REPORT ON DRILLED SHAFT LOAD TESTING (OSTERBERG METHOD)

Test Shaft #1 - Hwy 1 over Des Moines River Keosauqua, IA (LT-9183)

Prepared for: **Longfellow Drilling Company**
1209 County Highway J23
Clearfield, IA 50840

Attention: **Mr. Mike Kemery**

PROJECT NUMBER: LT-9183, May 18, 2006

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DEEP FOUNDATION TESTING, EQUIPMENT & SERVICES • SPECIALIZING IN OSTERBERG CELL (O-cell®) TECHNOLOGY

LOADTEST

May 18, 2006

Longfellow Drilling Company
1209 County Highway J23
Clearfield, IA 50840

Attention: Mr. Mike Kemery

Load Test Report: Test Shaft #1 - Hwy 1 over Des Moines River
Location: Keosauqua, IA (LT-9183)

Dear Mr. Kemery,

The enclosed report contains the data and analysis summary for the O-cell test performed on Test Shaft #1 - Hwy 1 over Des Moines River, on May 11, 2006. For your convenience, we have included an executive summary of the test results in addition to our standard detailed data report. Preliminary results were issued on May 17, 2006.

We would like to express our gratitude for the on-site and off-site assistance provided by your team and we look forward to working with you on future projects.

We trust that the information contained herein will suit your current project needs. If you have any questions or require further technical assistance, please do not hesitate to contact us at 352-378-3717.

Best Regards,

D. Tilson
for William G. Ryan, B.S.C.M.
Midwest Regional Manager, LOADTEST, Inc.

EXECUTIVE SUMMARY

On May 11, 2006, we tested a 36-inch (914-mm) diameter dedicated test shaft constructed by Longfellow Drilling Company. Mr. Michael D. Ahrens and Mr. Jon Sinnreich of LOADTEST, Inc. carried out the test. Longfellow Drilling Company constructed the 34-foot (10.4-meter) deep shaft wet using polymer slurry between May 1 and 3, 2006. Sub-surface conditions at the test shaft location consist primarily of clayey overburden underlain by limestone and sandstone. Representatives of the Iowa Department of Transportation and others observed construction and testing of the shaft.

The maximum sustained bi-directional load applied to the shaft was 9,275 kips (41.26 MN). At the maximum load, the displacements above and below the O-cell were 0.307 inches (7.79 mm) and 3.353 inches (85.17 mm), respectively. The average unit shear in the rock socket is calculated to be 60 ksf (2,850 kPa) and the maximum end bearing pressure applied was 1,312 ksf (62,827 kPa) at the above noted displacements.

LIMITATIONS OF EXECUTIVE SUMMARY

We include this executive summary to provide a very brief presentation of some of the key elements of this O-cell test. It is by no means intended to be a comprehensive or stand-alone representation of the test results. The full text of the report and the attached appendices contain important information which the engineer can use to come to more informed conclusions about the data presented herein.

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SITE CONDITIONS AND SHAFT CONSTRUCTION

Site Sub-surface Conditions: The sub-surface stratigraphy at the general location of the test shaft is reported to consist of clayey overburden underlain by limestone and sandstone. The generalized subsurface profile is included in Figure A and a boring log indicating conditions at the test shaft location is presented in Appendix E. More detailed geologic information can be obtained from the Iowa Department of Transportation.

Test Shaft Construction: Longfellow Drilling Company began excavation of the dedicated test shaft on May 1, 2006 and performed the final cleanout and concreting on May 3, 2006. We understand that the 36-inch (914-mm) diameter test shaft was excavated wet to a tip elevation of +538.0 feet (+163.98 meters) with polymer slurry. The shaft was started by predrilling the overburden and screwing in a temporary casing. The rock was cored and occasionally drilled with a rock auger. The final tip elevation was drilled with the auger and cleaned with a cleanout bucket. Previously-removed cores showed a stepped conical indentation in the center formed by the auger. Prior to concreting, the base of the shaft was airlifted. Approximately 2 linear feet of grout was placed in the base of the shaft by pump line. After extracting the pump line, the rebar cage with attached O-cell assembly was inserted and allowed to settle into the wet grout with the O-cell 0.7 feet (0.22 meters) above the center of the shaft tip. The pump line was then reinserted and concrete was placed until reaching cutoff elevation. The casing was charged with concrete and then fully extracted.

OSTERBERG CELL TESTING

Shaft Instrumentation: Test shaft instrumentation and assembly was carried out under the direction of Mr. Michael D. Ahrens of LOADTEST, Inc. on May 1 and 2, 2006. The loading assembly consisted of one 34-inch diameter O-cell located 0.7 feet (0.22 meters) above the tip of shaft. Calibrations of O-cell and instrumentation used for this test are included in Appendix B.

O-cell testing instrumentation included three Linear Vibrating Wire Displacement Transducers (LVWDTs) – (Geokon Model 4450 series) positioned between the base of the O-cell and the upper plate to measure expansion (Appendix A, Page 2). Two top plate telltale casings (nominal ½-inch steel pipe) were attached to the inside of the reinforcing cage, diametrically opposed, extending from the top of the O-cell assembly to beyond the top of concrete. Two bottom plate telltale casings were attached to the outside of the reinforcing cage, diametrically opposed, extending from the base of the O-cell assembly to beyond the top of concrete.

Strain gages were used to assess the side shear load transfer of the shaft above the Osterberg cell assembly. Six levels of two sister bar vibrating wire strain gages (Geokon Model 4911 Series) were installed, diametrically opposed, in the shaft above the base of the O-cell assembly. Details concerning the strain gage placement appear in Table B and Figures A & B. The strain gages were positioned as directed by the Iowa Department of Transportation.

Test Arrangement: Throughout the load test, key elements of shaft response were monitored using the equipment and instruments described herein. Top and bottom plate telltale movements were measured using ¼-inch telltales installed in the ½-inch steel pipes (described under Shaft Instrumentation) and monitored by Linear Voltage Displacement Transducers (LVDTs) (RDP DCW Series). Two automated digital survey levels (Leica NA3003) were used to monitor the top of shaft movement during testing from an average distance of 44 feet (13.4 meters). Top of shaft and telltale displacements are presented in Appendix A, Page 1

Both a Bourdon pressure gage and a vibrating wire pressure transducer were used to measure the pressure applied to the O-cell at each load interval. We used the Bourdon pressure gage for setting and maintaining loads and for data analysis. The transducer readings were used for real time plotting and as a check on the Bourdon gage. There was close agreement between the Bourdon gage and the pressure transducer.

Data Acquisition: All instrumentation were connected through a data logger (Campbell Scientific CR-10) to a laptop computer allowing data to be recorded and stored automatically at 30 second intervals and displayed in real time. The same laptop computer synchronized to the data logging system was used to acquire the Leica NA3003 data sets.

Testing Procedures: As with all of our tests, we begin by pressurizing the O-cell in order to break the tack welds that hold it closed (for handling and for placement in the shaft) and to form the fracture plane in the concrete surrounding the base of the O-cell. After the break occurs, we immediately release the pressure and then begin the loading procedure. Zero readings for all instrumentation are taken prior to the preliminary weld-breaking load-unload cycle, which in this case involved a maximum applied pressure of 600 psi (4.14 MPa) to the O-cell.

