APPENDIX 3G CONTAINMENT LINER ANCHOR LOAD TESTS

The information contained in this appendix was not revised, but has been extracted from the original FSAR and is provided for historical information.

APPENDIX 3G

CONTAINMENT LINER ANCHOR LOAD TESTS

FINAL REPORT

CONTAINMENT LINER ANCHOR LOAD TESTS

by

Edwin G. Burdette

February 5, 1981

Tests Performed for

United Engineers and Constructors

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Containment Liner Anchor Load Tests

by

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1. INTRODUCTION

The containment structure for the Public Service Company of New Hampshire's Seabrook Nuclear Power Station consists of a right vertical cylinder, a hemispherical dome, and a thick, flat base. In order to meet leak-tightness requirements for the containment acting as a pressure vessel, the entire inside surface of the concrete is covered with a steel liner. This liner is anchored to the concrete by embedded structural tees, angles, or studs which are welded to the steel liner plate. The containment is designed to resist the high temperature and pressure associated with the most severe break in a reactor coolant pipe. Under this postulated loading condition, the liner anchors must be adequate to maintain the structural integrity of the liner-liner anchor system. In order to evaluate, analytically, the adequacy of the liner anchors to perform their required function, experimental load-deflection data for individual anchors are needed for shear loads and displacements along the surface of the containment wall.

The results of load tests on liner anchors have been reported in References 2, 3 and 4. Of particular interest relative to the tests reported herein are the results reported in Reference 2 of tests performed at the University of Tennessee. These test results provide considerable information on load-deflection behavior of angles and a smaller amount of data on structural tees, both angles and tees being attached to 1/4 inch thick liner plates. The tests reported herein utilized the same test equipment and essentially the same test

procedure as those tests in Reference 2 and were designed to provide experimental data directly applicable to the containment liner at Seabrook.

1.1 Objective

The objective of the tests aeported here is to obtain the shear load-displacement relationships for a) the Japanese Tee 100x100mm with 1/4 inch fillet welds which was used to anchor the containment liner at Seabrook and b) for 3/4 inch diameter x 12 inch long studs. The boundary support conditions for the liner plate test specimens were designed to represent, as nearly as practicable, those existing in the field; if an accurate simulation of field conditions was not practical, the support conditions were designed to produce conservative results.

1.2 Scope

A total of six shear tests were performed to accomplish the stated objective three tests on the Japanese Tee 100x100mm and three tests on 3/4 inch diameter x 12 inch long studs. Information was obtained in each test to plot the load-deflection curve for the anchor being tested.

1.3 Acknowledgment

The work reported herein was performed as a part of United Engineers and Constructors, Inc., Purchase Order No. H.O. 56971, Change Order No. 1. The facilities of the Department of Civil Engineering at the University of Tennessee, Knoxville, were used to perform the tests. A number of Civil Engineering students participated in the performance of the tests, with special commendation due to Steve Stethen, graduate student in charge, and to James Haley.

2. TEST SPECIMENS

All of the test specimens were prepared on the Seabrook plant site using procedures and materials approved for construction of the containment structure. A complete description of the test specimens with appropriate drawings is contained in Reference 1, and a sketch showing the dimensions of the test specimens is shown in Figure 1 herein. The concrete blocks in which both the tees and the studs were embedded were 3'-4" x 3'-0" x 2'-3" high with the liner attached to the 3'-4" x 3'-0" top face. The embedded tees were 12 inches long, and the two studs were spaced 12 inches apart. The welds for the tees were 1/4 inch continuous fillets on both sides of the stem. The embedded anchors were located 20 inches from the loaded front face of the test block, a distance equal to the horizontal spacing of the structural tee anchors. The length of the liner plate beyond the front edge of the concrete test block was determined by the dimensions of the test rig. After the specimens were cast, they were shipped to the University of Tennessee via flat-bed truck for testing.

At the time of casting, concrete cylinders representative of the concrete in each specimen were cast and stored at the Seabrook site. On the day a particular specimen was tested at the University, three corresponding cylinders were tested at Seabrook to obtain the compressive strength of the concrete.

Four specimens were cast with embedded tees and four with embedded studs. The test plan called for the testing of three specimens of each type. The fourth specimen of each type was cast as a safety measure; if one specimen

was damaged in shipment or if the results of the first three tests suggested a revised testing procedure, the extra specimen would then be tested. It turned out that there was no reason to test the extra specimens; thus, three tee and three stud specimens were tested.

3. METHOD OF TESTING

3.1 Test Apparatus

The concrete block with the liner plate anchored to its top face was restrained by bearing against an abutment beam. The liner plate was fastened to a moveable head beam which was driven by two, 200kip capacity hydraulic rams. The driving of this head beam produced tension in the liner plate and, in turn, a shear load in the anchor. A hydrocal cap was placed between the leading top edge of the concrete block and the top 3 inches of the abutment beam. Calibration curves for the two load cells are included in Appendix C.

The test instrumentation consisted of the following key elements:

1. An LVDT was attached to the liner plate in the vicinity of the anchor. In the first test the LVDT was located behind the anchor - that is, on the side away from the applied load - but the rotation of the anchor and the resulting uplift of the plate behind the anchor caused some inaccuracies in LVDT readings at deflections beyond peak load (see Plates B1 and B2). Thus, for all later tests the LVDT was attached to the liner plate several inches in front of the anchor where there was no vertical movement of the liner plate (see Plate B8).
2. A Gilmore console was used to control the closed loop testing system. A voltage input at the console causes the pump to drive the hydraulic ram until a voltage output from the LVDT sends a feedback signal that precisely matches

the voltage input signal, at which point the system is in equilibrium.

3. Load cells are attached to the head beam which pulls the plate in such a way that the rams act directly against the cells. The signal from the load cells is transmitted to a digital strain indicator which is calibrated to read the load directly in kips.

4. An XY plotter is keyed into the system in such a way that it receives signals from both the LVDT and the load cells. These two signals cause the XY plotter to produce a continuous plot of load versus deflection while a test is in progress.

3.2 Test Procedure

The tests proceeded as follows:

1. A small input voltage, corresponding to a small deflection, was "dialed in" at the console. The pumps then drove the rams until sufficient movement of the anchor resulted in an output voltage from the LVDT which matched the input voltage. The load required to produce that deflection was read and recorded, and the XY plotter made a continuous record of load and deflection up to that point.

2. The procedure just described was repeated for increments of deflection small enough to obtain an accurate plot of the measured data. Measurement of load and deflection continued until the full 0.5 inch travel of the LVDT was reached or failure of the anchor occurred. For those tests where failure had not occurred at the limit of travel of the LVDT, the LVDT was disconnected from the specimen, and the test was continued to failure to observe the mode of failure of the embedded anchors. A dial gage was attached to the specimen to provide a check on the deflections measured by the LVDT.

3.3 General Comments

Two aspects of the testing procedure merit special comment:

1. The load was applied to the anchors in the tests through a pull on the plate rather than a push on the plate as used in the tests in Reference 4. This type of load application obviated the need for any bending stiffeners on the liner plate, permitting a realistic representation of the rotation of the liner plate at the anchor. However, the fact that the unloaded end of the liner plate was unrestrained permitted it to lift off the test block as a result of the anchor rotation. In an actual liner-liner anchor system, this lift-off would be restrained by another embedded tee or row of studs, restraint that would add to the stability of the system. This effect is particularly important in the tee tests. Therefore, the method of testing these specimens was such that the load-deflection curve obtained for an anchor would be a conservative representation of the actual load-deflection relationship for an anchor in an actual field installation.

2. The tests were controlled by deflection rather than by load. The input voltage corresponded to a deflection and the rams acted to produce this deflection; the load required to produce this deflection was then read from the multimeter. This method of controlling the tests permitted the definition of the descending portion of the load-deflection curve for an anchor.

4. TEST RESULTS

The test results are summarized in Tables 1 and 2, and load-deflection curves are shown in Figures 2 and 3. Original data, including XY plots, are included in Appendix C. Selected photographs are presented in Appendix B to

illustrate the testing operations and the mode of failure of the anchors.

4.1 Discussion of Results

The irregularities present in the load-deflection curves shown in the XY plots in Appendix C are due, for the most part, to relaxation of the concrete causing a reduction in load under a constant deflection. When the test was stopped to take readings or, for that matter, when the person dialing in the voltage hesitated a bit, the system responded by maintinaing constant deflection; and the load required to maintain this deflection immediately decreased.

The load-deflection curves for the tees, shown in Figure 2, drop off sharply immediately after peak load is reached. At peak load the rotation of the tee in the concrete produces a crack on the back side of the flange of the tee. The local instability of the anchor results in a sharply reduced load-carrying capacity; in fact, the only load-carrying capacity remaining is that required to fail the concrete wedge directly in front of the embedded tee.

The drop-off in load beyond the peak was so sudden that, for T-1 and T-3, the testing equipment was incapable of tracking it accurately. The sudden load instability of the concrete around the tee would permit the anchor to move too far forward, "overshooting" the dialed in voltage. The rams would then try to rectify the situation by retracting; however, the rams were not connected to the head beam, so their retraction allowed the load to go to zero. This situation is illustreted by the load-deflection curves obtained from the XY plotter and included in Appendix C. This loss of load presented no particular problem; a new, higher voltage was dialed in, the test was continued, and

a continuation of the load-deflection curve was obtained. In an actual containment liner-liner anchor system, the restraint provided by an adjacent anchor would almost certainly reduce the sharpness of the drop-off of the load-deflection curve and enhance the ductility of the tee anchors.

The distinctly different shapes of the load-deflection curves for the tees and for the studs reflect the different modes of failure for the two anchor systems. The fillet welds joining the tee's to the liner plate were of sufficient strength to prevent a failure of the steel embedment; thus, the shear strength of the anchor was limited by concrete tension acting to resist the rotation of the tee produced by the applied shear. Ductility of the embedded tees resulted from the development of a secondary mode of failure, namely, the diagonal tension failure of the wedge of concrete directly in front of the tee. Conversely, the limiting strength element in a stud test was the shear strength of the studs. In each case the studs sheared just below the weld which attached them to the liner plate. The resulting load-deflection relationship resembles the stress-strain curve for steel, with a corresponding high degree of ductility. Interestingly, the maximum shear stress in the studs for an average of the three tests was 60 ksi.

5. CONCLUSIONS

The load-deflection curves shown in Figures 2 and 3 represent, in the opinion of this writer, a reasonable description of the shear load-deflection behavior of the anchors tested. Because of the absence of any hold-down restraint on the free ends of the liner plates in the tests, the descending portions of the curves for the tees should be somewhat higher. Thus, the curves in

Figure 2 may be thought of as reasonable but somewhat conservative representations of the behavior of actual embedded tee anchors.

REFERENCES

1. Galunic, Branko, "Procedure for Containment Liner Anchor Load Test", United Engineers and Constructors, Inc., Philadelphia, PA 19101, Revised August 25, 1980 (attached to Purchase Order No. H.O. 56971, Change Order No. 1).

2. Burdette, Edwin G. and Rogers, Larry W., "Liner Anchorage Tests", Journal of the Structural Division, ASCE, Vol. 101, No. ST7, Proc. Paper 11432, July 1975, pp 1455-1468.

3. Lee, T. and Gurbuz, O., "Assessment of Behavior and Designing Steel Liners for Concrete Reactor Vessels", Final Report, Engineering Research Institute, Iowa State University, Ames, Iowa, Nov. 1973 (prepared for the U.S. Atomic Energy Commission Under Contract No. AT(11-1)-2267).

4. "Liner Plate Anchorage Tests", Bechtel Corporation, San Francisco, California, for Arkansas Nuclear One, Arkansas Power and Light Co., April 18, 1969.

APPENDIX A

TABLES AND FIGURES

Table 1

Test Data for Tee Specimens

Specimen	Concrete Age (Days)	Concrete f'c (psi)	Peak Load (kips)	Peak Load (k/in)	Defl. Peak Load (ins.)	Load at Δ = 0.25 in. (kips)
T-1	20	5,710	152	12.67	0.070	36
T-2	24	5,770	156	13.0	0.070	34
T-3	28	5,950	144	12.0	0.060	32
Avg.		5,810	150.7	12.6	0.067	34

Table 2

Test Data for Stud Specimens

Specimen	Concrete Age (Days)	Concrete f'c (psi)	Peak Load (kips)	Peak Load (k/stud)	Defl. at Peak Load (Ins.)	Load at Δ = 0.25 in. (kips)
S-1	42	6,100	51.5	25.8	0.390	48
S-2	56	6,060	54.8	27.4	0.620	46
S-3	67	6,500	52.5	26.3	0.395	49
Avg.		6,220	52.9	26.5	0.468	47.7

