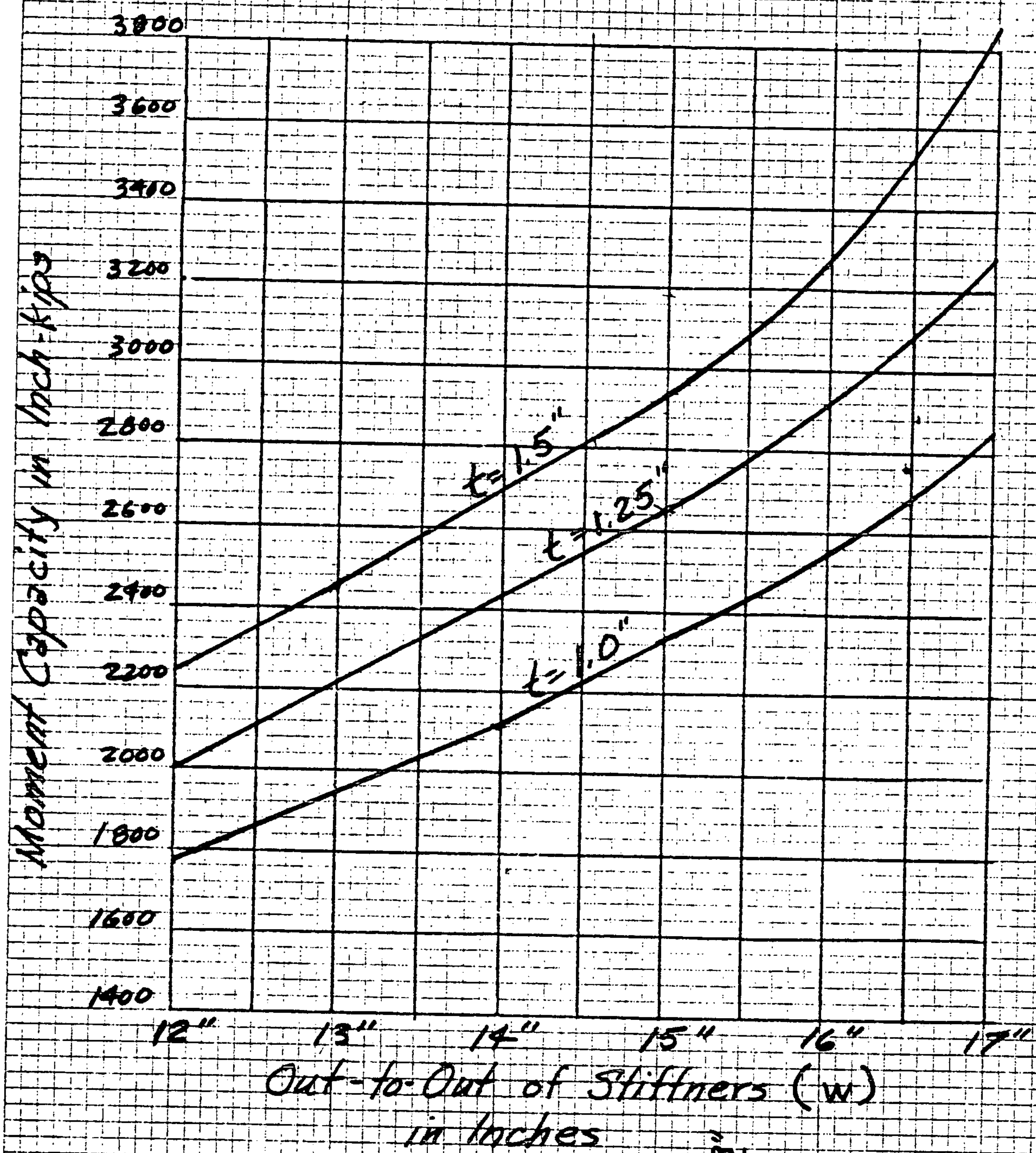


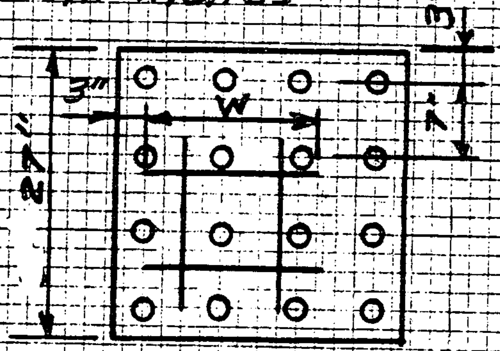


Minimum Plate Requirements

Exhibit #17

Welded Stud Anchors
3/4" @ 7" o.c.