The Osterberg cell load test was conducted as follows: We pressurized the 34-inch (860-mm) diameter O-cell, with its base located 0.7 feet (0.22 meters) above the base of shaft to assess the end bearing below the O-cell and the side shear above. We pressurized the O-cell in 15 loading increments to 15,000 psi (103.43 MPa) resulting in a bi-directional gross O-cell load of 9,275 kips (41.26 MN). The loading was halted after load interval 1L-15 because the maximum capacity of the hydraulic system had been reached. The O-cell was then depressurized in five decrements and the test was concluded.

We applied the load increments using the Quick Load Test Method for Individual Piles (ASTM D1143 *Standard Test Method for Piles Under Static Axial Load*), holding each successive load increment constant for eight minutes by manually adjusting the O-cell pressure. The data logger automatically recorded the instrument readings every 30 seconds, but herein we report only the 1, 2, 4 and 8-minute readings (where applicable) during each increment of maintained load.

TEST RESULTS AND ANALYSES

General: The loads applied by the O-cell act in two opposing directions, resisted by the capacity of the shaft above and below. Theoretically, the O-cell does not impose an additional upward load until its expansion force exceeds the buoyant weight of the shaft above the O-cell. Therefore, *net load*, which is defined as gross O-cell load minus the buoyant weight of the shaft above, is used to determine side shear resistance above the O-cell and to construct the equivalent top-loaded load-settlement curve. For this test we calculated a buoyant weight of shaft of 34 kips (0.15 MN) above the O-cell.

Upper Side Shear Resistance: The maximum upward applied *net load* to the upper side shear was 9,242 kips (41.11 MN) which occurred at load interval 1L-15. At this loading, the upward movement of the O-cell top was 0.307 inches (7.79 mm).

In order to assess the side shear resistance of the test shaft, loads are calculated based on the strain gage data (Appendix A, Pages 4 and 5) and estimates of shaft stiffness (AE) which are presented below. We used the ACI formula ($E_c=57000\sqrt{f'_c}$) to calculate an elastic modulus for the concrete, where f'_c was reported to be 4,100 psi (28.27 MPa) on the day of the test. This, combined with the area of reinforcing steel and nominal shaft diameter, provided an average shaft stiffness (AE) of 5,560,000 kips (24,700 MN) in the temporarily-cased section, 4,220,000 kips (18,800 MN) in the uncased section above the O-cell and 3,720,000 kips (16,500 MN) below the O-cell. Net unit shear curves are presented in Appendix F. Net unit shear values for loading increment 1L-15 follow in Table A:

TABLE A: Average Net Unit Side Shear Values for 1L-15

Load Transfer Zone	Displacement *	Net Unit Side Shear **
Top of Shaft to Strain Gage Level 6	↑ 0.085"	0.1 ksf (5 kPa)
Strain Gage Level 6 to Strain Gage Level 5	↑ 0.086"	0.9 ksf (44 kPa)
Strain Gage Level 5 to Strain Gage Level 4	↑ 0.086"	5.3 ksf (253 kPa)
Strain Gage Level 4 to Strain Gage Level 3	↑ 0.088"	9.2 ksf (440 kPa)
Strain Gage Level 3 to Strain Gage Level 2	↑ 0.101"	44.3 ksf (2123 kPa)
Strain Gage Level 2 to Strain Gage Level 1	↑ 0.145"	55.0 ksf (2632 kPa)
Strain Gage Level 1 to Top of O-cell	↑ 0.242"	120.8 ksf (5782 kPa)

* Average displacement of load transfer zone.

** For upward-loaded shear, the buoyant weight of shaft in each zone has been subtracted from the load shed in the respective zone above the O-cell.

NOTE: Net unit shear values derived from the strain gages above the O-cell assembly may not be ultimate values. See Appendix F for net unit shear vs. average shear zone displacement plots.

End Bearing Resistance: The maximum O-cell load applied to the end bearing was 9,275 kips (41.26 MN) which occurred at load interval 1L-15 (Appendix A, Page 3, Figure 1). At this load, the average downward movement of the O-cell base was 3.353 inches (85.17 mm). Assuming all of the downward load was applied to the base of the shaft the unit end bearing is calculated to be 1,312 ksf (62,827 kPa) at the above noted displacement. A unit end bearing curve is presented in Appendix F.

Creep Limit: See Appendix D for our O-cell method for determining creep limit. The end bearing creep data (Appendix A, Page 3) indicates an indeterminate creep limit (Figure 4). The side shear creep data (Appendix A, Page 3) indicates that no apparent creep limit was reached at a maximum movement of 0.31 inches (7.8 mm) (Figure 5). A top-loaded shaft will not begin significant creep until both components begin creep movement. This will occur at the maximum of the movements required to reach the creep limit for each component. We believe that significant creep for this shaft will not begin until a top loading exceeds the maximum load plotted in Figure 2 by some unknown amount.

Equivalent Top Load: The test shaft was loaded to a combined side shear and end-bearing load of 18,517 kips (82.4 MN). Figure 2 presents the equivalent top-loaded load-settlement curves. The lighter curve, described in Procedure Part I of Appendix C, was generated by using the measured upward top of O-cell and downward base of O-cell data. Because it is often an important component of the settlements involved, the equivalent top load curve requires an adjustment for the additional elastic compression that would occur in a top-load test. The darker curve as described in Procedure Part II of Appendix C includes this adjustment.

Note that, as explained previously, the equivalent top load curve applies to incremental loading durations of eight minutes. Creep effects will reduce the ultimate resistance of both components and increase shaft top movement for a given loading over longer times. The Engineer can estimate such additional creep effects by suitable extrapolation of time effects using the creep data presented herein. However, our experience suggests that such corrections are small and perhaps negligible for top loadings below the creep limit indicated in Figure 2.

Shaft Compression Comparison: The measured maximum shaft compression, averaged from two telltales, is 0.222 inches (5.65 mm) at 1L-15 (Appendix A, Page 2). Using a shaft stiffness of 5,560,000 kips (24,700 MN) in the temporarily-cased section and 4,220,000 kips (18,800 MN) in the uncased section and the load distribution in Figure 3 at 1L-15, we calculated an elastic compression of 0.142 inches (3.61 mm) over the length of the compression telltales.

LIMITATIONS AND STANDARD OF CARE

The instrumentation, testing services and data analysis provided by LOADTEST, Inc., outlined in this report, were performed in accordance with the accepted standards of care recognized by professionals in the drilled shaft and foundation engineering industry.

Please note that some of the information contained in this report is based on data (i.e. shaft diameter, elevations and concrete strength) provided by others. The engineer, therefore, should come to his or her own conclusions with regard to the analyses as they depend on this information. In particular, LOADTEST, Inc. typically does not observe and record drilled shaft construction details to the level of precision that the project engineer may require. In many cases, we may not be present for the entire duration of shaft construction. Since construction technique can play a significant role in determining the load bearing capacity of a drilled shaft, the engineer should pay close attention to the drilled shaft construction details that were recorded elsewhere.

We trust that this information will meet your current project needs. If you have any questions, please do not hesitate to contact us at 800-368-1138.