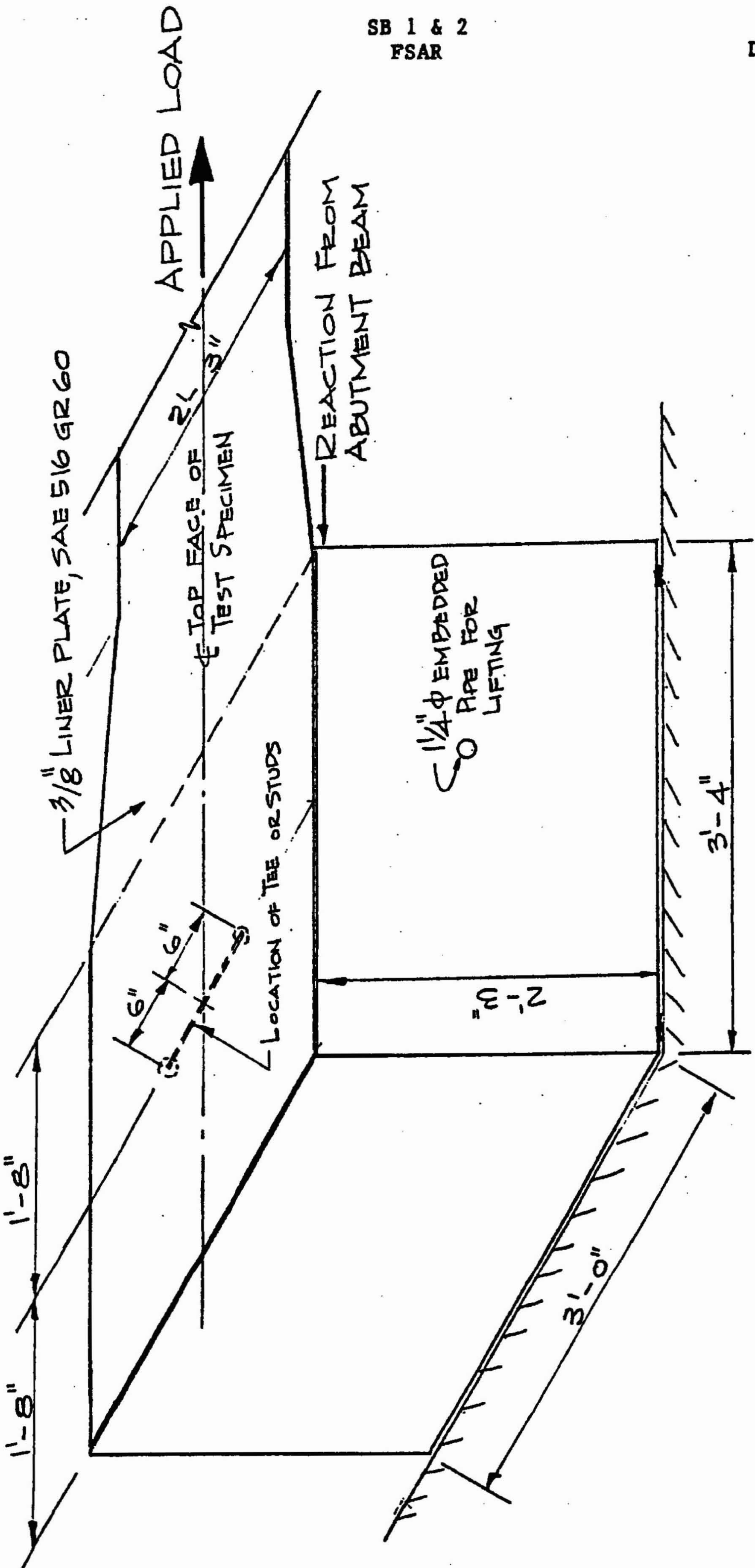


FIGURE 1. SKETCH SHOWING DIMENSIONS OF TEST SPECIMENS

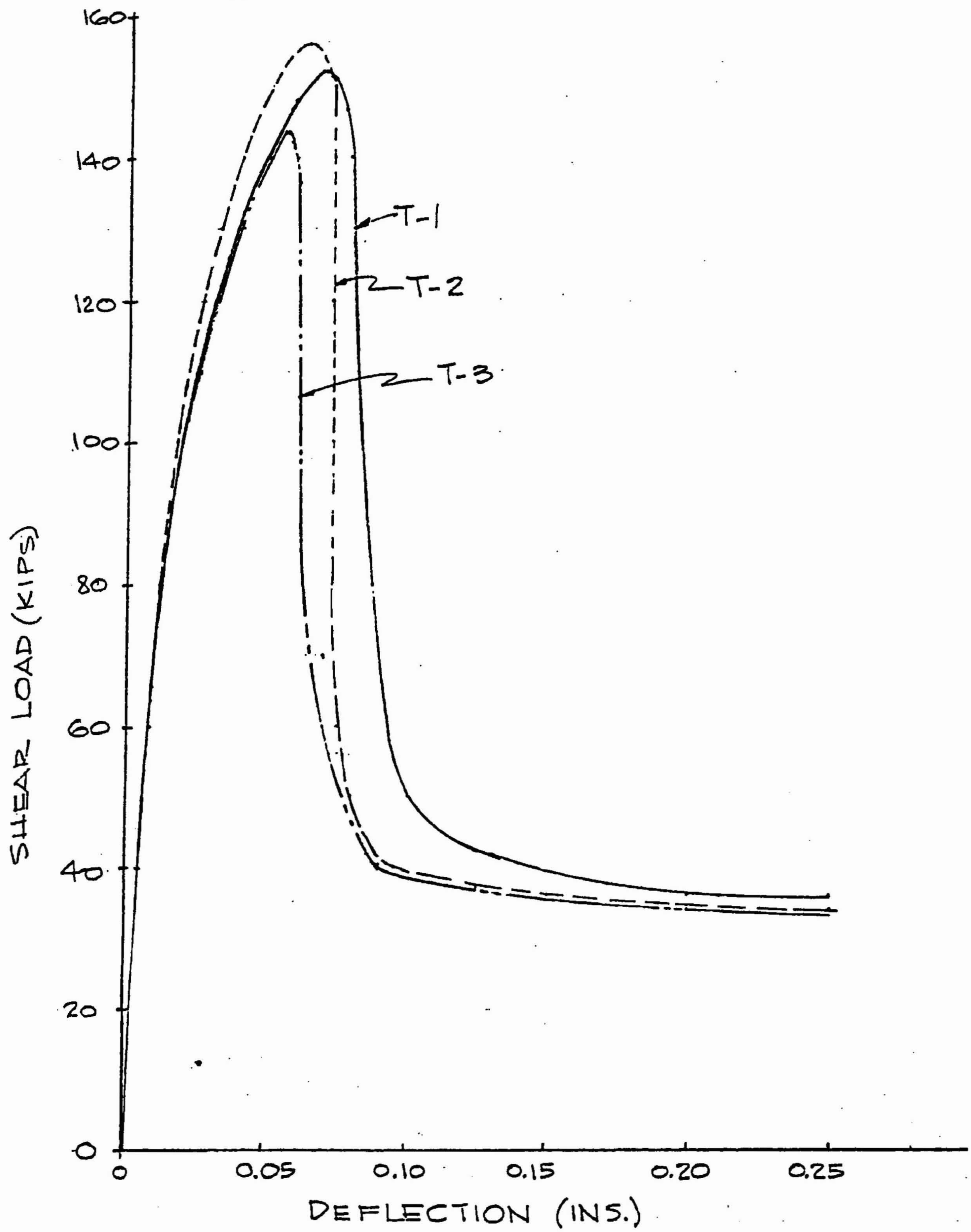


FIGURE 2. LOAD-DEFLECTION CURVES ~ TEE SPECIMENS
~ JAPANESE TEE 100 x 100MM w/ 1/4" WELDS -

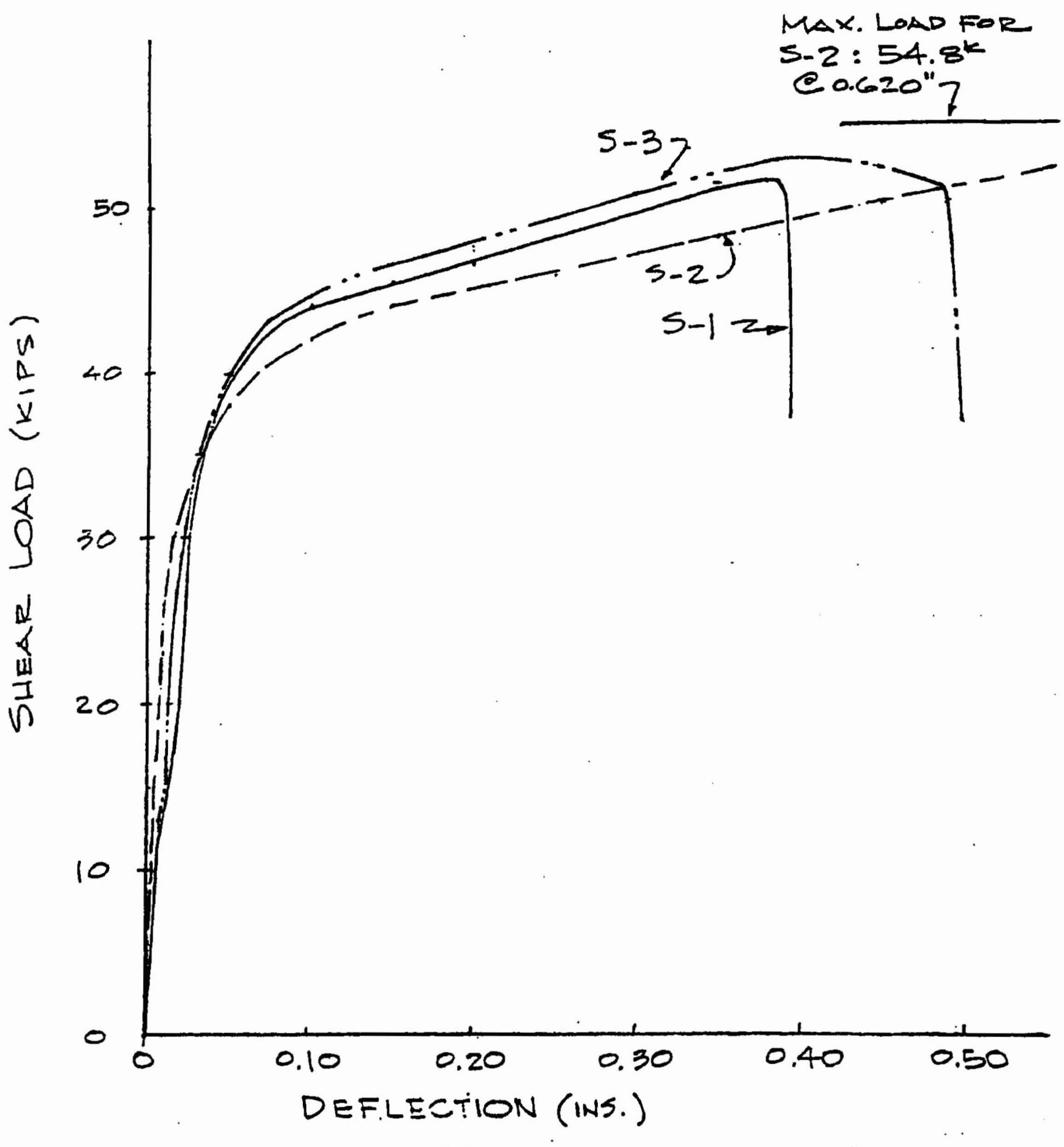


FIGURE 3. LOAD-DEFLECTION CURVES ~ STUD SPECIMENS
- 2, 3/4" φ × 12" LONG STUDS -

APPENDIX B

PHOTOGRAPHS

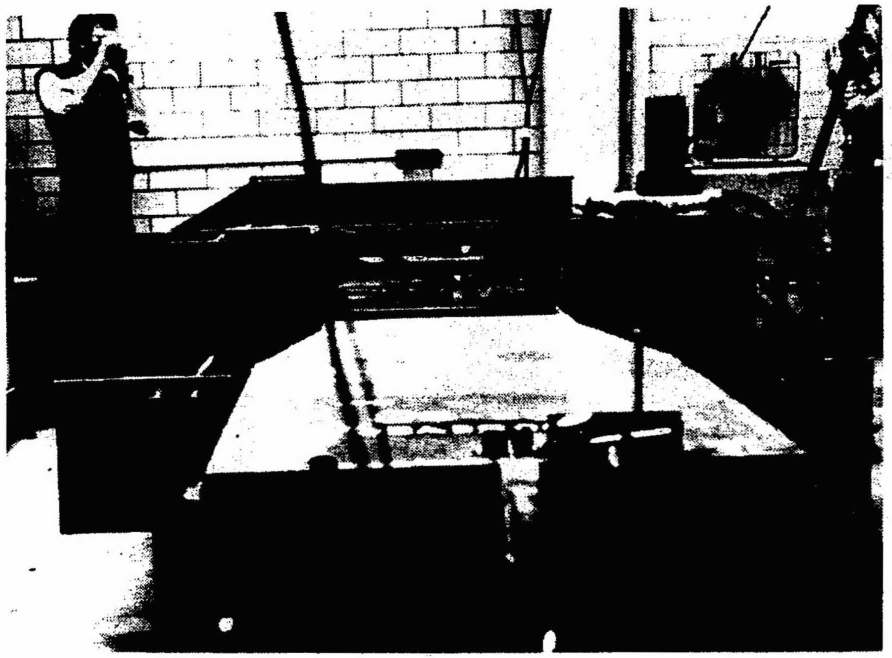


Plate B1: Specimen T-1. Test Assembly at Start of Test

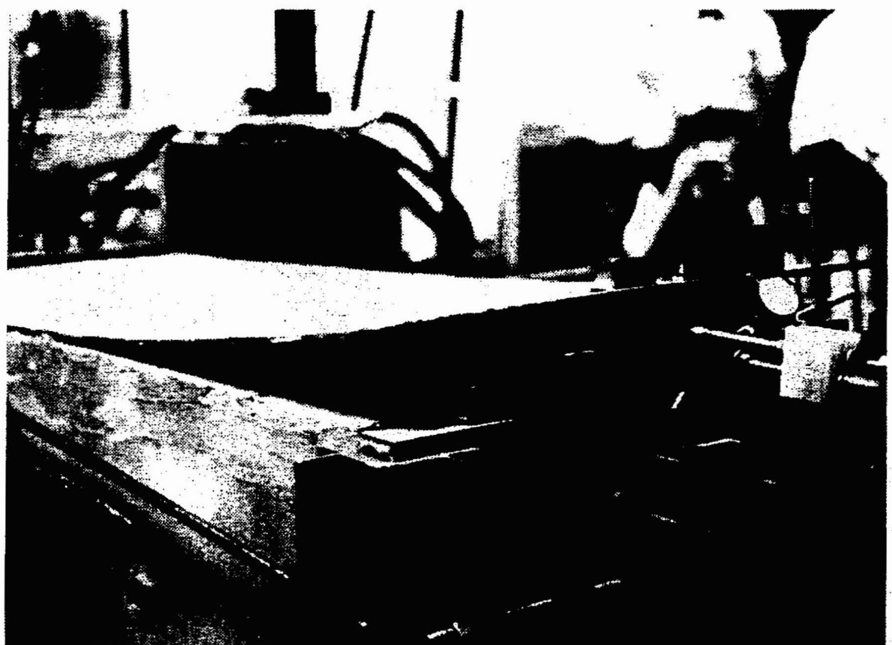


Plate B2: Specimen T-1. Plate Deformation During Final Stages of Testing

Plate B3: Specimen T-1. Concrete Surface After Removal of Liner Plate

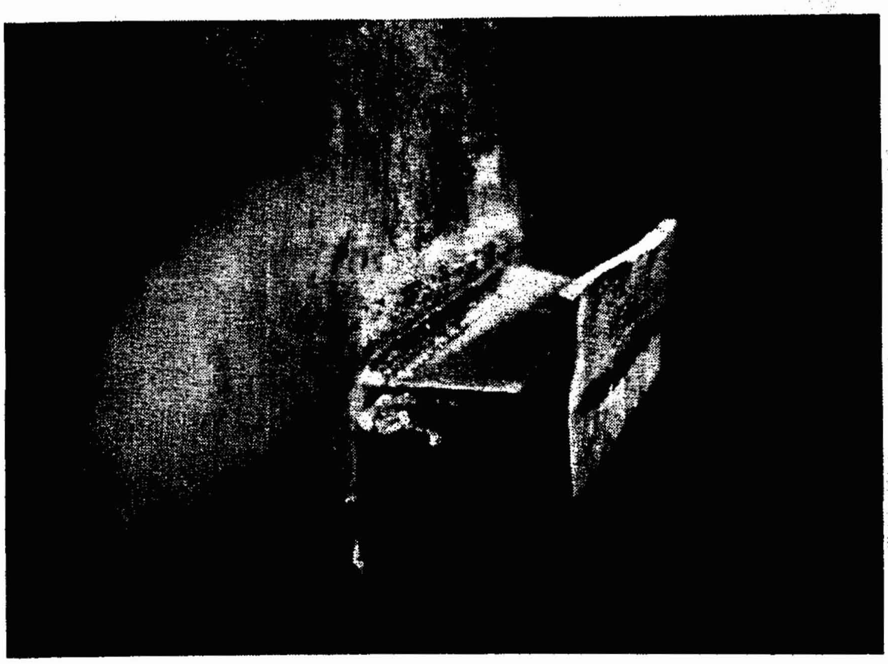


Plate B4: Specimen T-1. Liner Anchor (Tee) After Test

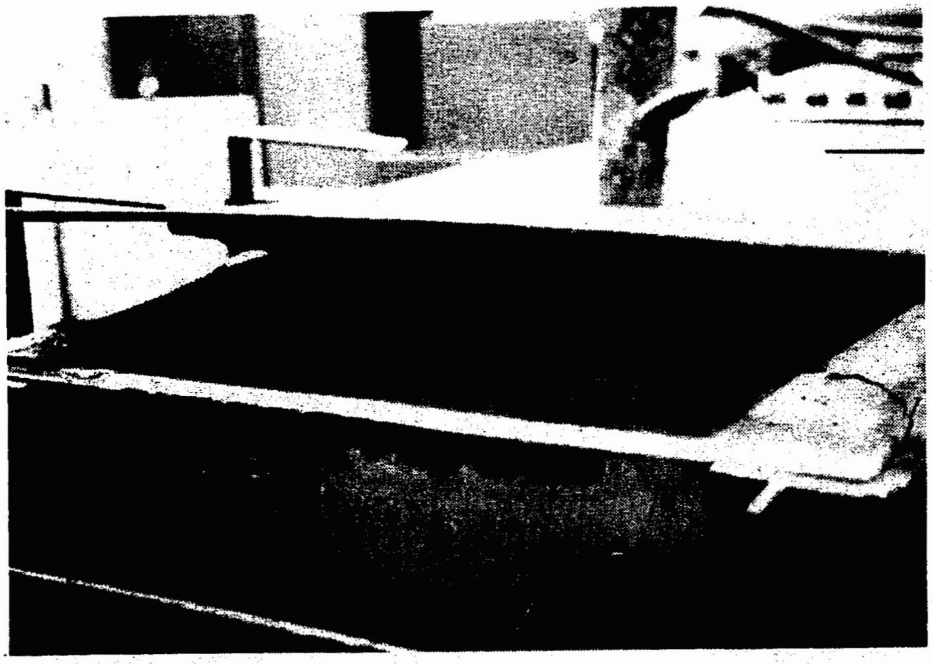


Plate B5: Specimen T-2. Liner Deformation at End of Test

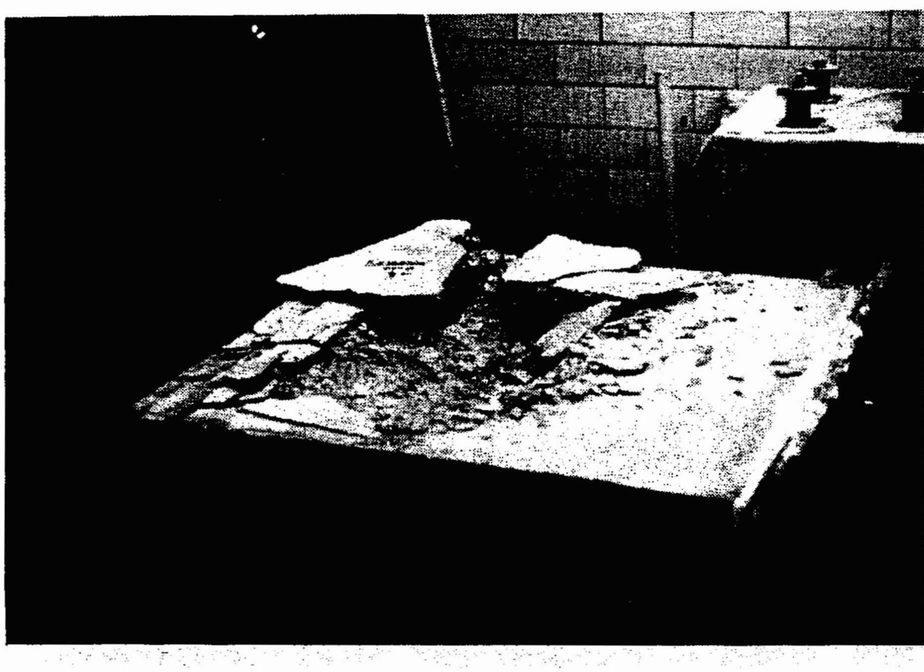