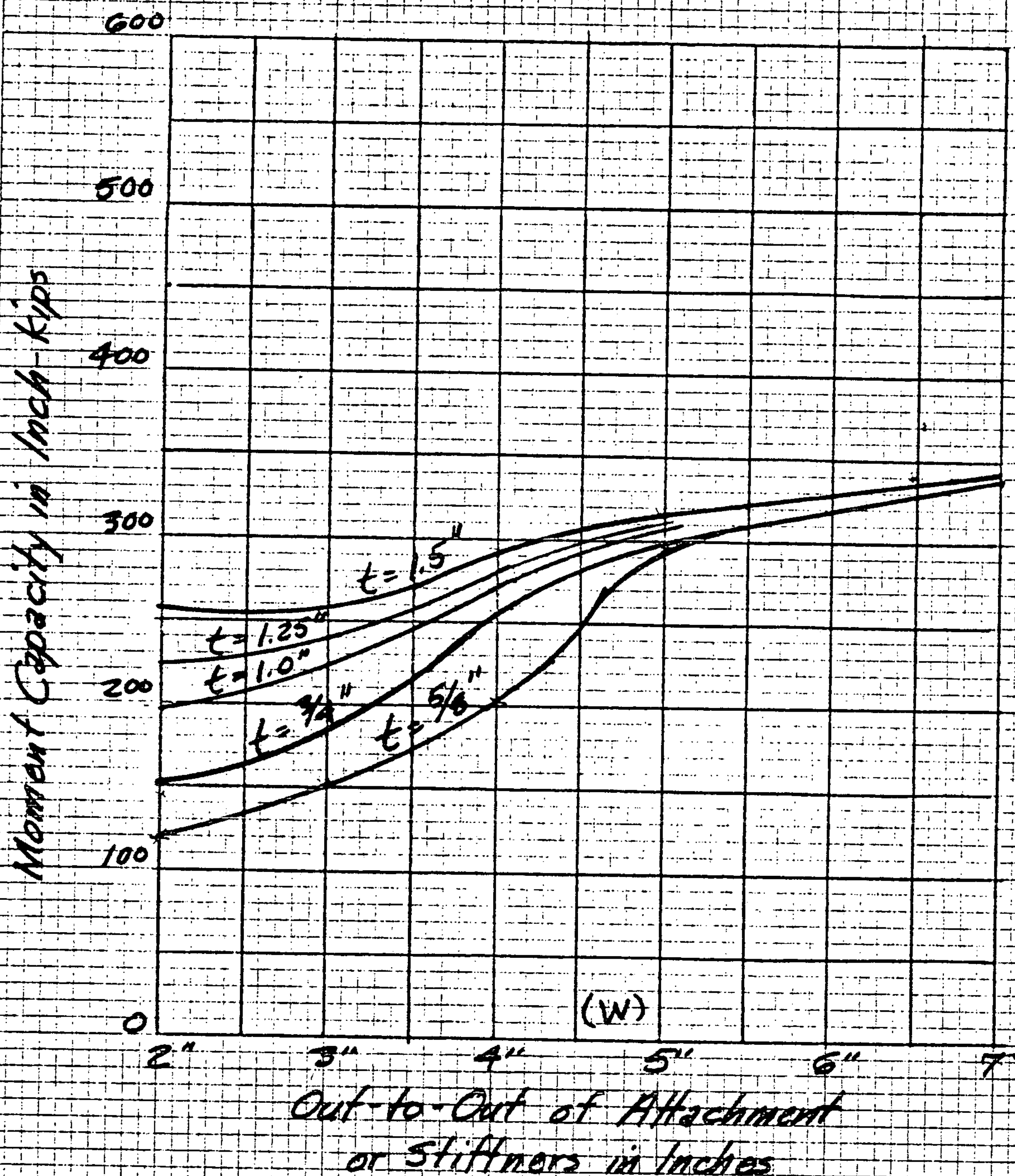


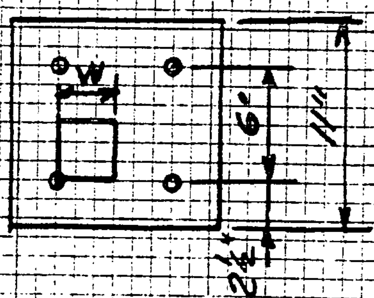


Minimum Plate Requirements

Exhibit #18

Welded Stud Anchors
5/8" @ 6"oc