Prepared for LOADTEST, Inc. by

D. Nilson

for Michael D. Ahrens, P.E.
Geotechnical Engineer

Reviewed by

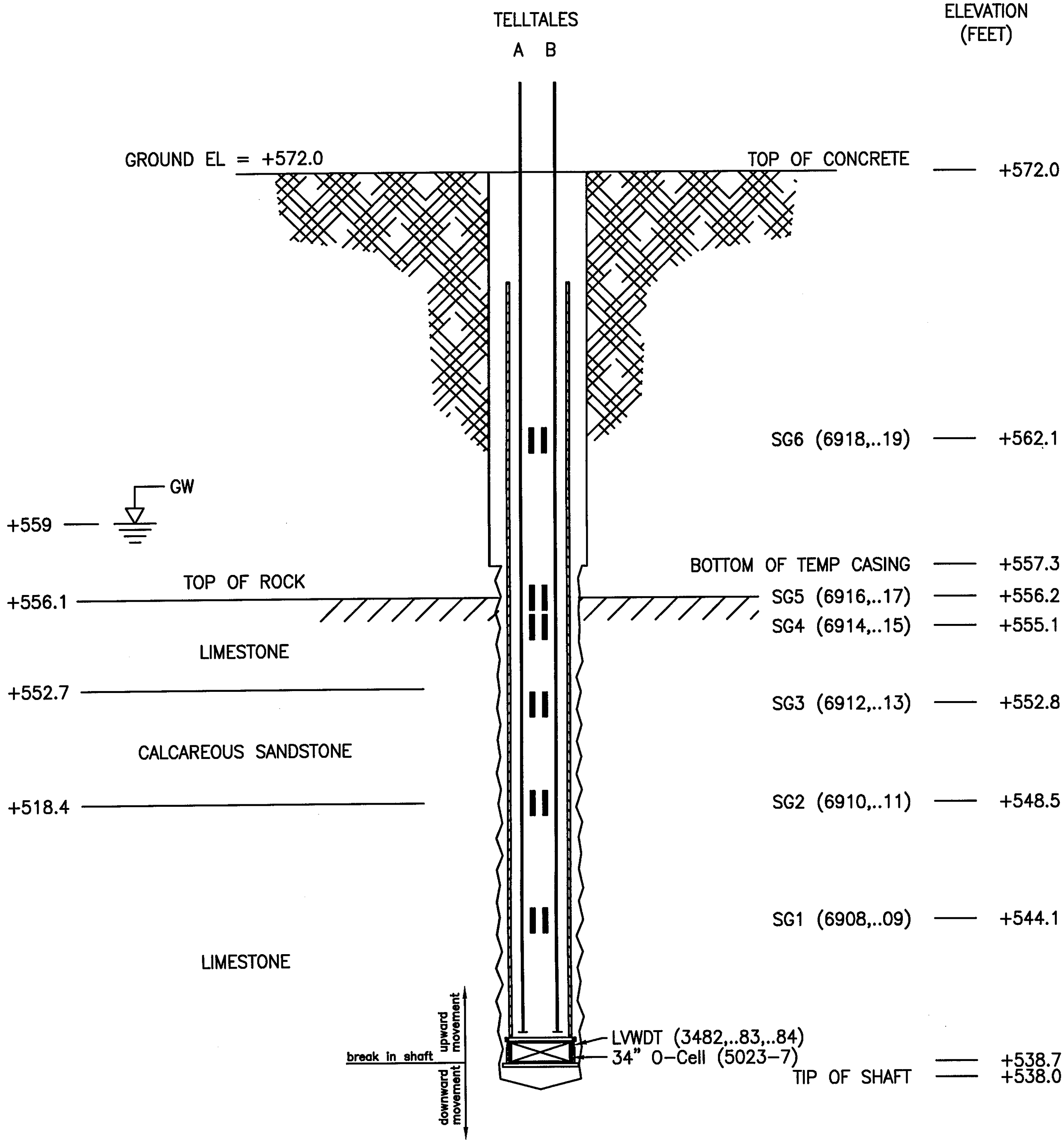
for Shing K. Pang, P.E.
Geotechnical Engineer

David J. Jakstis, P.E.
Project Engineer

TABLE B:
SUMMARY OF DIMENSIONS, ELEVATIONS & SHAFT PROPERTIES

Shaft:			
Nominal shaft diameter (EL +572.0 ft to +557.3 ft)	=	42 in	1067 mm
Nominal shaft diameter (EL +557.3 ft to +538.0 ft)	=	36 in	914 mm
O-cell: 5023-7	=	34 in	860 mm
Bouyant weight of pile above base of O-cell	=	34 kips	0.15 MN
Estimated shaft stiffness, AE (EL +572.0 ft to +557.3 ft)	=	5,560,000 kips	24,700 MN
Estimated shaft stiffness, AE (EL +557.3 ft to +538.7 ft)	=	4,220,000 kips	18,800 MN
Estimated shaft stiffness, AE (EL +538.7 ft to +538.0 ft)	=	3,720,000 kips	16,500 MN
Elevation of top of shaft concrete / ground surface	=	+572.0 ft	+174.35 m
Elevation of water table	=	+559.0 ft	+170.38 m
Elevation of base of O-cell (The break between upward and downward movement.)	=	+538.7 ft	+164.20 m
Elevation of shaft tip	=	+538.0 ft	+163.98 m
Casings:			
Elevation of top of temporary casing (42.0 in O.D.)	=	+573.3 ft	+174.75 m
Elevation of bottom of temporary casing (42.0 in O.D.)	=	+557.3 ft	+169.87 m
Compression Sections:			
Elevation of top of telltale used for shaft compression	=	+572.0 ft	+174.35 m
Elevation of bottom of telltale used for shaft compression	=	+539.9 ft	+164.55 m
Strain Gages:			
Elevation of strain gage Level 6	=	+562.1 ft	+171.33 m
Elevation of strain gage Level 5	=	+556.2 ft	+169.54 m
Elevation of strain gage Level 4	=	+555.1 ft	+169.20 m
Elevation of strain gage Level 3	=	+552.8 ft	+168.50 m
Elevation of strain gage Level 2	=	+548.5 ft	+167.19 m
Elevation of strain gage Level 1	=	+544.1 ft	+165.85 m
Miscellaneous:			
Top plate diameter (1.375 in thickness)	=	34.25 in	870 mm
ReBar size (20 No.)	=	# 9	M 29
Spiral size (10 in spacing)	=	# 5	M 16
ReBar cage diameter	=	30 in	762 mm
Unconfined compressive concrete / grout strength	=	4100 psi	28.3 MPa
O-cell LVWDTs @ 0°, 180° and 270° with radius	=	16.75 in	425 mm