Plate B6: Specimen T-2. Top of Concrete at End of Test

Plate B7: Specimen T-2. Liner and Tee at End of Test

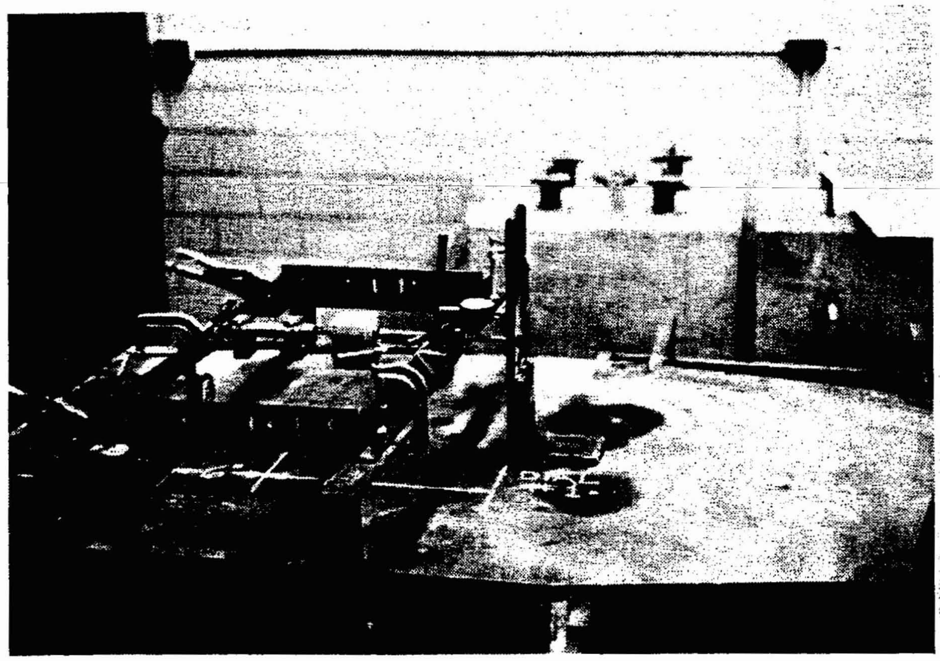


Plate B8: Specimen T-3. Instrumentation at Start of Test

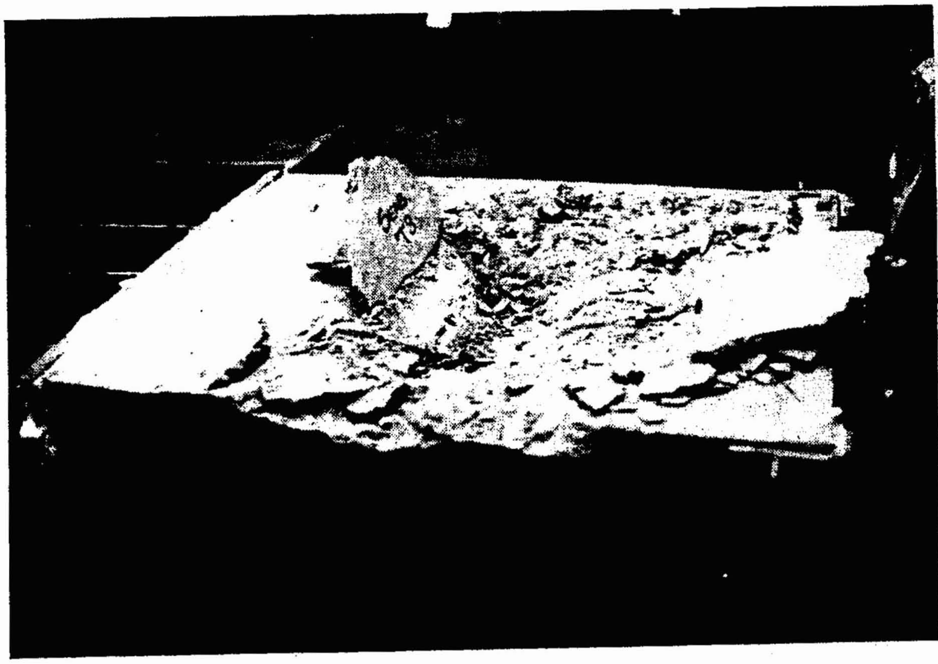


Plate B9: Specimen T-3. Concrete Surface After Removal of Liner Plate

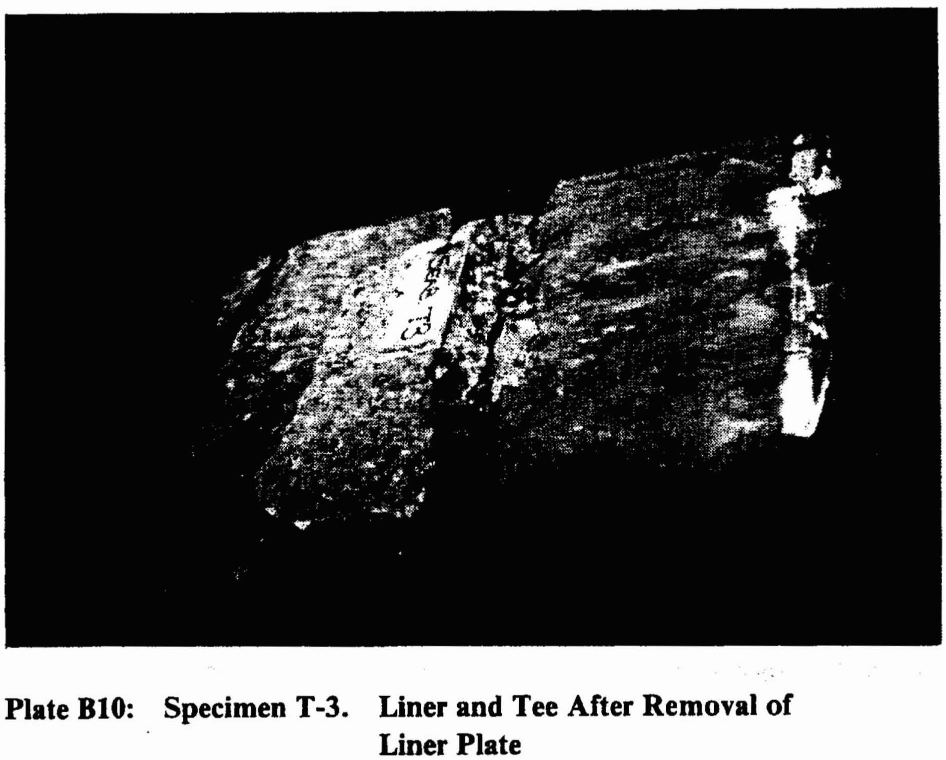


Plate B10: Specimen T-3. Liner and Tee After Removal of Liner Plate

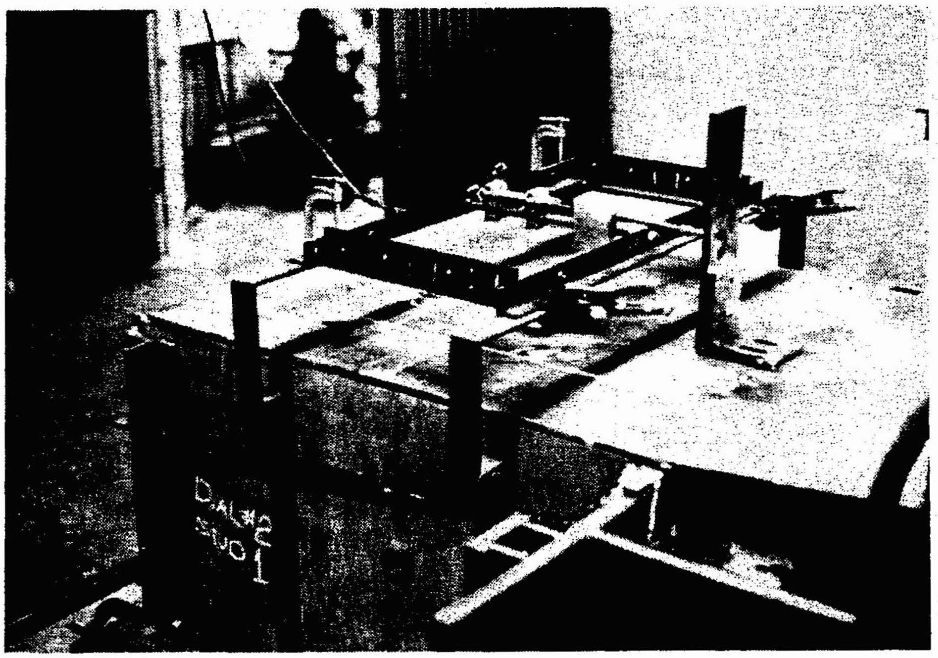


Plate B11: Specimen S-1. Start-up of Test

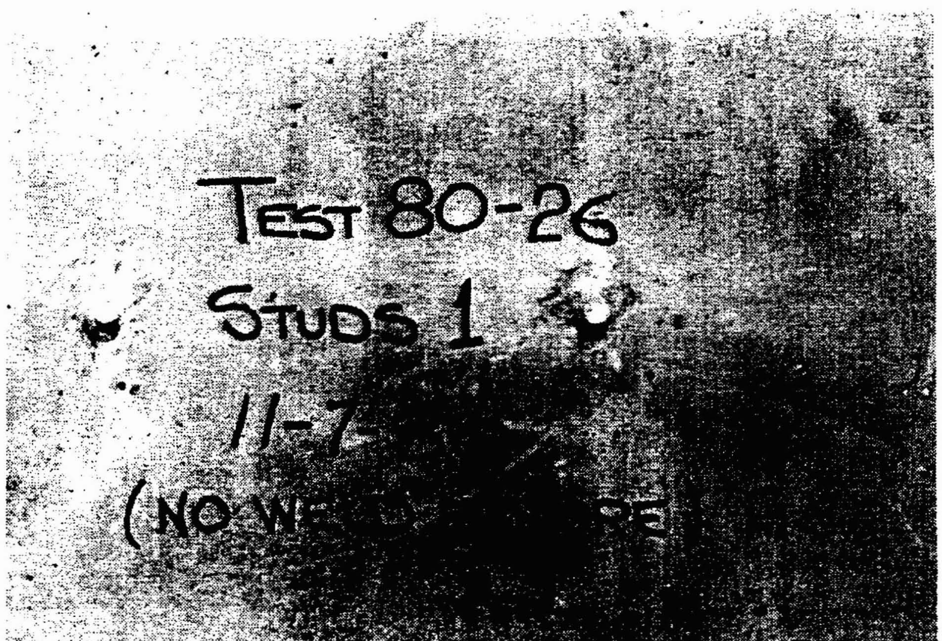


Plate B12: Specimen S-1. Studs in Concrete After Shear Failure

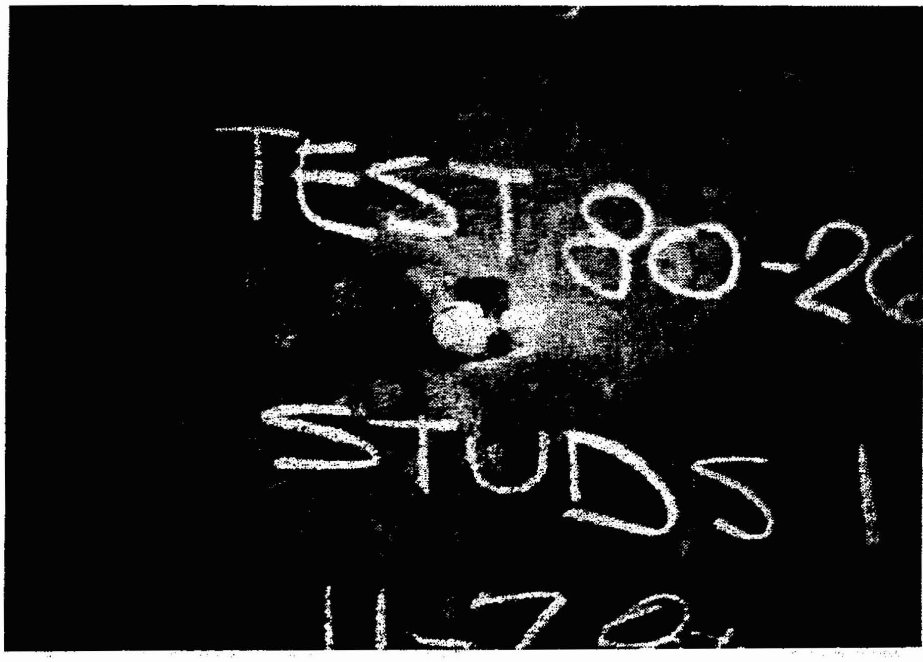


Plate B13: Specimen S-1. Detail of Sheared Stud in Plate

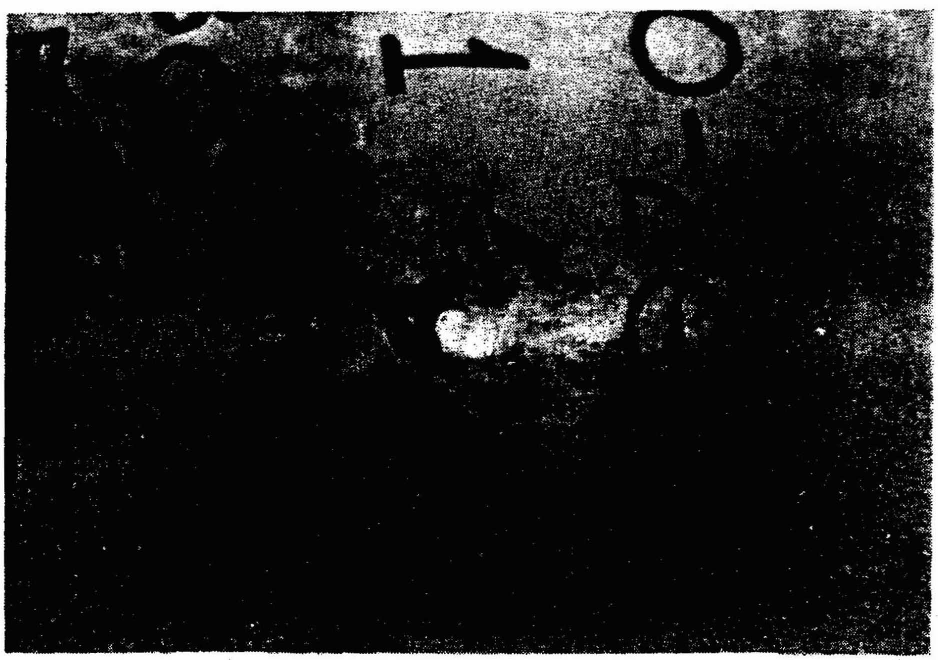


Plate B14: Specimen S-1. Detail of Sheared Stud in Concrete

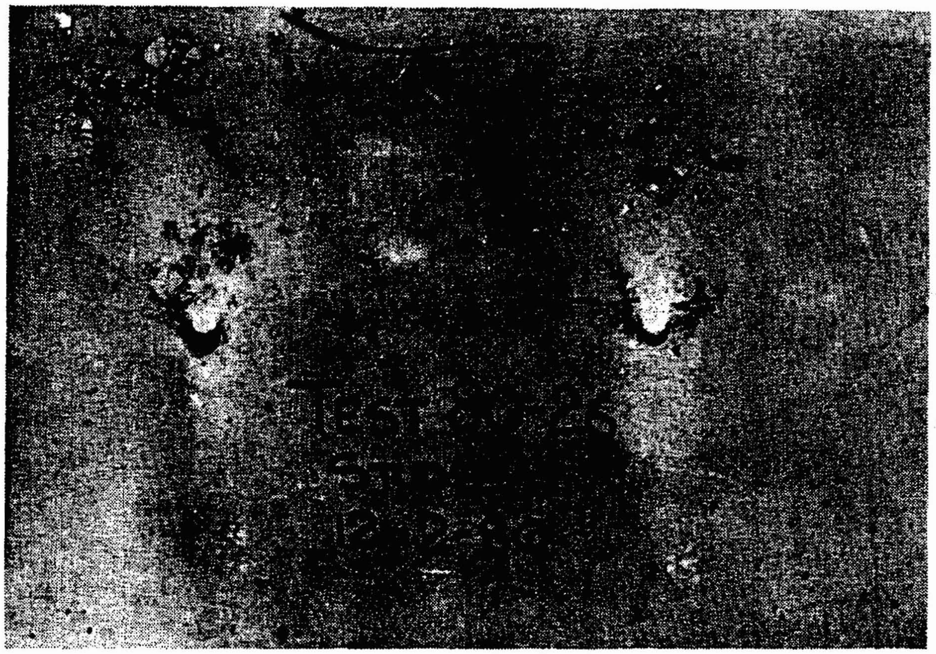


Plate B19: Specimen S-3. Sheared Studs in Concrete After Test

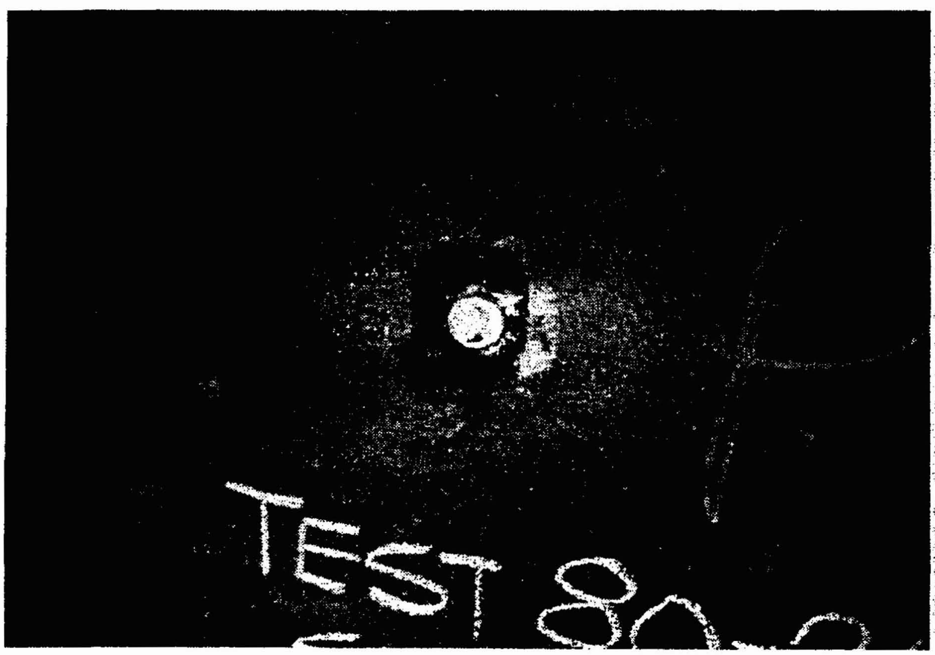