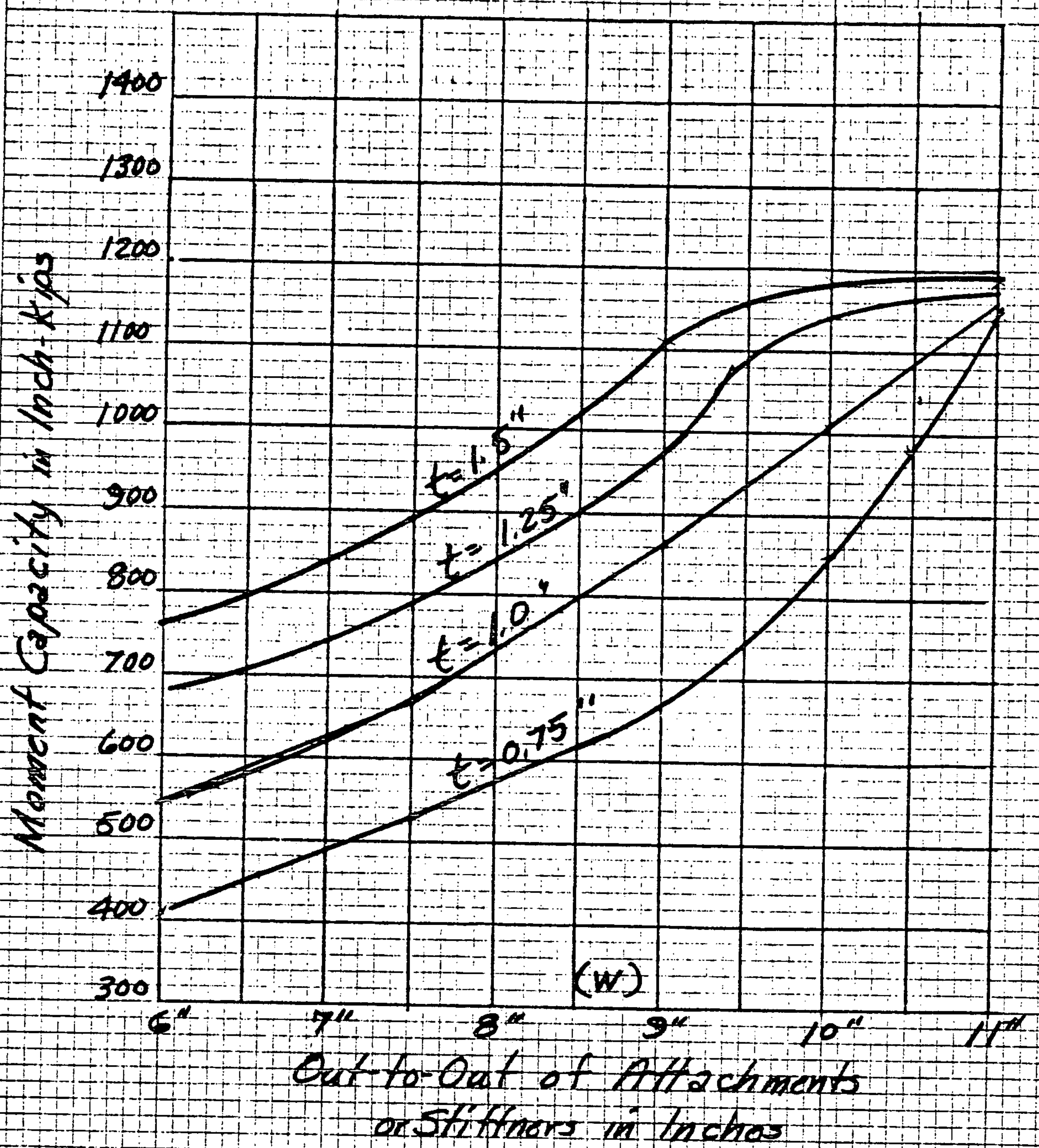


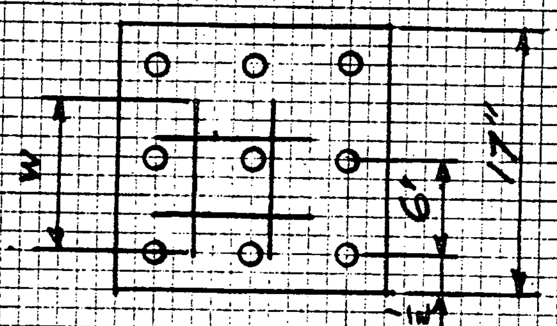


Minimum Plate Requirements

Exhibit # 19

Welded Stud Anchors
5/8" @ 6" oc

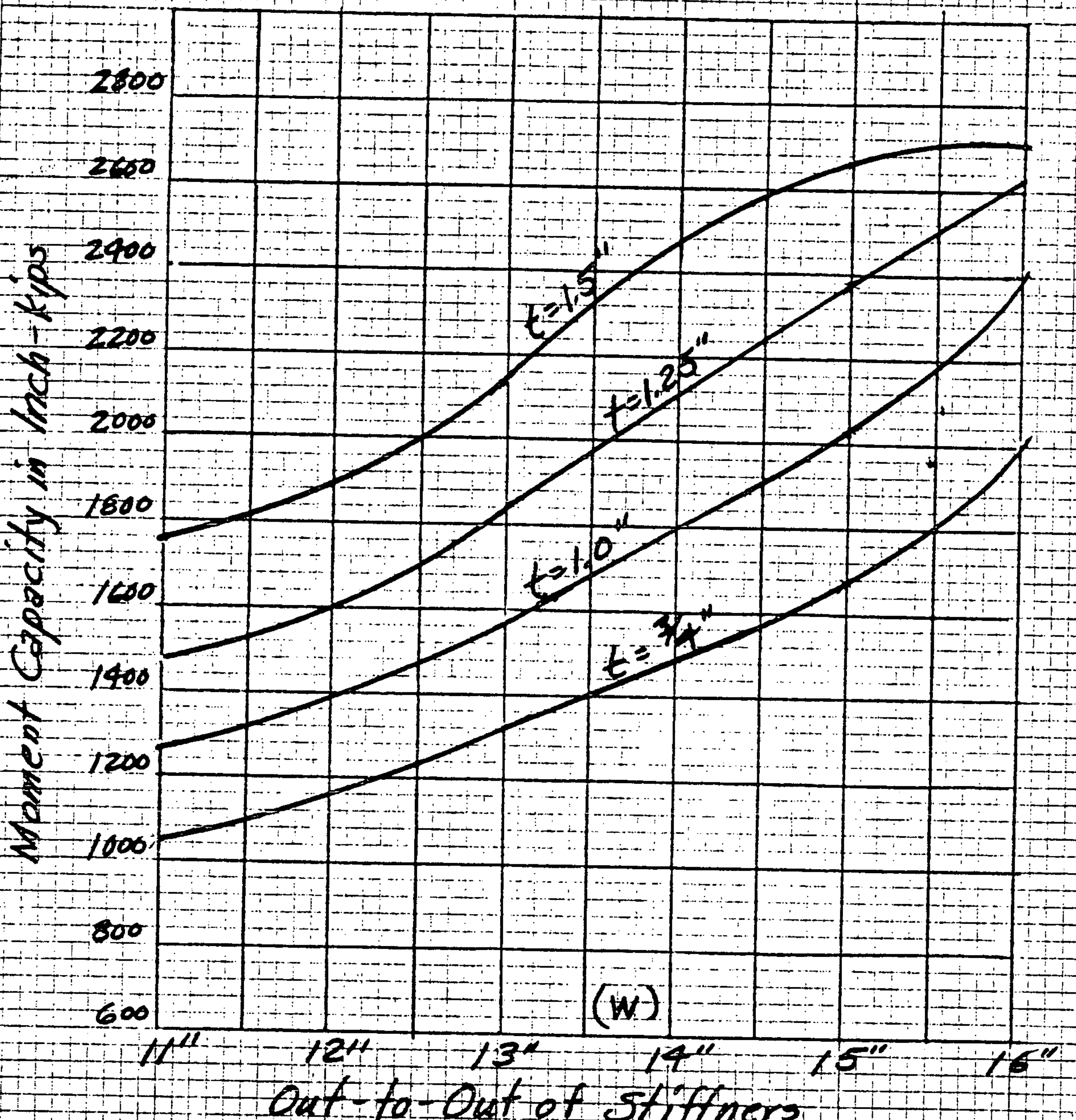


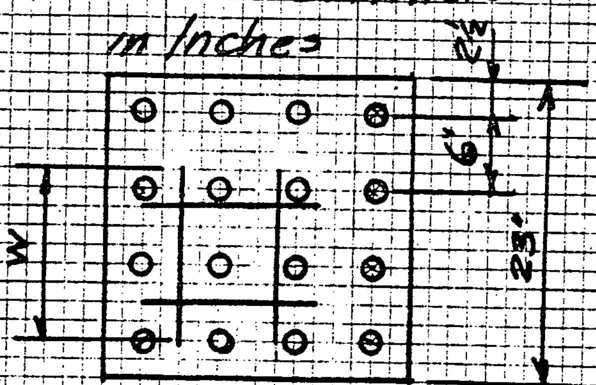


Minimum Plate Requirements

Exhibit #20

Welded Stud Anchors
5/8" @ 6"oc





Minimum Plate Requirements

Exhibit #21