NOTE:
- NOMINAL TEMP CASING 42" OD
- NOMINAL SHAFT 36"ø

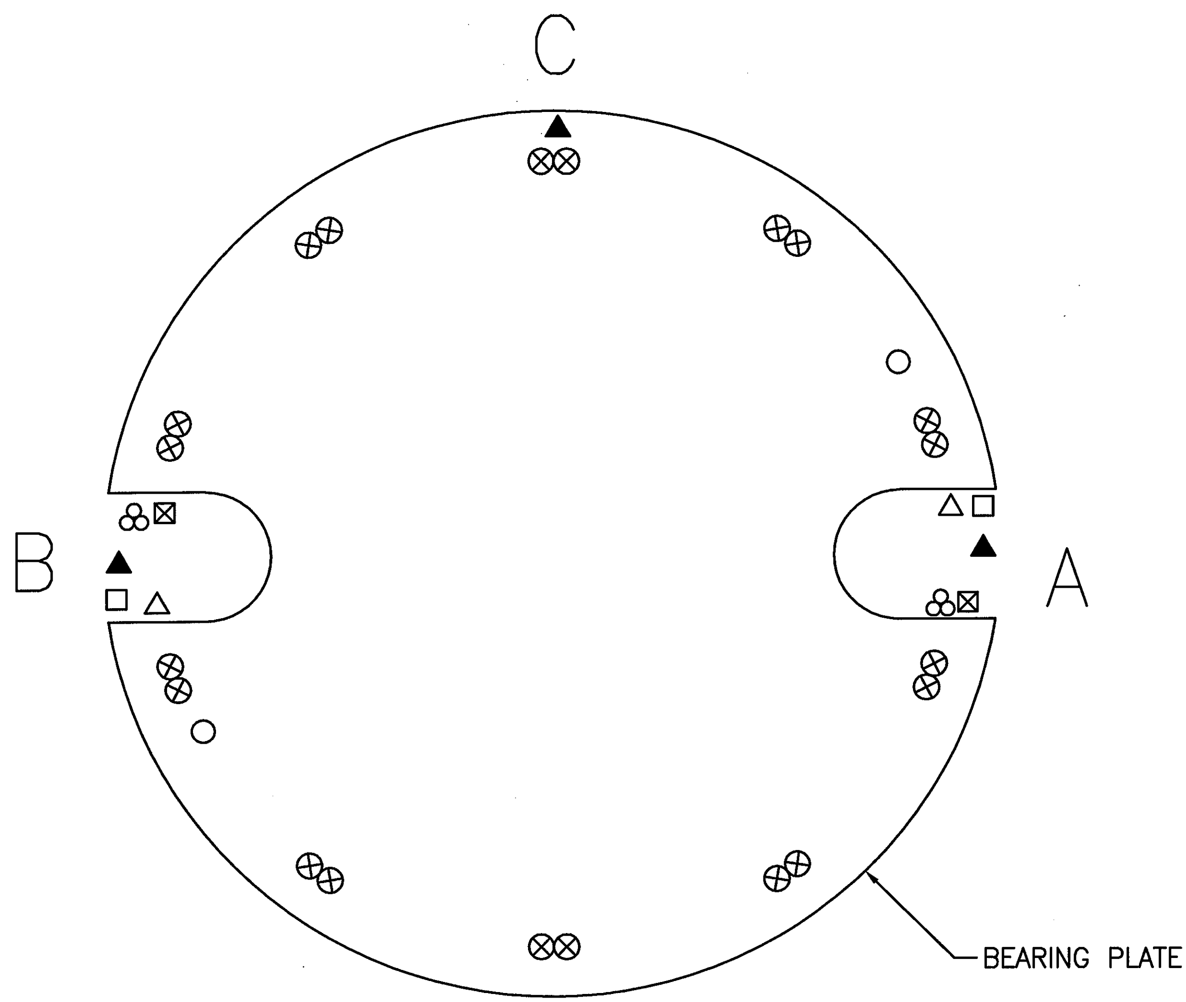


GENERALIZED SOIL PROFILE
BASED ON BORING TB1

LOADTEST
2631-D NW 41st St.
Gainesville, FL 32606
Phone 800-368-1138
FAX 352-378-3934

SCHEMATIC SECTION OF TEST SHAFT
Iowa Hwy 101 over Des Moines River – Van Buren County, IA

DRAWN BY: JAG	DATE: 5/17/06	CHECKED BY: MDA	LT-9183
REVISED BY:	DATE:	SCALE: NTS	FIGURE A



LEGEND:

STRAIN GAGE	△
LVWDT	▲
TELLTALE	○
VENT PIPE	□
HYDRAULIC HOSES	⊠
REBAR	⊗
CABLE BUNDLE	♣

LOADTEST
2631–D NW 41st St.
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INSTRUMENTATION LAYOUT