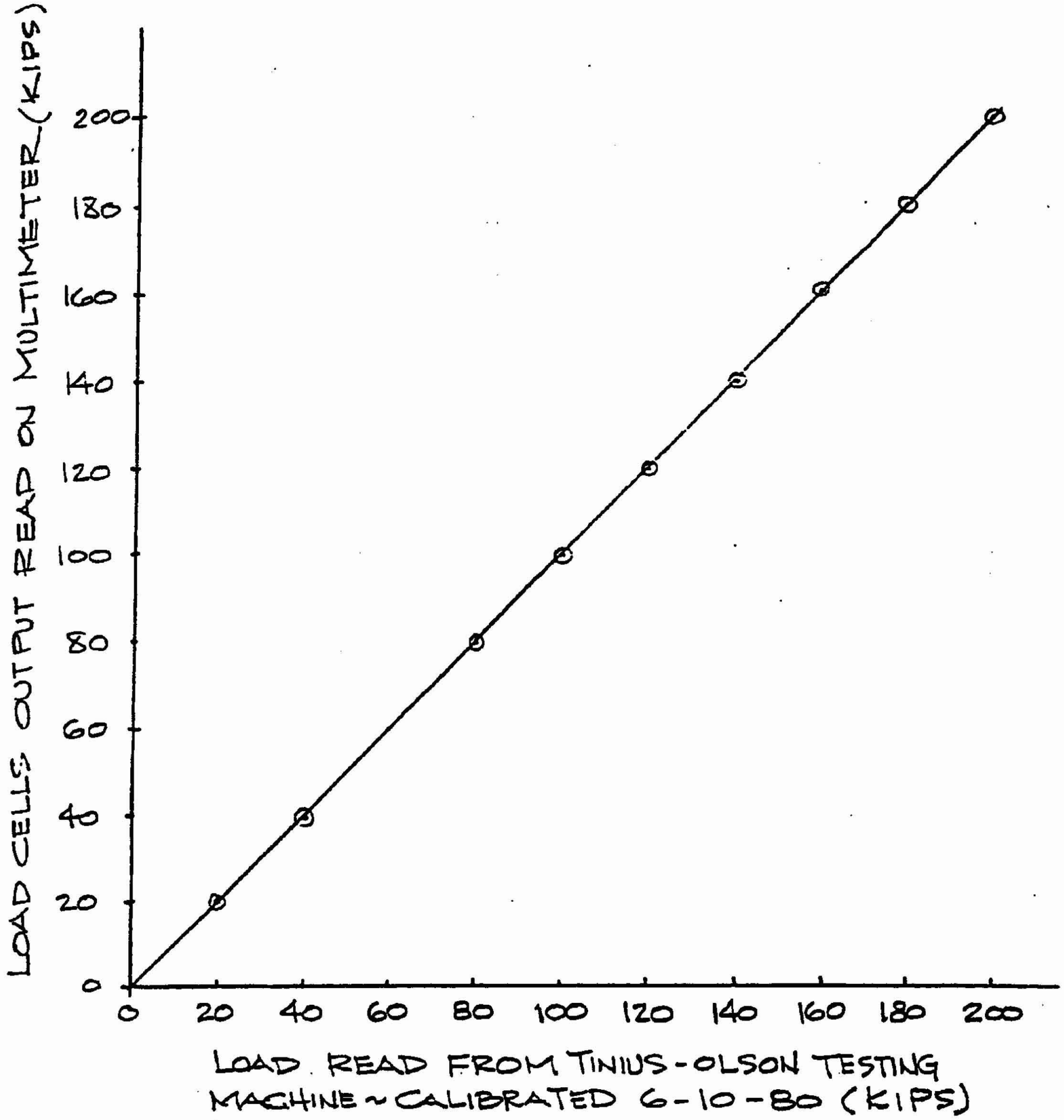


Plate B20: Specimen S-3. Sheared Stud in Plate After Test

APPENDIX C

LOAD CELL CALIBRATION AND ORIGINAL DATA



CALIBRATION CURVE FOR LOAD CELLS

UNITED ENGINEERS CONTAINMENT LINER ANCHOR LOAD TEST

TEST SPECIMEN: Seabrook T1
PEAK LOAD: 152 KIPS
f'c: PSI
DIAL # 1 LOCATION: ON LINER PLATE TO VERIFY HORIZONTAL DEFLECTION
DIAL # 2 LOCATION: ON CENTER OF BLANK FACE OF BLOCK TO INDICATE BLOCK MOVEMENT
VISHAY-ELLIS CALIBRATION #: 290

DATE: 10-16-80

2 OF 2

WITNESSES: STETHEN, HALEY, COPLEY, BURDETTE, LONG, GALUNIC, GRUSETSKIE, KALAWADIA

MULTI-METER READING (VOLTS)	LVDT DEFL (IN)	LOAD (KIPS)	DIAL#1 (IN) x10³	DIAL#2 (IN) x10³
3.75	0.188	35.2	204.	32
4.00	0.200	35.4	222	32
4.25	0.213	35.8	237	32
4.50	0.225	35.1	248	33
4.75	0.238	35.0	263	33
5.00	0.250	35.4	275	33
5.25	0.263	34.2	289	33
SHUT DOWN PUMP TO DISCONNECT LVDT & DIAL #1				
2.73	0.137	0.00	145	33
—	—	28.4	—	33

COMMENTS:

	00	388
	00	392
	00	393
	00	397
	00	400
	00	398
	00	401
	00	386
	00	406
	00	393
	00	403
	00	385
	00	375
	00	345
1.60	- - - -	- - - -
	00	283
	00	250
	00	213
	00	172
1.30	00	111

RESET LVDT AT
HORIZONAL DEFL. OF 0.10"

	00	450
	00	559
	00	752
	00	886
	00	1313
	00	1415
	00	1497
	00	1495
	00	1477
	00	1452
	00	1394
	00	1354
	00	1325
	00	1296
	00	1253
	00	1165
	00	1071
	00	985
	00	892
	00	723
	00	445
BEGIN TEST	00 -	000
	CHANNEL	LOAD (KIPS)

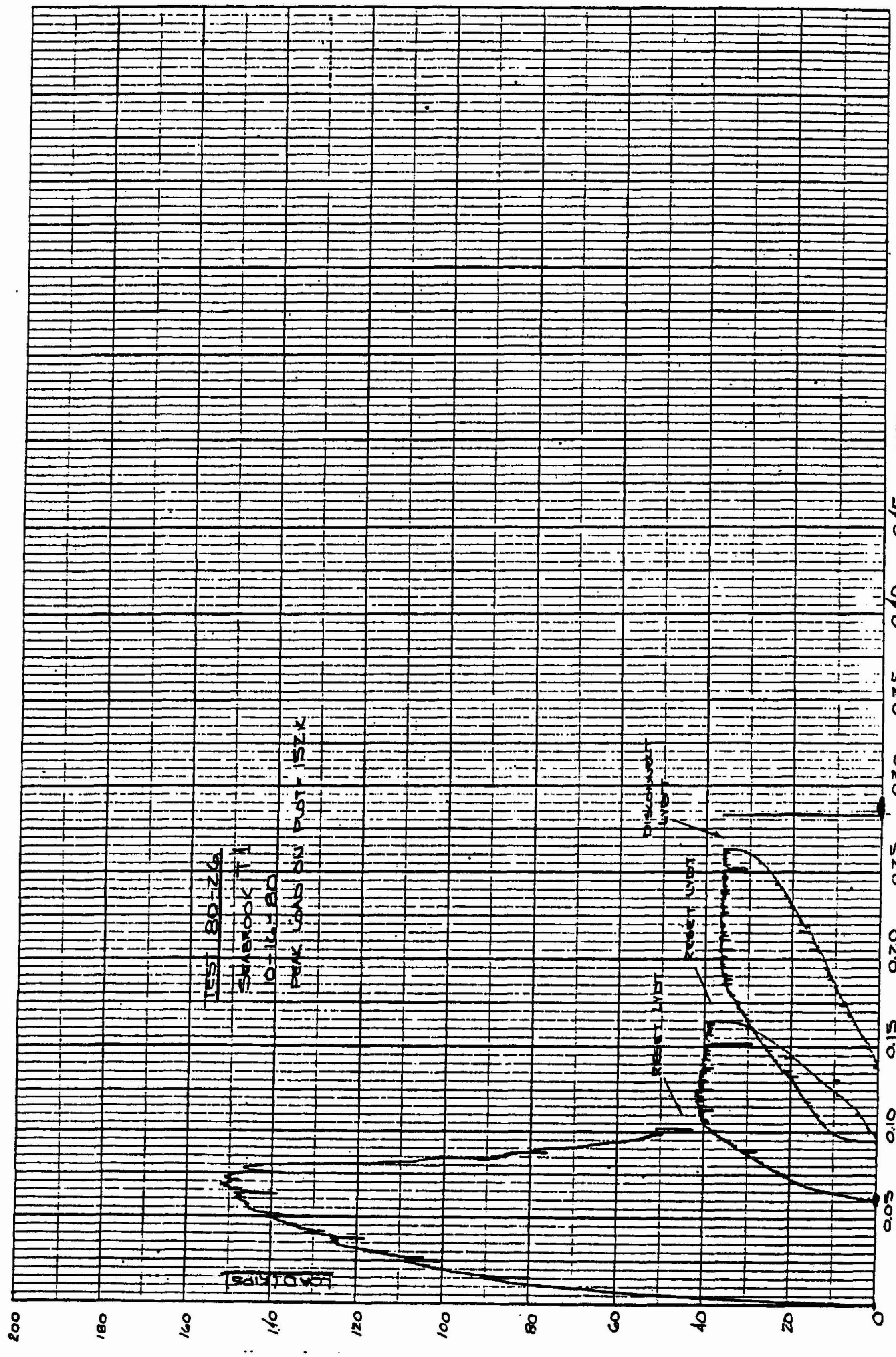
TEST 80-26
SEABROOK T1

	00	284

DISCONNECT LVDT
AT HORIZONAL DEFL. OF
0.263"

	00	355
	00	352
	00	354
	00	357
	00	355
	00	356
	00	359
	00	357
	00	356
	00	359
	00	360
	00	360
	00	353
	00	355
	00	358
	00	341
	00	341
	00	326
	00	313
	00	300
	00	285
	00	278
	00	262
	00	243
	00	230
	00	2 6
	00	190
	00	181
	00	167
	00	154
	00	140
	00	126
	00	102
1.90	00	049

RESET LVDT AT
HORIZONAL DEFL. OF 0.163"


TEST 80-26
SEABROOK T-1
10-16-80
PEAK LOAD ON PLOT = 152 K
LOAD (KIPS)
DEFLECTION (INCHES)
DISCHARGE LVDT
RESET LVDT
RESET LVDT
200
180
160
140
120
100
80
60
40
20
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

UNITED ENGINEERS CONTAINMENT LINER ANCHOR LOAD TEST

TEST SPECIMEN: Seabrook T2
PEAK LOAD: 156 KIPS
f'c: PSI
DIAL # 1 LOCATION: SLIGHTLY ABOVE LVDT PROBE TO VERIFY HORIZONAL DEFLECTION
DIAL # 2 LOCATION: 7" FROM BACK FACE MOUNTED ON SIDE FACE TO INDICATE ROTATION
VISHAY-ELLIS CALIBRATION #: 290

DATE: 10-20-80
WITNESSES: Stethell, Haley, Hayes, Cooley, Burdette and Holbrook

1 OF 1

Test 80-26

MULTI-METER READING (VOLTS)	LVDT DEFL (IN)	LOAD (KIPS)	DIAL#1 (IN) x10³	DIAL#2 (IN) x10³
0.00	0.000	0.0	0	0
0.25	0.013	7.48	13	3
0.50	0.025	118.0	26	9
0.75	0.038	137.1	39	13
1.00	0.050	148.0	52	19
1.25	0.063	153.7	66	25
1.50	0.075	62.9	80	5
1.75	0.088	39.9	97	5
2.00	0.100	37.7	113	4
2.50	0.125	36.9	145	4
3.00	0.150	34.8	175	4
3.50	0.175	34.1	203	4
4.00	0.200	34.3	231	4
4.50	0.225	34.1	259	4
5.00	0.250	34.0	288	4
6.00	0.300	28.2	344	4
7.00	0.350	18.9	403	4
8.00	0.400	20.2	458	4
9.00	0.450	20.6	515	4
9.96	0.498	19.7	569	4
6.18	0.309	0.0	569	2

COMMENTS:
PUMP SHUT DOWN TO DISCONNECT LVDT AND DIAL #1

DEFL. (INCH)	CHANNEL	LOAD (KIPS)
	00	341
	00	345
	00	346
	00	337
	00	345
0.20	00	343
	00	334
	00	343
	00	345
	00	348
	00	341
	00	352
	00	350
	00	349
	00	351
0.15	00	348
	00	359
	00	360
	00	358
	00	355
	00	369
	00	365
	00	369
	00	375
	00	352
0.10	00	378
	00	378
	00	398
	00	435
	00	517
	00	629
	00	1529
	00	1520
	00	1542
	00	1511
0.05	00	1475
	00	1443
	00	1377
	00	1339
	00	1252
	00	1180
	00	1050
	00	896
	00	683
	00	376
0.00	00	000

TEST 80-26

SEABROOK TZ

PEAK LOAD ON PLOT=156K

PEAK LOAD ON TAPE=154.2K

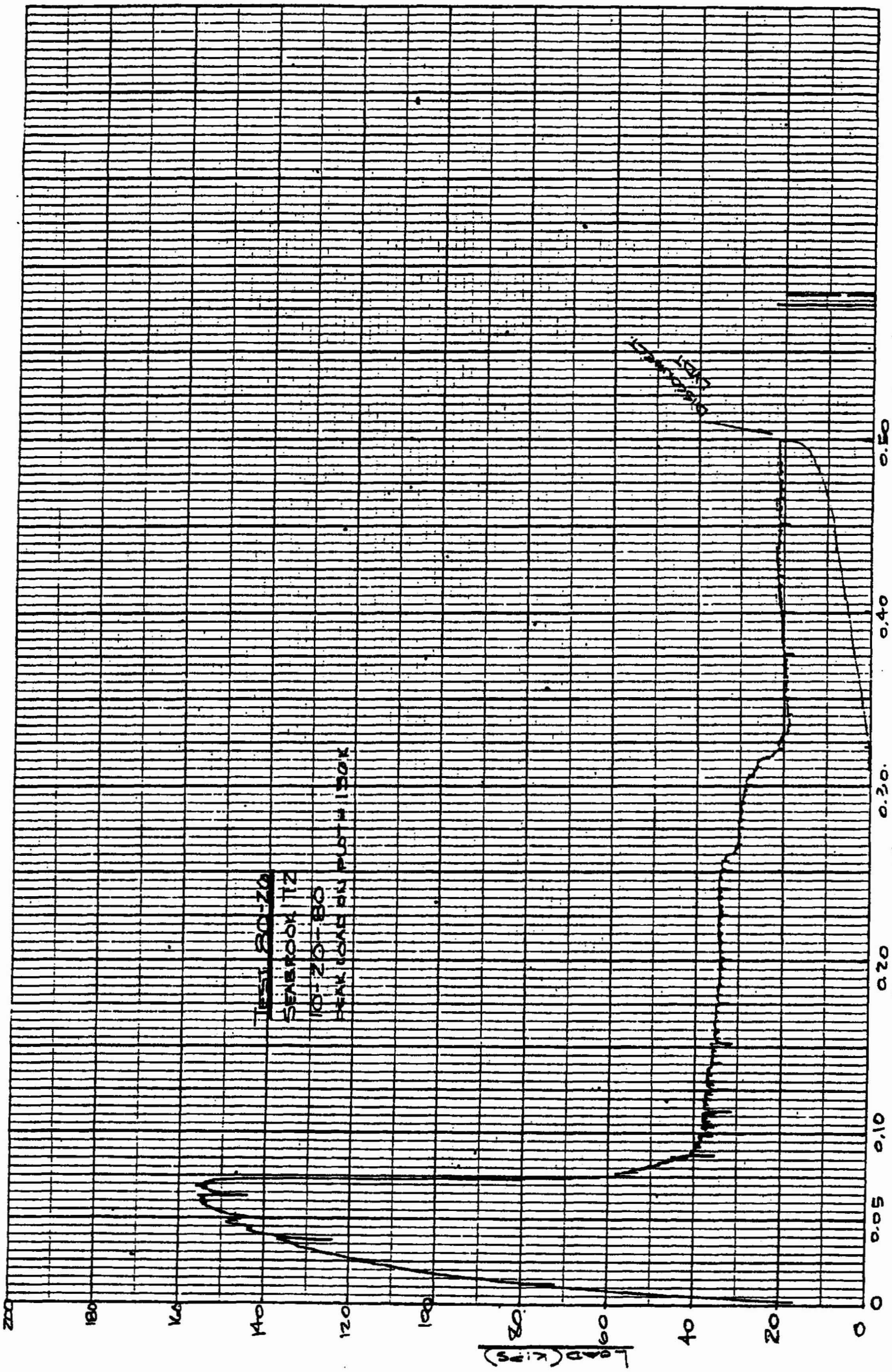
10-20-80

0.50	00	202
	00	212
	00	212
	00	213
	00	204
	00	210
	00	209
	00	211
	00	210
	00	213
0.45	00	206
	00	209
	00	211
	00	218
	00	209
	00	214
	00	203
	00	210
	00	209
	00	210
0.40	00	202
	00	206
	00	203
	00	202
	00	199
	00	199
	00	196
	00	195
	00	192
	00	189
0.35	00	189
	00	187
	00	188
	00	186
	00	191
	00	210
	00	213
	00	247
	00	263
	00	277
0.30	00	282
	00	288
	00	296
	00	296
	00	297
	00	302
	00	301
	00	304
	00	315
	00	337
0.25	00	340
	00	344
	00	347

END TEST

	00	033
	00	006
	00	194
	00	217
INTERMITTENT	00	191
LOAD READINGS	00	181
	00	170
	00	161
	00	155
	00	119
	00	053

DISCONNECT LVDT & DIAL #1


SEABROOK T2
10-20-80
DEFLECTION (INS.)
LOAD (KIPS)
0
0.05
0.10
0.20
0.30
0.40
0.50
20
40
60
80
100
120
140
160
180
200

UNITED ENGINEERS CONTAINMENT LINER ANCHOR LOAD TEST

TEST SPECIMEN: SEABROOK T3
PEAK LOAD: 144 KIPS
f'c: PSI
DIAL # I LOCATION: 1.5 IN. ABOVE LVDT PROBE TO VERIFY HORIZONAL DEFL 14" FROM T
DIAL # 2 LOCATION: 7" FROM BACK FACE MOUNTED ON SIDE FACE TO INDICATE ROTATION
VISHAY-ELLIS CALIBRATION #: 290

DATE: 10-24-80
WITNESSES: STETHEN, HALEY HAYES, COPLEY, HOLBROOK, & BURDETTE

DIAL #3 LOCATION: 6 IN BEHIND T TO MEASURE PLATE LIFT-UP

TEST 80-26

MULTI-METER READING (VOLTS)	LVDT DEFL (IN)	LOAD (KIPS)	DIAL#I (IN) x10³	DIAL#2 (IN) x10³	DIAL#3 (IN) x10³
0.00	0.000	0.0	0	0	0
0.25	0.013	76.6	13	0	16
0.50	0.025	106.9	27	1	39
0.75	0.038	128.3	40	2	69
1.00	0.050	141.3	53	3	102
1.25	0.063	85.3	65	1	240 @ PEAK 290 ABRUPT 310 @ 1.25
1.50	0.075	67.0	82	0	297
1.75	0.088	35.0	92	0	428
2.00	0.100	39.7	105	0	505
2.50	0.125	39.4	133	0	629
3.00	0.150	39.0	160	0	745
3.50	0.175	38.6	186	0	855
4.00	0.200	38.2	213	0	DISCONNECT
5.00	0.250	31.6	268	2	—
6.00	0.300	32.1	322	2	—
7.00	0.350	26.0	375	0	—
8.00	0.400	25.8	429	0	—
9.00	0.450	25.5	482	0	—
9.96	0.500	22.8	534	0	—
6.37	0.319	0.0	365	0	—