Hwy 1 over Des Moines River – Van Buren County, IA

DWN BY: JAG	DATE: 5/17/06	CHECKED BY: MDA	LT–9183
REVISED BY:	DATE:	SCALE: NTS	**FIGURE B**

Osterberg Cell Load-Movement Curves

Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA

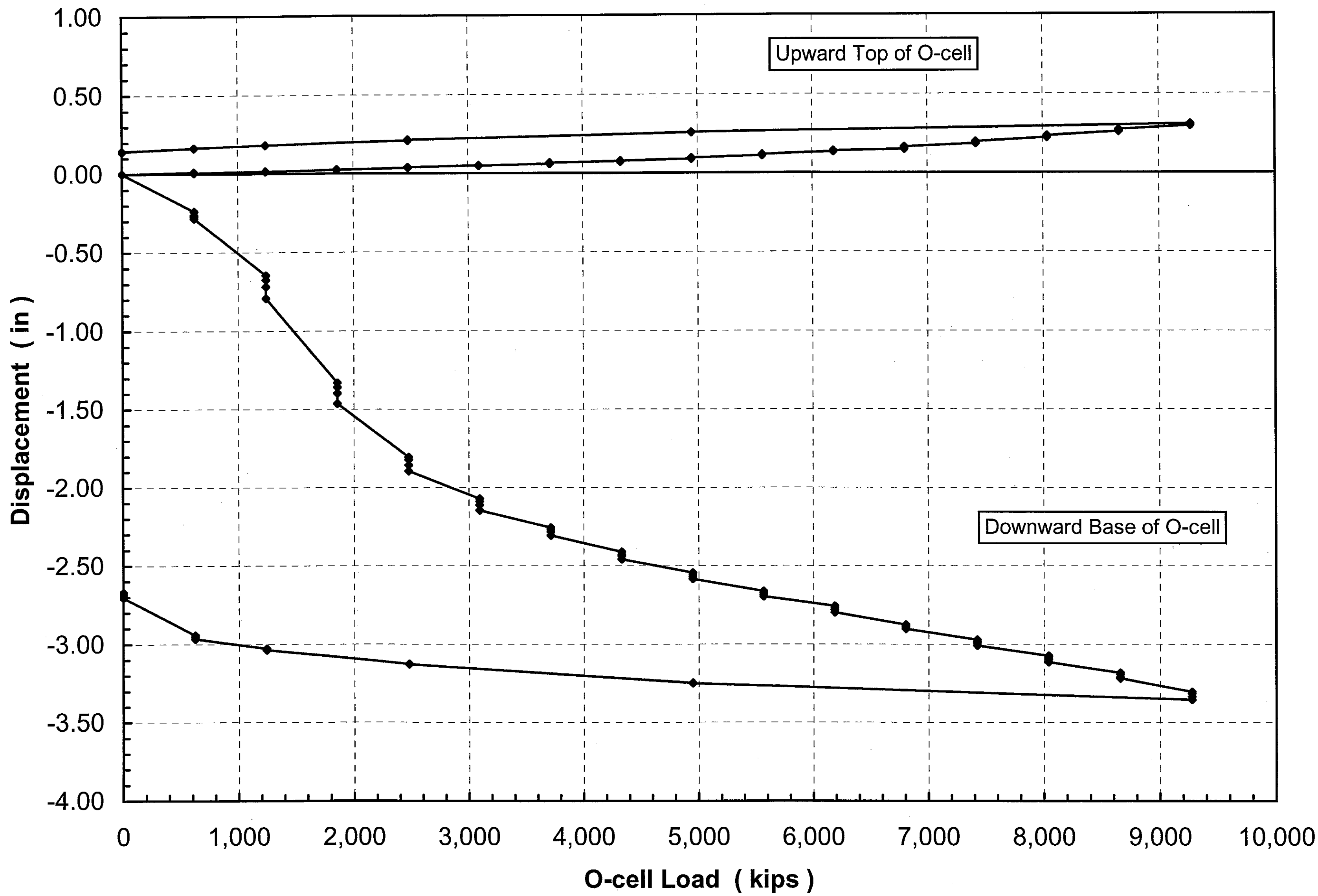

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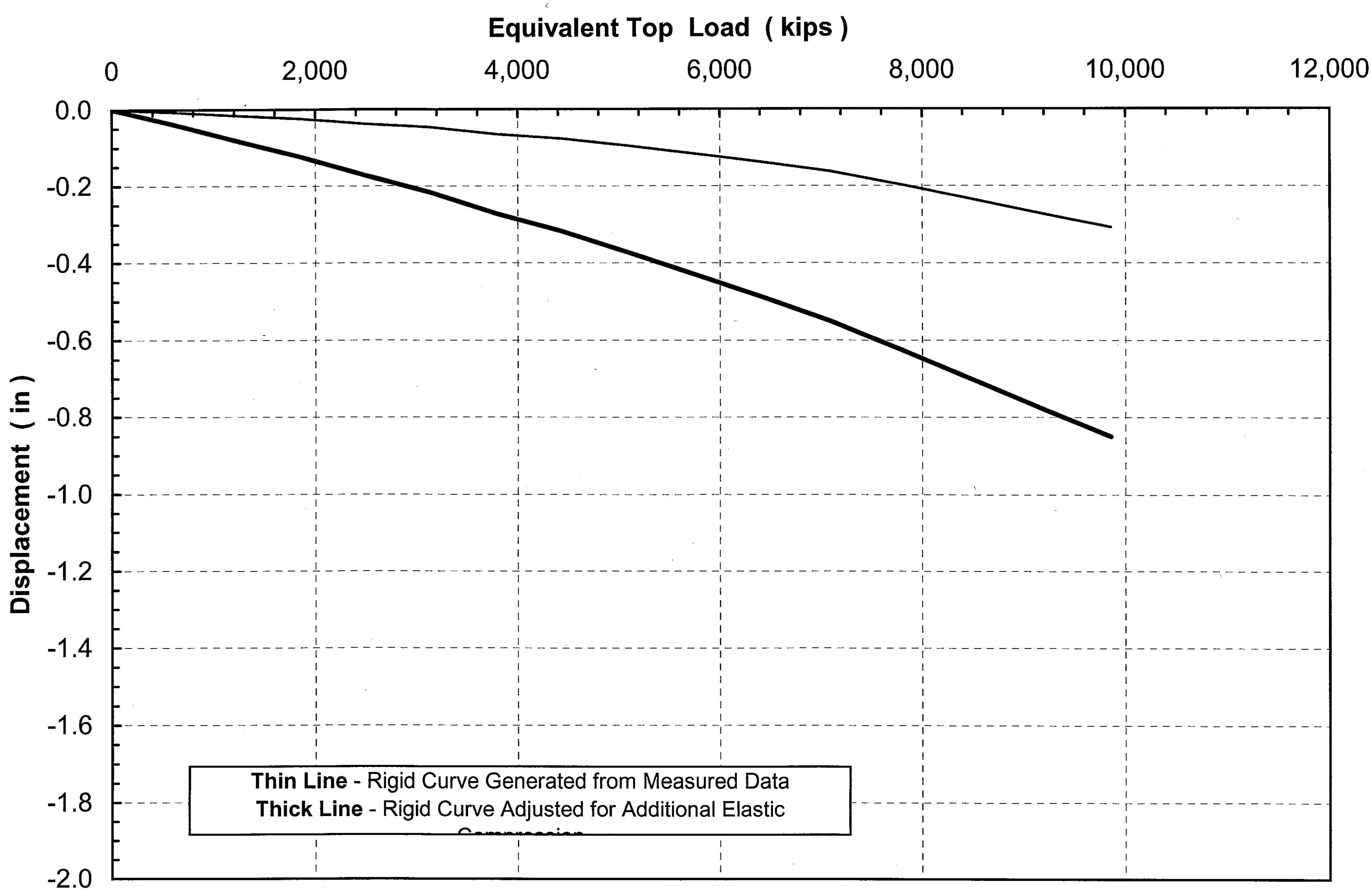
Figure 1 of 5