COMMENTS:

DEFL (INCH)	CHANNEL	LOAD (KIPS)
	00	354
	00	357
	00	365
	00	375
DISCONNECT	00	381
DIAL# 3	00	382
0.20		
	00	385
	00	387
	00	387
	00	388
	00	386
	00	386
	00	389
	00	391
	00	387
0.15	00	390
	00	394
	00	396
	00	397
	00	396
	00	394
	00	392
	00	387
	00	391
	00	397
0.101	00	392
0.10	00	397
	00	389
	00	370
	00	326
	00	257
	00	090
	00	751
	00	822
	00	1404
	00	1438
0.05	00	1413
	00	1372
	00	130
	00	1257
	00	1177
	00	1069
	00	973
	00	839
	00	692
	00	460
0.00	00	000

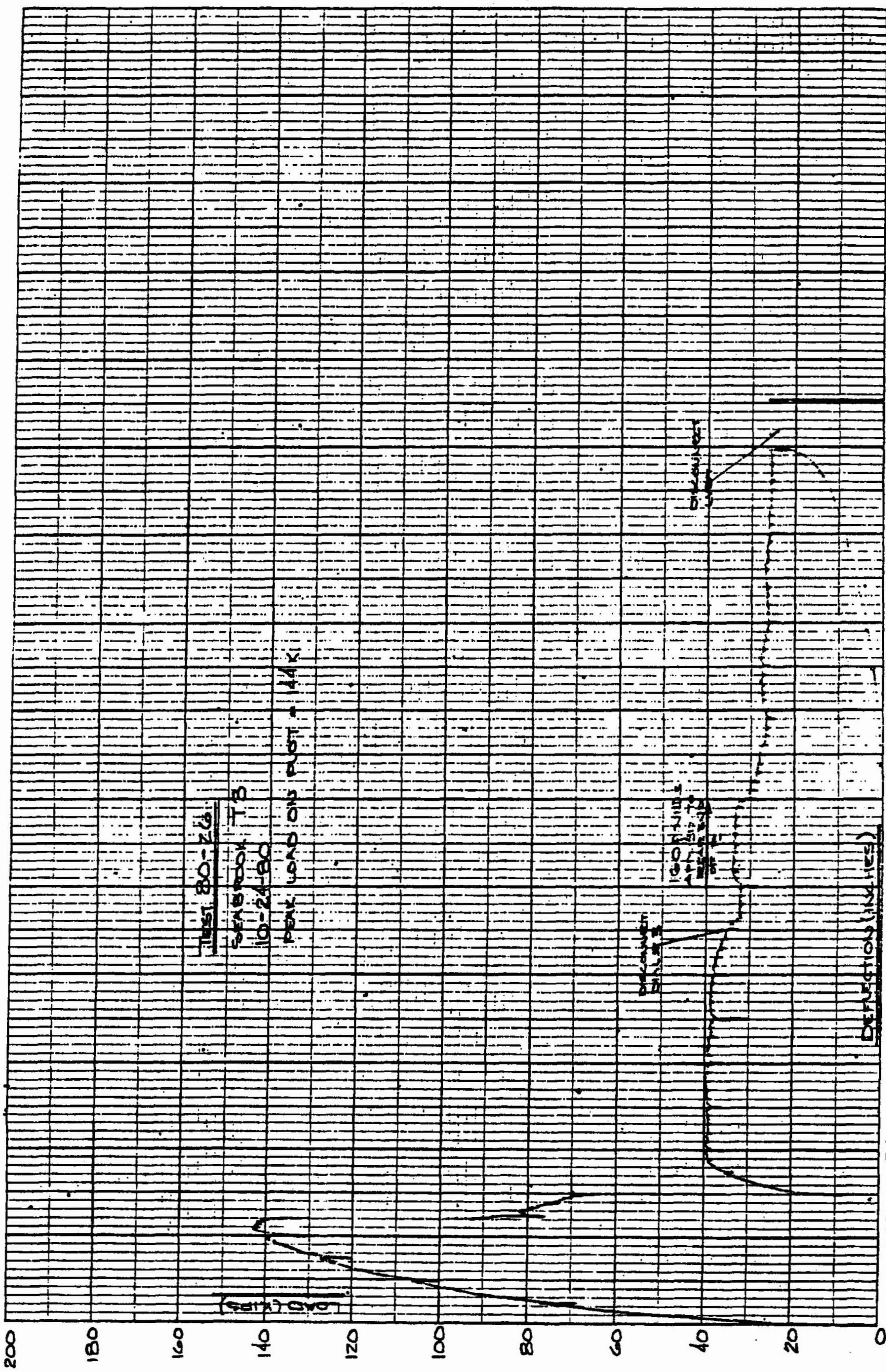
TEST 80-26
SEABROOK T3
PEAK LOAD ON PLOT = 143K
PEAK LOAD ON TAPE = 143.8

DEFL (INCH)	CHANNEL	LOAD (KIPS)
0.50	[illegible]	[illegible] (23.3)
	00	250
	00	252
	00	252
	00	252
	00	253
	00	252
	00	255
	00	256
	00	254
0.45	00	255
	00	258
	00	261
	00	262
	00	262
	00	262
	00	256
	00	258
	00	257
	00	260
0.40	00	258
	00	263
	00	265
	00	269
	00	275
	00	272
	00	271
	00	270
	00	266
	00	272
0.35	00	260
	00	262
	00	262
	00	265
	00	270
	00	278
	00	278
	00	282
	00	286
	00	290
0.30	00	321
	00	331
	00	332
	00	333
	00	337
	00	335
	00	336
	00	337
	00	332
	00	330
0.25	00	316
	00	321
	00	324
	[illegible]	[illegible]

END TEST

	CHANNEL	LOAD
	00	000
	00	007
	00	046
	00	043
	00	016
	00	005
	00	128
	00	092
	00	142
	00	136
	00	127
	00	181
INTERMITTENT	00	166
LOAD	00	172
READINGS	00	158
	00	138
	00	112
	00	074
	00	249
	00	252
	00	238
	00	241
	00	235
	00	194
	00	140
	00	100
	00	065
	00	042
	00	023
	00	009

DISCONNECT LVDT


TEST 80-26
SEABROOK T3
10-24-80
PEAK LOAD ON PLOT = 144K
DEFLECTION (INCHES)
0.05
0.10
0.15
0.20
0.25
0.35
0.50
200
180
160
140
120
100
80
60
40
20
0

UNITED ENGINEERS CONTAINMENT LINER ANCHOR LOAD TEST

TEST SPECIMEN: STUDS 1
PEAK LOAD: 51 KIPS
f'c: PSI
DIAL # 1 LOCATION: 1.5 IN ABOVE LVDT PROBE TO VERIFY HORIZONTAL DEFL. 1/4" FROM STUDS
DIAL # 2 LOCATION: 7" FROM BACK FACE MOUNTED ON SIDE FACE TO INDICATE ROTATION
VISHAY-ELLIS CALIBRATION #: 290

DATE: 11-7-80
WITNESSES: STETHEN, HOLBROOK, CANNON, BURDETTE, FUNK, PERRY

DIAL #3 LOCATION: 5 IN BEHIND STUDS TO MEASURE PLATE

TEST 80-26

MULTI-METER READING (VOLTS)	LVDT DEFL (IN)	LOAD (KIPS)	DIAL#1 (IN) x10³	DIAL#2 (IN) x10³	DIAL#3 (IN) x10³
0.00	0.000	0.0	0	—	0
0.25	0.013	15.5	12	—	8
0.50	0.025	28.7	24	—	18
0.75	0.038	36.3	37	—	28
1.00	0.050	39.4	50	—	36
1.25	0.063	41.2	63	—	43
1.50	0.075	42.4	76	—	49
1.75	0.088	43.0	90	—	53
2.00	0.100	43.7	104	—	58
2.50	0.125	44.0	129	—	65
3.00	0.150	44.9	155	—	72
4.00	0.200	46.3	207	—	84
5.00	0.250	46.9	258	—	92
6.00	0.300	49.1	310	—	100
7.00	0.350	50.0	362	—	103
8.00	0.400	0.0	FAILURE OF 1 STUD ONLY (RIGHT STUD)		
9.00	0.450	26.2	—	—	—
9.95	0.500	24.0	—	—	—
9.59	0.480	0.0	—	—	—
1/2" MAXIMUM TRAVEL REACHED, LOAD REMAINING STUD TO FAILURE (SEE B:OT)					

COMMENTS:

DEFL (IN)	CHANNEL	LOAD (KIPS)
	00	465
	00	469
	00	469
	00	468
0.20	00	463
	00	465
	00	467
	00	460
	00	460
	00	456
	00	446
	00	451
	00	449
	00	453
0.15	00	449
	00	453
	00	447
	00	447
	00	446
	00	440
	00	442
	00	436
	00	441
	00	434
0.10	00	437
	00	435
	00	428
	00	430
	00	429
	00	424
	00	420
	00	416
	00	408
	00	400
0.05	00	388
	00	383
	00	369
	00	362
	00	316
	00	287
	00	196
	00	161
	00	143
	00	101
0.0	00	000

TEST 80-26
STUDS 1
PEAK LOAD ON PLOT = 51.5K
PEAK LOAD ON TAPE = 50.9K

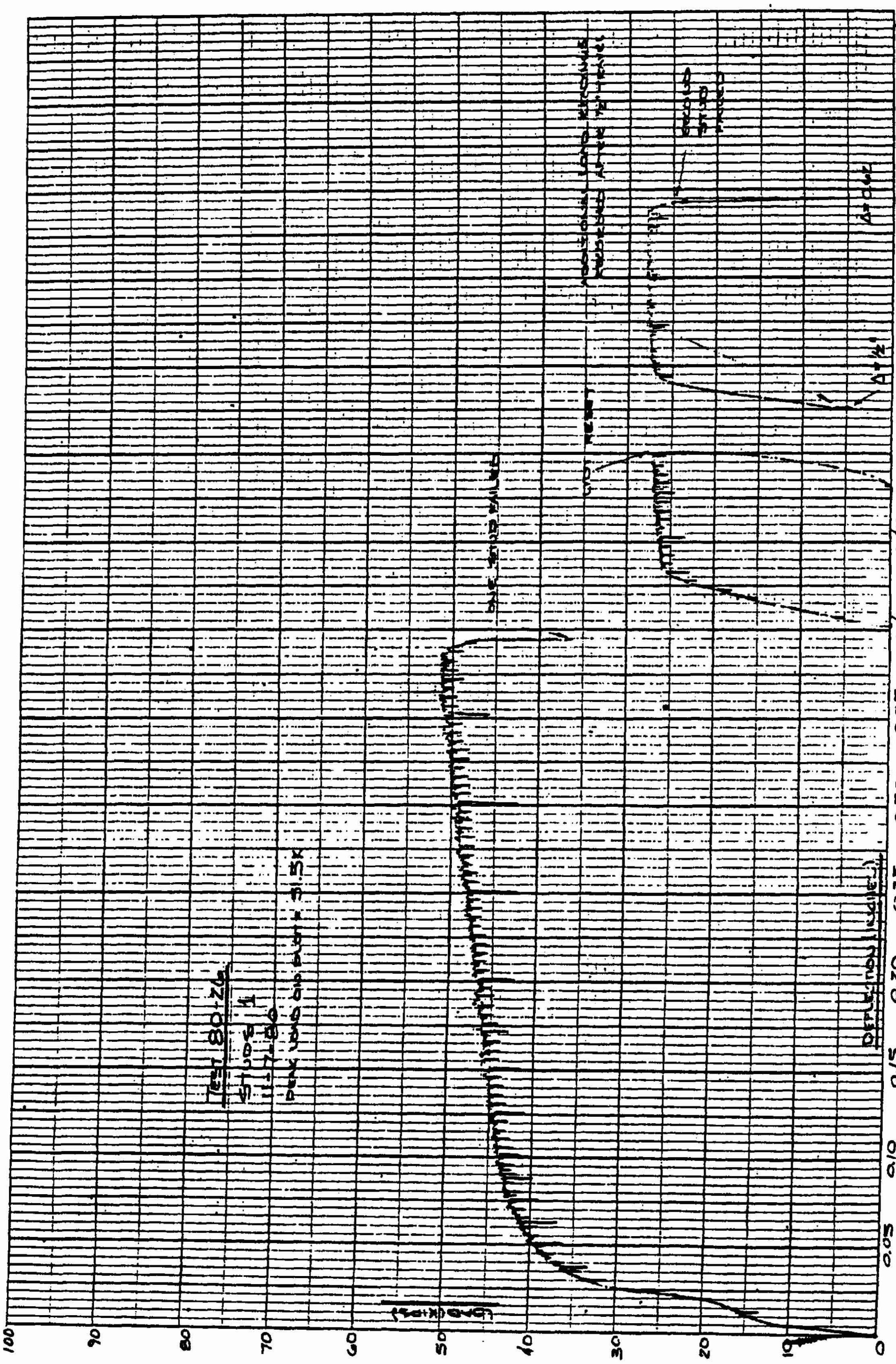
	00	262
	00	264
0.45	00	260
	00	262
	00	260
	00	256
	00	255
	00	251
	00	230
	00	193
	00	161
	00	108
0.40	00	052

RIGHT STUD FAILED
CONTINUE LOADING

	00	486
	00	504
	00	504
	00	506
	00	503
	00	509
	00	507
	00	502
0.35	00	500
	00	504
	00	500
	00	503
	00	498
	00	496
	00	493
	00	492
	00	487
	00	494
0.30	00	491
	00	485
	00	489
	00	489
	00	485
	00	484
	00	485
	00	483
	00	485
	00	483
0.25	00	469
	00	477
	00	475
	00	474

MAXIMUM TRAVEL OFF 1/2"

00	240
00	265
00	262
00	262
00	259
00	266
00	263


0
10
20
30
40
50
60
70
80
90
100
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

UNITED ENGINEERS CONTAINMENT LINER ANCHOR LOAD TEST

TEST SPECIMEN: STUDS 2
PEAK LOAD: 54.8 KIPS
f'c: PSI
DIAL # 1 LOCATION: 1.5 IN ABOVE LVDT PROBE TO VERIFY HORIZONAL DEFL. 14 IN FROM STUDS
DIAL # 2 LOCATION: 7 IN FROM BACK FACE MOUNTED ON SIDE FACE TO INDICATE ROTATION
VISHAY-ELLIS CALIBRATION #: 290

DATE: 11-21-80
WITNESSES: STEPHEN, BURDETTE, P. HAYES, T. HAYES, FUNK, PERRY, COBLEY

DIAL #3 LOCATION: 3 IN BEHIND STUDS TO MEASURE PLATE UPLIFT

TEST 80-26

MULTI-METER READING (VOLTS)	LVDT DEFL (IN)	LOAD (KIPS)	DIAL#1 (IN) x10³	DIAL#2 (IN) x10³	DIAL#3 (IN) x10³
0.00	0.000	0.0	0	0	0
0.25	0.013	24.2	12	0	9
0.50	0.025	29.8	24	0	17
0.75	0.038	34.6	37	0	25
1.00	0.050	37.9	50	0	32
1.25	0.063	38.3	64	0	39
2.00	0.100	41.6	103	0	52
3.00	0.150	42.8	155	0	65
4.00	0.200	44.0	208	0	77
5.00	0.250	44.2	260	0	83
6.00	0.300	46.4	312	0	88
7.00	0.350	47.6	364	0	92
8.00	0.400	49.7	416	0	95
9.00	0.450	49.7	468	0	96
9.96	0.500	48.8	518	0	99
9.14	0.457	0.0	—	—	—
RESET LVDT, CONTINUE TEST (SEE PLOT)					

	00	507
	00	507
	00	508
	00	502
	00	505
	00	502
0.45	00	497
	00	483
	00	493
	00	490
	00	493
	00	494
	00	497
	00	490
	00	494
	00	492
0.40	00	481
	00	490
	00	488
	00	485
	00	484
	00	481
	00	473
	00	481
	00	480
	00	476
0.35	00	476
	00	477
	00	474
	00	471
	00	470
	00	473
	00	467
	00	467
	00	464
	00	457
0.30	00	464
	00	459
	00	463
	00	461
	00	450
	00	456
	00	459
	0C	454
	00	458
	00	453
0.25	00	43
	00	450
	00	452
	00	451
	00	450
	00	448

	00	446
	00	449
	00	433
	00	446
0.20	00	440
	00	441
	00	435
	00	442
	00	438
	00	435
	00	439
	00	438
	00	434
	00	432
0.15	00	428
	00	434
	00	429
	00	431
	00	428
	00	425
	00	426
	00	428
	00	419
	00	417
0.10	00	416
	00	415
	00	415
	00	407
	00	405
	00	401
	00	401
	00	397
	00	386
	00	383
0.05	00	379
	00	373
	00	359
	00	347
	00	323
	00	298
	00	301
	00	286
	00	240
	00	155
0.00	00 -	000
DEFL (IN)	CHANNEL	LOAD (KIP)

TEST 80-26

PEAK LOAD ON PLOT = 54.8K

PEAK LOAD ON TAPE = 54.2K

11-21-80

	00	033
	00 -	001

ONE STUD FAILED, DISCONNECT PLOTTER & TAKE RANDOM LOAD READINGS OF FINAL STUD

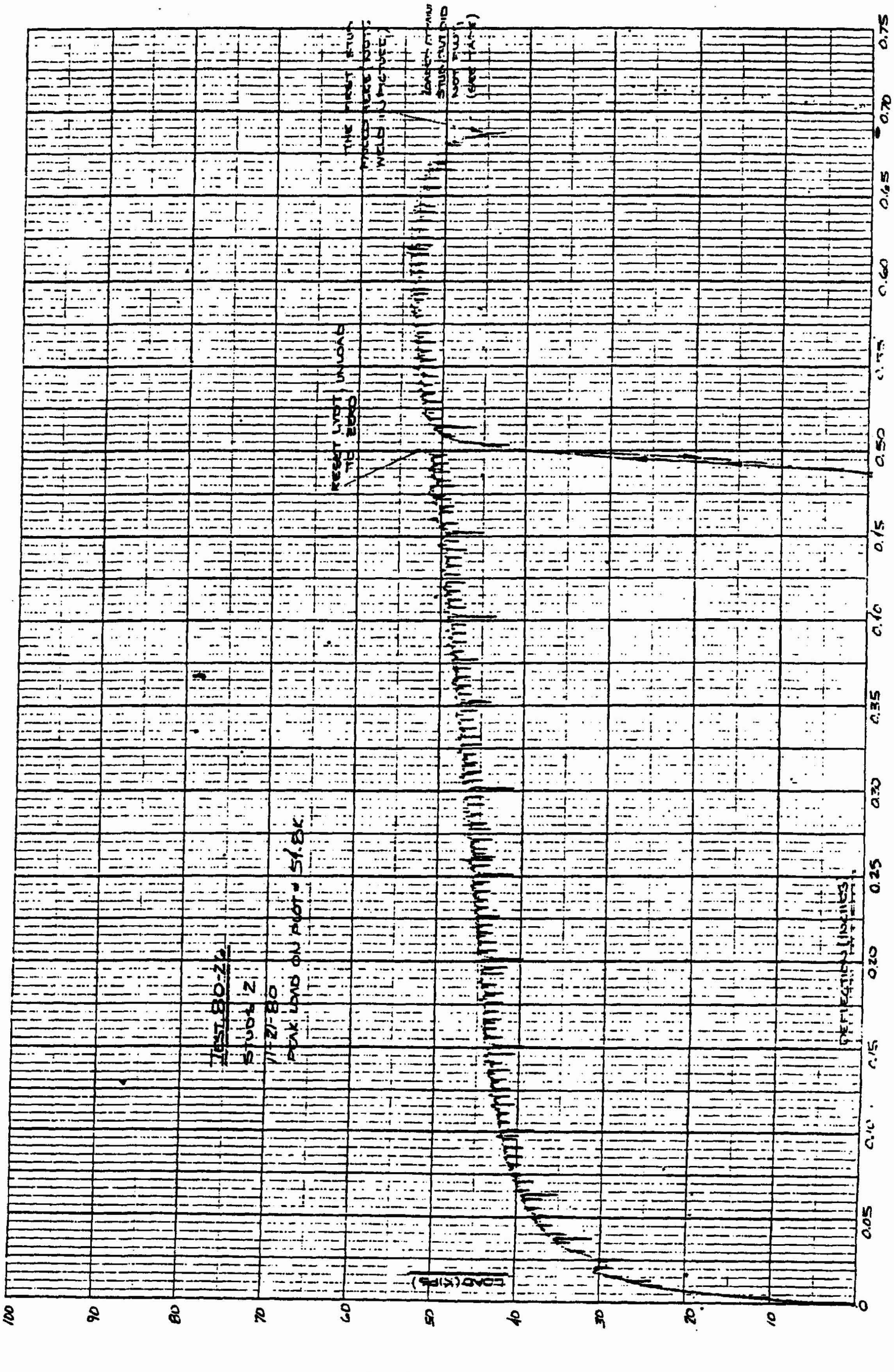
0.68	00	468
	00	496
	00	507
	00	511
	00	520
	00	521
0.65	00	528
	00	519
	00	531
	00	529
	00	538
	00	531
	00	542
	00	539
	00	540
	00	532
0.60	00	539
	00	534
	00	540
	00	535
	00	535
	00	533
	00	536
	00	531
	00	535
	00	526
0.55	00	515
	00	512
	00	524
	00	519
	00	519
	00	518
	00	518
	00	514
	00	502
	00	500
0.50	00	424

RESET LVDT & CONTINUE LOADING

0.50	00	488
	00	509
	00	514
	00	512

SECOND STUD FAILED, END TEST

00 -	002
00	280
00	275
00	284
00	287
00	288
00	283
00	286
00	286
00	287
00	286
00	282
00	282
00	279
00	279
00	276
00	268
00	239
00	204
00	164
00	116
00	070


LOAD (KIPS)
DEFLECTION (INCHES)
RESET LVDT UNLOAD TO ZERO
11-21-80
PEAK LOAD ON PLOT = 51.8K
0
10
20
30
40
50
60
70
80
90
100
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.60
0.65
0.70
0.75

UNITED ENGINEERS CONTAINMENT LINER ANCHOR LOAD TEST

TEST SPECIMEN: Studs 3
PEAK LOAD: 52.5 KIPS
f'c: PSI
DIAL # I LOCATION: 1.5 in above LVDT probe to indicate horizontal deflection of plate
DIAL # 2 LOCATION: 7 in from the back face of block to indicate rotation
VISHAY-ELLIS CALIBRATION #: 290

DATE: 12-2-80
WITNESSES: Stethen, Haley, Cobley, Burdette, T. Hayes, Galunic

Dial #3 location: 3½ in behind studs to measure plate uplift

Test 80-26

MULTI-METER READING (VOLTS)	LVDT DEFL (IN)	LOAD (KIPS)	DIAL#I (IN) x10³	DIAL#2 (IN) x10³	DIAL#3 (IN) x10³
0.00	0.000	0.0	0	0	0
0.25	0.013	15.7	12	0	5
0.50	0.025	29.9	24	0	17
0.75	0.038	37.9	36	0	27
1.00	0.050	39.7	50	0	38
1.25	0.063	40.6	62	0	46
1.50	0.075	42.7	76	0	52
2.00	0.100	43.8	102	0	61
3.00	0.150	45.9	154	0	77
4.00	0.200	47.1	207	0	93
5.00	0.250	48.4	258	0	104
6.00	0.300	49.6	311.	0	115
7.00	0.350	50.0	361	0	125
8.00	0.400	50.9	415	0	130
9.00	0.450	50.3	466	0	135
One stud failed, reset LVDT, disconnect dial # 1					
6.30	0.550	24.1	———	2	132
7.30	0.600	Second stud failed			
*Note: Both studs failed outside the weld region					

COMMENTS:

DEFL. (IN)	CHANNEL	LOAD (KIPS)
	00	504
	00	513
	00	505
	00	507
	00	511
	00	510
	00	512
0.45	00	503
	00	498
	00	508
	00	507
	00	508
	00	496
	00	506
	00	506
	00	510
	00	512
0.40	00	509
	00	508
	00	516
	00	515
	00	513
	00	513
	00	511
	00	510
	00	505
	00	514
0.35	00	500
	00	502
	00	507
	00	505
	00	502
	00	505
	00	503
	00	500
	00	487
	00	501
0.30	00	496
	00	497
	00	492
	00	494
	00	495
	00	497
	00	489
	00	487
	00	488
	00	487
0.25	00	484
	00	483
	00	480
	00	473
	00	480
	00	476
	00	478
	00	473
	00	473
	00	470
0.20	00	471
	00	468
	00	471
	00	468
	00	468
	00	464
	00	463
	00	462
	00	459
	00	462
0.15	00	459
	00	453
	00	448
	00	449
	00	452
	00	449
	00	448
	00	447
	00	436
	00	444
0.10	00	438
	00	439
	00	436
	00	435
	00	432
	00	427
	00	427
	00	418
	00	413
	00	411
0.05	00	397
	00	390
	00	380
	00	365
	00	334
	00	299
	00	267
	00	214
	00	129
	00	088
0.0	00	000

TEST 80-26

PEAK LOAD ON PLOT = 52.5K
PEAK LOAD ON TAPE = 51.6K

STUDS 3

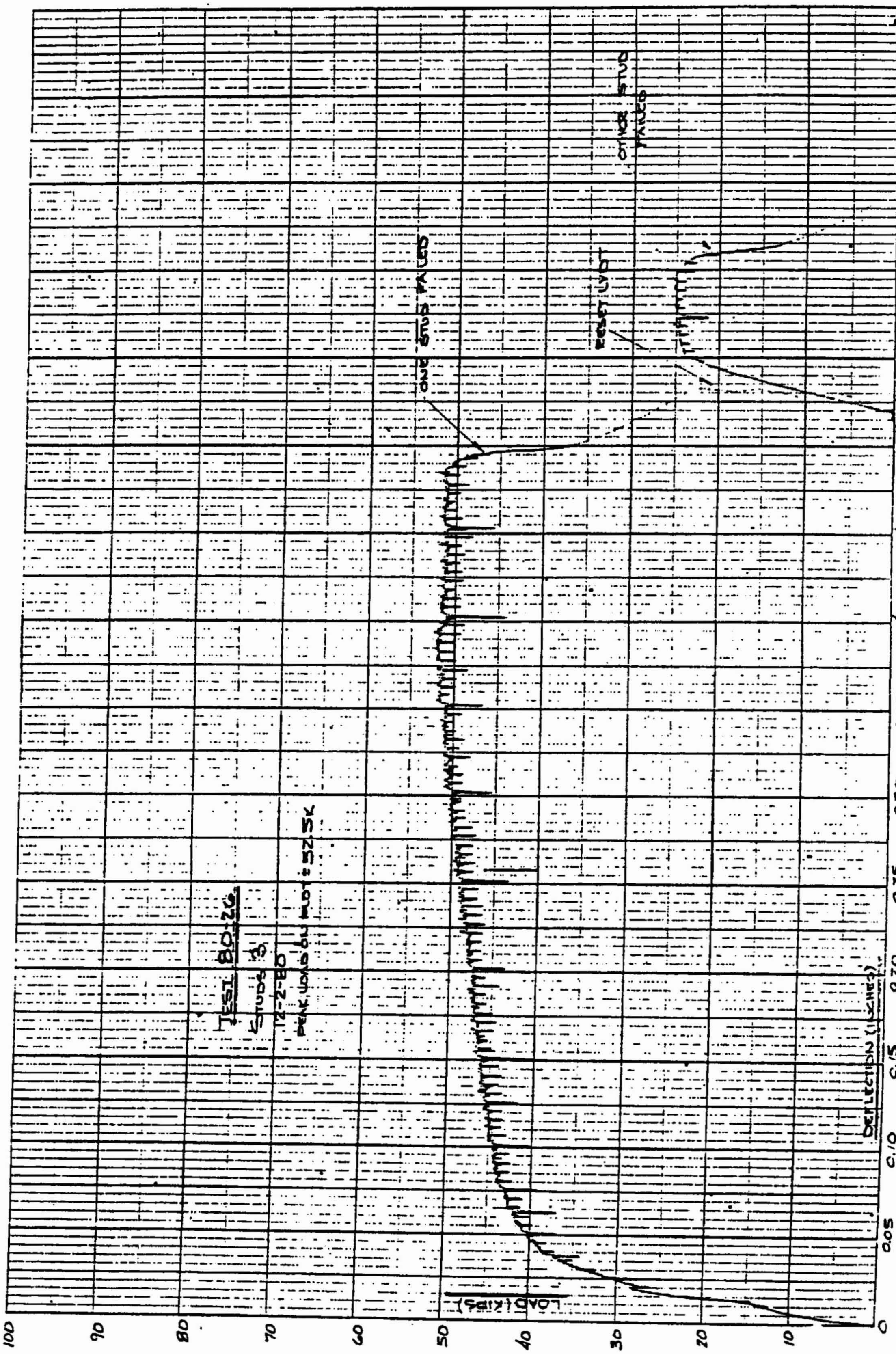
17-7-80

SECOND STUD FAILED,
END TEST

0.585	00	214
	00	237
	00	244
	00	245
	00	245
	00	246
	00	245
0.55	00	241
	00	241
	00	243
	00	241
	00	238
	00	219
	00	191
	00	157
	00	109
	00	067
0.50	00	025