Equivalent Top Load Load-Movement Curve

Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA



Strain Gage Load Distribution Curves

Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA

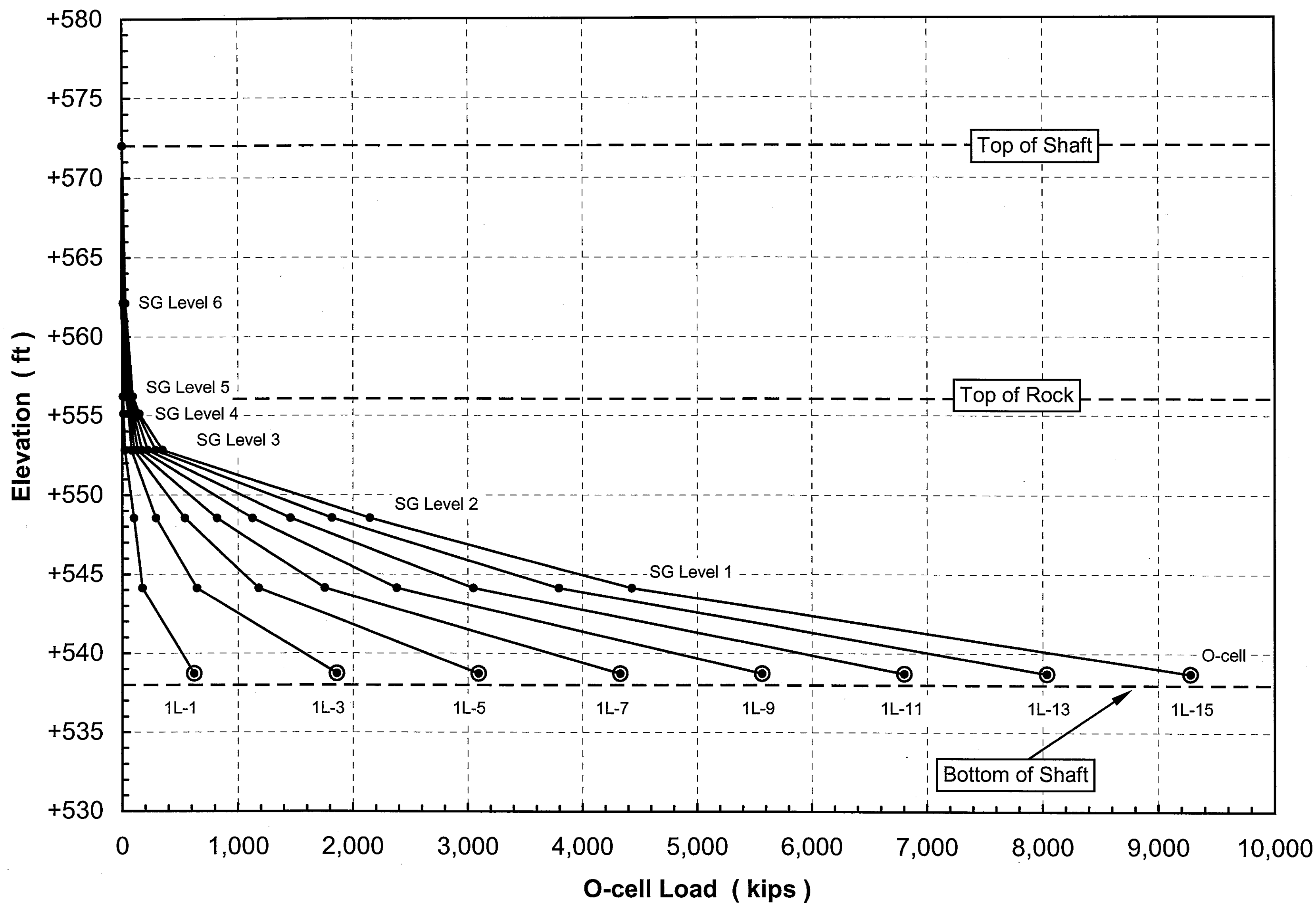


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Figure 3 of 5

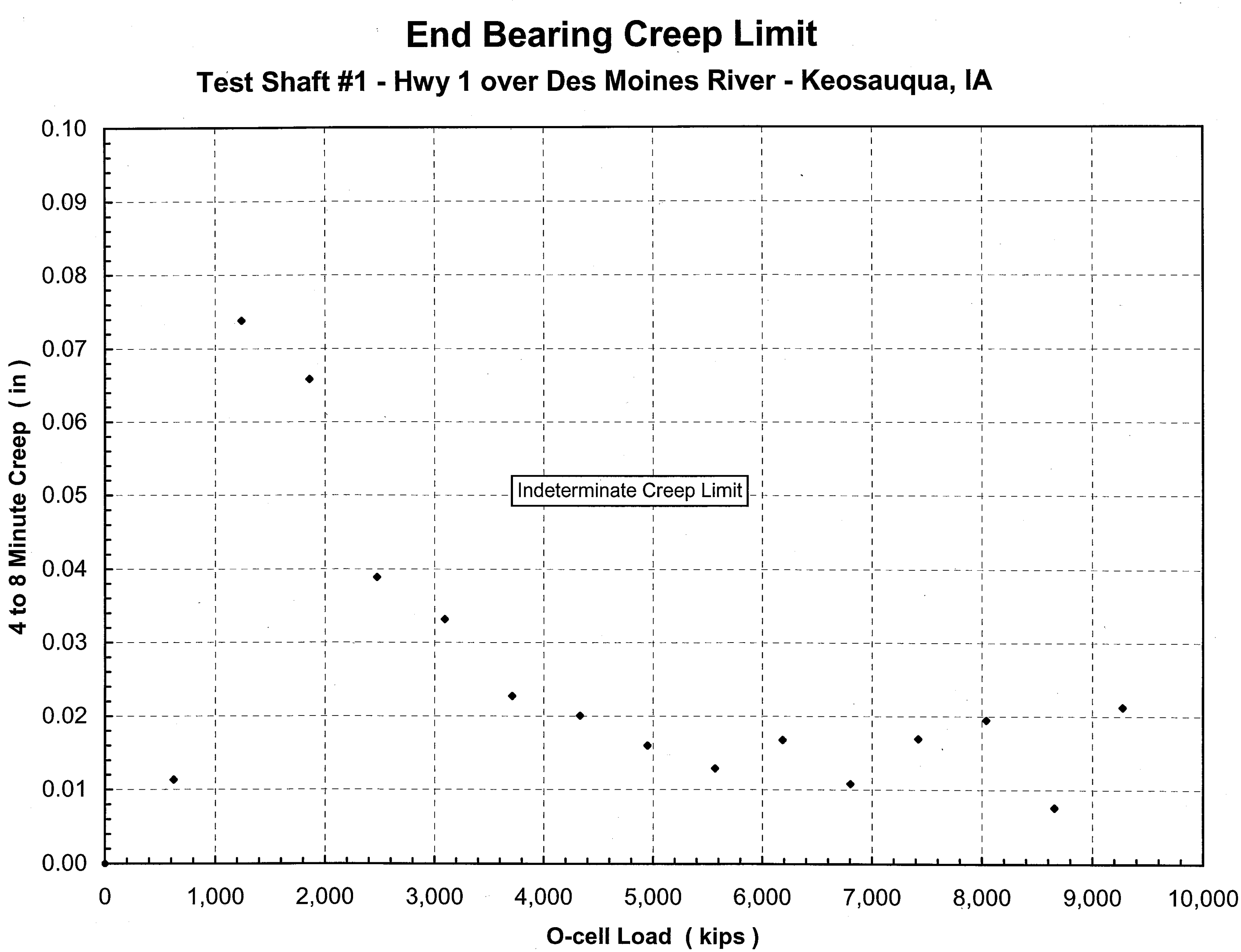
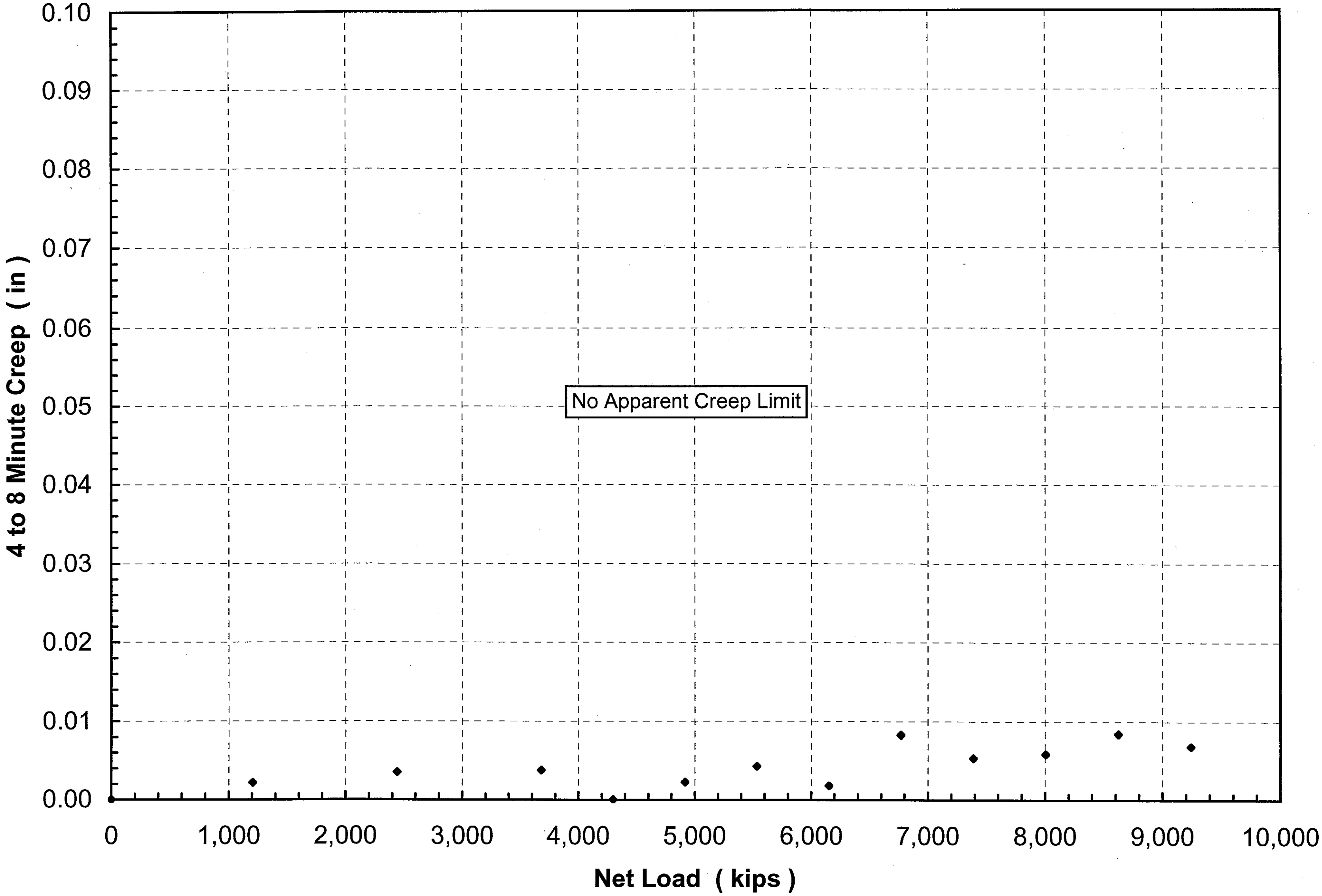