ONE STUD FAILED,
RESET LVDT, REMOVE
DIAL # 1

0.495	00	– 000
	00	487


TEST 80-26
LOAD (KIPS)
DEFLECTION (INCHES)
ONE STUD FAILED
RESET LVDT
OTHER STUD FAILED
0
10
20
30
40
50
60
70
80
90
100
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60

CONTAINMENT LINER ANCHOR LOAD TEST

FABRICATION OF SPECIMENS

SEABROOK PROJECT

Date: April 7, 1981

Prepared by: Branko Galunic
B. Galunic

Containment Liner Anchor Load Test
Fabrication of Specimens
Seabrook Project

1. INTRODUCTION

The containment structure at the Seabrook Nuclear Project is a right vertical cylinder having an inside radius of 140 feet and wall thickness of 4'-6", and it has a hemispherical dome which is 3'-6" thick. At the base is a 10 foot thick mat. It is designed to resist the pressure from the most severe break in a reactor coolant pipe. In order to meet the leak tightness requirements of the vessel, a steel liner plate is installed over the inside surface of the concrete. The liner is generally 3/8 inch thick in the cylindrical portion and is thickened to 3/4 inches in the penetration areas near the base. The liner in the dome has a uniform thickness of 1/2 inch and it is 1/4 inch thick on top of the mat. It is anchored to the concrete shell by embedded structural tees and studs welded to the liner plate. Headed studs are only used on the 3/4 inch plates in the penetration area. The tees are used in all other regions.

The purpose of these tests is to define a load-deflection curve for the anchors which can be used in the analysis of the liner/anchor system. The liner strains and anchor displacements must meet the requirements of the ASME Section III Division 2 Code.

2. MATERIALS

2.1 Tees

The tees are made from SA36 steel. They were rolled in Japan and accordingly have metric dimensions. The tee WT 100x100 corresponds very closely

with the American WT 4x7.5 (3.94 in. vs 4.0 in. flange width).

2.2 Studs

The stud material conforms to ASTM Specification A-108 Grade 1018. The yield stress is approximately 50 ksi and the ultimate strength is approximately 60 ksi.

2.3 Liner Plate

The liner plate is made from SA 516 Grade 60 steel (Specification 9763.006 15-1). The plate was cut so that the tensile load on the plate during the test is applied in the direction of rolling. The plate thickness used for all tests, including the studs, was 3/8 inch. In the containment structure the studs are welded to a 3/4 inch plate. It is expected that the thinner plate used in the test will permit larger rotations of the anchor in the vicinity of the plate causing larger stresses in the concrete and thereby conservative results.

2.4 Concrete

All concrete was mixed in accordance with PSNH Specification 9763.006 69-7 and 9763-69-3. The design strength was 4000 psi. The concrete mix is the same as used in the containment structure. An air-entraining and retarding admixture was used. The concrete was Atlantic Type II and the coarse aggregate conforms to ASTM C-67.

2.5 Reinforcement

The concrete is reinforced with rebar that conforms to ASTM A615 Grade 60 Specifications.

3. DESIGN OF SPECIMENS

The dimensions of the specimens, the reinforcement and pertinent details are shown in the drawing LT-1. The overall size of the specimens and the length and taper of the liner were based on the dimensional limitations of the testing equipment. The reinforcement served two purposes. It first provided a confinement of the concrete and prevented cracking that could occur during transportation and other handling. Also, additional rebar were placed on the side of the tees away from the load application. The purpose of these bars was to prevent overall cracking of the specimen when the test load is applied. They are intended to eliminate failure modes that might occur due to the physical limitations of the test specimen. Any cracking of the free vertical surfaces would not be representative of what could occur in the actual structure which is continuous. The length of the tee specimens was held to 12 inches, to minimize the effect of the free edge.

These problems are not expected to occur when studs are used because the failure will be localized to a small area. The same overall dimensions were used for simplicity of fabrication.

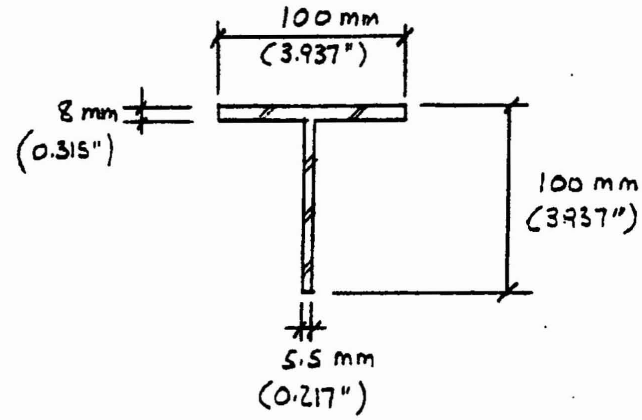
4. POURING PROCEDURE

The test block forms were fabricated at the Seabrook site. The liner formed one side of the form as is the case in the containment structure. The tees were oriented vertically during the pouring operation. Before the concrete was poured a thin coating of WD-40 was sprayed on the liner to eliminate bond between the liner and concrete. Concrete was mixed at the Site Batch Plant and brought to the test area by trucks. The concrete was placed into the forms by a pump truck to simulate actual field placement conditions.

Each specimen was fabricated in three lifts. After each lift a vibrator was used to consolidate the concrete and eliminate voids. Two different trucks were used. Twelve cylinders were taken from each truck. In addition, six cylinders were made for each specimen. These were stored on site in a controlled environment curing room. Three were broken on the day of the test of the specimen. At the end of the pour the top of the concrete surface was troweled to a smooth finish. A chemical curing compound was applied to the exposed surface to seal in moisture and thereby replace water curing.

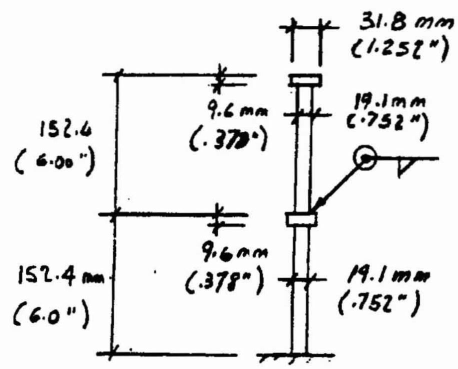
5. TRANSPORTATION

The specimens were transported to Knoxville, Tennessee on two flatbed trucks 14 days after fabrication. Five day cylinder breaks indicated a strength of 3550 psi.



TEE SECTION

FIGURE 1.



STUD DETAIL

FIGURE 2

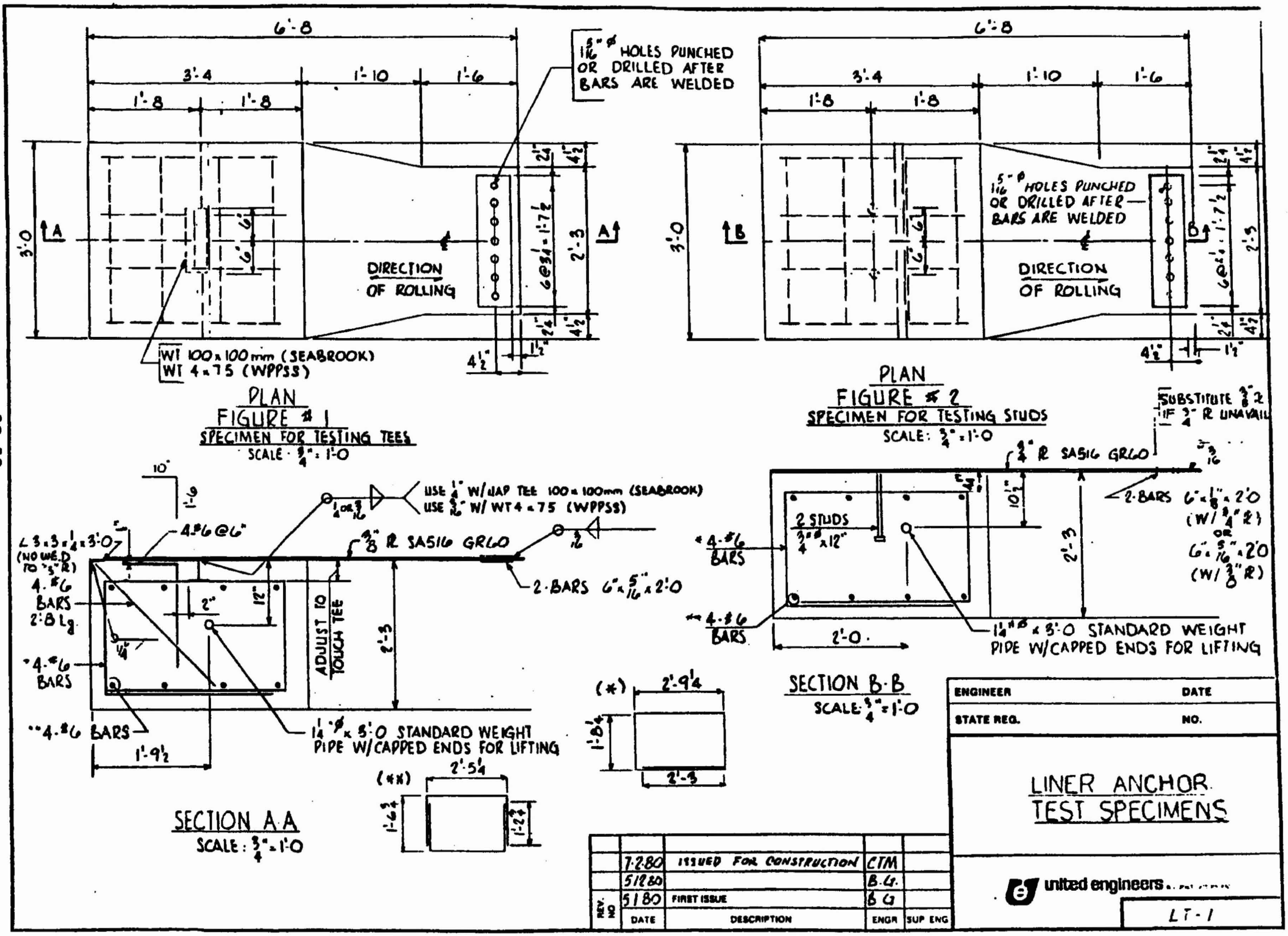

6'-8
3'-4
1'-10
1'-6
1'-8
1'-8
5/16" ⌀ HOLES PUNCHED OR DRILLED AFTER BARS ARE WELDED
DIRECTION OF ROLLING
WT 100 x 100 mm (SEABROOK)
WT 4 x 7.5 (WPPSS)
PLAN
FIGURE # 1
SPECIMEN FOR TESTING TEES
SCALE: 3/4" = 1'-0
PLAN
FIGURE # 2
SPECIMEN FOR TESTING STUDS
SCALE: 3/4" = 1'-0
SUBSTITUTE 3/8" R IF 3/4" R UNAVAIL
3/4" R SA516 GR60
2-BARS 6" x 1/2" x 2'-0 (W/ 3/4" R) OR 6" x 5/16" x 2'-0 (W/ 3/8" R)
2 STUDS 3/4" ⌀ x 12"
4-#6 BARS
1 1/4" ⌀ x 3'-0 STANDARD WEIGHT PIPE W/CAPPED ENDS FOR LIFTING
SECTION B-B
SCALE: 3/4" = 1'-0
USE 1/4" W/JAP TEE 100 x 100mm (SEABROOK)
USE 3/16" W/ WT 4 x 7.5 (WPPSS)
L 3 x 3 x 1/4 x 3'-0 (NO WELD TO 3/8" R)
4-#6 @ 6"
3/8" R SA516 GR60
2-BARS 6" x 5/16" x 2'-0
4-#6 BARS 2'-8 Lg.
ADJUST TO TOUCH TEE
4-#6 BARS
1 1/4" ⌀ x 3'-0 STANDARD WEIGHT PIPE W/CAPPED ENDS FOR LIFTING
SECTION A-A
SCALE: 3/4" = 1'-0
ENGINEER
DATE
STATE REG.
NO.
LINER ANCHOR TEST SPECIMENS
7-2-80 ISSUED FOR CONSTRUCTION CTM
5/12/80 B.G.
5/1/80 FIRST ISSUE B.G.
REV. NO
DATE
DESCRIPTION
ENGR
SUP ENG
united engineers
LT-1

Plate 1: Close-up of tee welded to liner plate

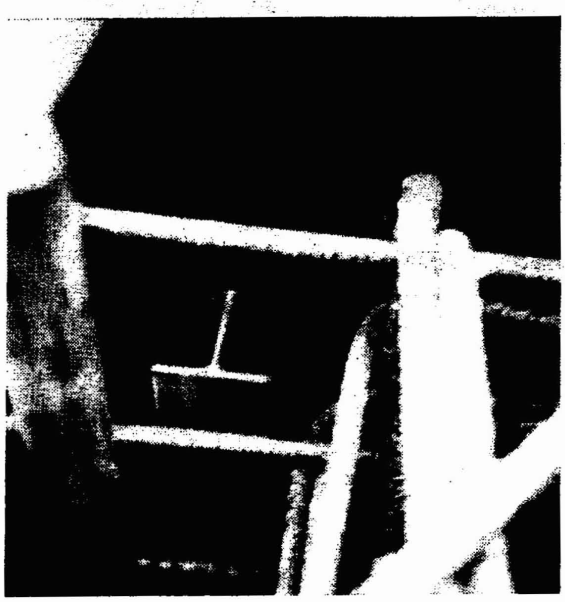


Plate 2: Reinforcing cage and tee

Plate 3: Finished specimens at end of pouring operation

APPENDIX 3H **(DELETED IN AMENDMENT 53)**