End Bearing Creep Limit
Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA
4 to 8 Minute Creep (in)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
O-cell Load (kips)
Indeterminate Creep Limit

Figure 4 of 5

Upper Side Shear Creep Limit

Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA



APPENDIX A

FIELD DATA & DATA REDUCTION

Upward Top of Shaft and Telltales Displacement
Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell Pressure (psi)	O-cell Load (kips)	Top of Shaft A (in)	Top of Shaft B (in)	Top of Shaft Average (in)	Top Plate Telltales * A - 3354 (in)	Top Plate Telltales * B - 3355 (in)	Top Plate Telltales * Average (in)	Bottom Plate Telltales * A - 2262 (in)	Bottom Plate Telltales * B - 2263 (in)	Bottom Plate Telltales * Average (in)
1 L - 0	-	11:00:00	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1 L - 1	1	11:14:30	1,000	622	0.001	0.006	0.003	0.006	0.006	0.006	0.301	0.182	0.242
1 L - 1	2	11:15:30	1,000	622	0.000	0.001	0.000	0.006	0.006	0.006	0.323	0.201	0.262
1 L - 1	4	11:17:30	1,000	622	0.000	0.001	0.000	0.006	0.006	0.006	0.333	0.211	0.272
1 L - 1	8	11:21:30	1,000	622	-0.003	0.002	-0.001	0.006	0.007	0.007	0.340	0.221	0.280
1 L - 2	1	11:26:30	2,000	1,240	0.000	0.003	0.001	0.014	0.014	0.014	0.622	0.656	0.639
1 L - 2	2	11:27:30	2,000	1,240	0.000	-0.003	-0.002	0.014	0.014	0.014	0.642	0.685	0.664
1 L - 2	4	11:29:30	2,000	1,240	-0.001	-0.001	-0.001	0.014	0.014	0.014	0.676	0.739	0.707
1 L - 2	8	11:33:30	2,000	1,240	0.000	0.001	0.000	0.015	0.015	0.015	0.742	0.824	0.783
1 L - 3	1	11:41:00	3,000	1,858	0.001	0.001	0.001	0.021	0.023	0.022	1.236	1.404	1.320
1 L - 3	2	11:42:00	3,000	1,858	0.000	-0.002	-0.001	0.022	0.023	0.022	1.261	1.433	1.347
1 L - 3	4	11:44:00	3,000	1,858	0.003	0.002	0.002	0.022	0.023	0.023	1.302	1.477	1.390
1 L - 3	8	11:48:00	3,000	1,858	0.002	-0.001	0.000	0.022	0.024	0.023	1.364	1.547	1.455
1 L - 4	1	12:06:00	4,000	2,476	0.005	0.003	0.004	0.029	0.031	0.030	1.683	1.924	1.803
1 L - 4	2	12:07:00	4,000	2,476	0.004	0.005	0.005	0.030	0.032	0.031	1.699	1.943	1.821
1 L - 4	4	12:09:00	4,000	2,476	0.005	0.002	0.003	0.030	0.032	0.031	1.728	1.974	1.851
1 L - 4	8	12:13:00	4,000	2,476	0.006	0.006	0.006	0.031	0.033	0.032	1.773	2.021	1.897
1 L - 5	1	12:20:00	5,000	3,094	0.013	0.010	0.011	0.038	0.041	0.040	1.951	2.218	2.084
1 L - 5	2	12:21:00	5,000	3,094	0.010	0.010	0.010	0.039	0.041	0.040	1.966	2.234	2.100
1 L - 5	4	12:23:00	5,000	3,094	0.009	0.008	0.008	0.039	0.042	0.040	1.988	2.259	2.124
1 L - 5	8	12:27:00	5,000	3,094	0.008	0.004	0.006	0.040	0.043	0.041	2.022	2.290	2.156
1 L - 6	1	12:32:00	6,000	3,712	0.011	0.010	0.011	0.047	0.051	0.049	2.140	2.409	2.274
1 L - 6	2	12:33:00	6,000	3,712	0.010	0.009	0.009	0.047	0.051	0.049	2.152	2.422	2.287
1 L - 6	4	12:35:00	6,000	3,712	0.011	0.013	0.012	0.048	0.052	0.050	2.173	2.441	2.307
1 L - 6	8	12:39:00	6,000	3,712	0.017	0.013	0.015	0.049	0.053	0.051	2.201	2.467	2.334
1 L - 7	1	12:44:30	7,000	4,330	0.018	0.014	0.016	0.057	0.062	0.060	2.307	2.578	2.442
1 L - 7	2	12:45:30	7,000	4,330	0.014	0.008	0.011	0.058	0.063	0.060	2.319	2.590	2.454
1 L - 7	4	12:47:30	7,000	4,330	0.016	0.016	0.016	0.058	0.064	0.061	2.334	2.607	2.471
1 L - 7	8	12:51:30	7,000	4,330	0.019	0.010	0.015	0.060	0.065	0.063	2.353	2.627	2.490
1 L - 8	1	12:57:00	8,000	4,949	0.018	0.017	0.018	0.068	0.075	0.071	2.442	2.723	2.582
1 L - 8	2	12:58:00	8,000	4,949	0.023	0.015	0.019	0.069	0.076	0.073	2.452	2.734	2.593
1 L - 8	4	13:00:00	8,000	4,949	0.021	0.019	0.020	0.070	0.077	0.073	2.469	2.750	2.610
1 L - 8	8	13:04:00	8,000	4,949	0.024	0.018	0.021	0.071	0.078	0.075	2.476	2.768	2.622
1 L - 9	1	13:09:00	9,000	5,567	0.024	0.025	0.024	0.081	0.089	0.085	2.536	2.856	2.696
1 L - 9	2	13:10:00	9,000	5,567	0.026	0.022	0.024	0.082	0.090	0.086	2.544	2.864	2.704
1 L - 9	4	13:12:00	9,000	5,567	0.028	0.022	0.025	0.083	0.091	0.087	2.558	2.878	2.718
1 L - 9	8	13:16:00	9,000	5,567	0.030	0.025	0.027	0.085	0.093	0.089	2.573	2.898	2.735
1 L - 10	1	13:20:30	10,000	6,185	0.037	0.033	0.035	0.094	0.104	0.099	2.638	2.977	2.808
1 L - 10	2	13:21:30	10,000	6,185	0.035	0.032	0.033	0.095	0.105	0.100	2.638	2.987	2.812
1 L - 10	4	13:23:30	10,000	6,185	0.036	0.033	0.035	0.097	0.107	0.102	2.639	3.003	2.821
1 L - 10	8	13:27:30	10,000	6,185	0.036	0.032	0.034	0.099	0.109	0.104	2.638	3.021	2.830
1 L - 11	1	13:33:30	11,000	6,803	0.035	0.029	0.032	0.111	0.122	0.116	2.686	3.107	2.897
1 L - 11	2	13:34:30	11,000	6,803	0.035	0.029	0.032	0.112	0.124	0.118	2.694	3.115	2.905
1 L - 11	4	13:36:30	11,000	6,803	0.039	0.032	0.035	0.113	0.126	0.119	2.695	3.129	2.912
1 L - 11	8	13:40:30	11,000	6,803	0.042	0.040	0.041	0.116	0.128	0.122	2.693	3.149	2.921
1 L - 12	1	13:46:00	12,000	7,421	0.048	0.047	0.047	0.129	0.143	0.136	2.768	3.237	3.002
1 L - 12	2	13:47:00	12,000	7,421	0.048	0.042	0.045	0.130	0.145	0.138	2.777	3.249	3.013
1 L - 12	4	13:49:00	12,000	7,421	0.053	0.047	0.050	0.133	0.149	0.141	2.791	3.269	3.030
1 L - 12	8	13:53:00	12,000	7,421	0.053	0.049	0.051	0.137	0.153	0.145	2.808	3.290	3.049
1 L - 13	1	13:57:30	13,000	8,039	0.064	0.060	0.062	0.151	0.168	0.159	2.877	3.378	3.127
1 L - 13	2	13:58:30	13,000	8,039	0.067	0.062	0.064	0.152	0.170	0.161	2.887	3.392	3.139
1 L - 13	4	14:00:30	13,000	8,039	0.067	0.059	0.063	0.156	0.174	0.165	2.900	3.411	3.156
1 L - 13	8	14:04:30	13,000	8,039	0.066	0.062	0.064	0.160	0.180	0.170	2.919	3.437	3.178
1 L - 14	1	14:12:00	14,000	8,657	0.073	0.070	0.071	0.176	0.198	0.187	2.996	3.552	3.274
1 L - 14	2	14:13:00	14,000	8,657	0.073	0.073	0.073	0.178	0.200	0.189	3.003	3.563	3.283
1 L - 14	4	14:15:00	14,000	8,657	0.074	0.070	0.072	0.180	0.203	0.192	3.012	3.578	3.295
1 L - 14	8	14:19:00	14,000	8,657	0.077	0.075	0.076	0.184	0.208	0.196	3.029	3.602	3.316
1 L - 15	1	14:25:30	15,000	9,275	0.084	0.081	0.083	0.200	0.226	0.213	3.112	3.715	3.413
1 L - 15	2	14:26:30	15,000	9,275	0.085	0.080	0.082	0.201	0.228	0.215	3.121	3.727	3.424
1 L - 15	4	14:28:30	15,000	9,275	0.083	0.082	0.082	0.204	0.231	0.217	3.135	3.747	3.441
1 L - 15	8	14:32:30	15,000	9,275	0.087	0.082	0.084	0.208	0.237	0.222	3.154	3.779	3.467
1 U - 1	1	14:35:00	8,000	4,949	0.069	0.067	0.068	0.177	0.205	0.191	3.034	3.654	3.344
1 U - 1	2	14:36:00	8,000	4,949	0.069	0.065	0.067	0.177	0.205	0.191	3.032	3.652	3.342
1 U - 1	4	14:38:00	8,000	4,949	0.066	0.066	0.066	0.176	0.205	0.191	3.030	3.650	3.340
1 U - 2	1	14:40:30	4,000	2,476	0.053	0.054	0.053	0.146	0.175	0.160	2.910	3.524	3.217
1 U - 2	2	14:41:30	4,000	2,476	0.051	0.051	0.051	0.144	0.174	0.159	2.905	3.519	3.212
1 U - 2	4	14:43:30	4,000	2,476	0.051	0.051	0.051	0.144	0.174	0.159	2.903	3.517	3.210
1 U - 3	1	14:45:30	2,000	1,240	0.043	0.044	0.043	0.125	0.152	0.138	2.808	3.412	3.110
1 U - 3	2	14:46:30	2,000	1,240	0.043	0.042	0.043	0.123	0.151	0.137	2.803	3.404	3.104
1 U - 3	4	14:48:30	2,000	1,240	0.047	0.043	0.045	0.123	0.151	0.137	2.797	3.399	3.098
1 U - 4	1	14:50:30	1,000	622	0.038	0.039	0.039	0.112	0.139	0.125	2.726	3.314	3.020
1 U - 4	2	14:51:30	1,000	622	0.040	0.039	0.040	0.111	0.136	0.123	2.715	3.301	3.008
1 U - 4	4	14:53:30	1,000	622	0.043	0.037	0.040	0.110	0.136	0.123	2.708	3.294	3.001
1 U - 5	1	14:55:30	0	0	0.037	0.042	0.040	0.094	0.115	0.105	2.489	3.023	2.756
1 U - 5	2	14:56:30	0	0	0.037	0.040	0.039	0.093	0.114	0.104	2.477	3.012	2.745
1 U - 5	4	14:58:30	0	0	0.036	0.041	0.039	0.092	0.113	0.103	2.466	2.998	2.732
1 U - 5	8	15:02:30	0	0	0.038	0.038	0.038	0.091	0.112	0.102	2.454	2.983	2.718

* Top and bottom plate telltale gages referenced to the top of shaft.

O-cell Expansion
Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell Pressure (psi)	O-cell Load (kips)	O-cell Expansion A - 3482 (in)	B - 3483 (in)	C - 3484 * (in)	Avg. LVWDT (in)	TPTT + BPTT
1 L - 0	-	11:00:00	0	0	0.000	0.000	0.000	0.000	0.000
1 L - 1	1	11:14:30	1,000	622	0.289	0.205	0.134	0.247	0.248
1 L - 1	2	11:15:30	1,000	622	0.313	0.225	0.147	0.269	0.268
1 L - 1	4	11:17:30	1,000	622	0.323	0.235	0.155	0.279	0.278
1 L - 1	8	11:21:30	1,000	622	0.334	0.245	0.164	0.290	0.287
1 L - 2	1	11:26:30	2,000	1,240	0.616	0.707	0.496	0.661	0.653
1 L - 2	2	11:27:30	2,000	1,240	0.638	0.736	0.524	0.687	0.678
1 L - 2	4	11:29:30	2,000	1,240	0.674	0.789	0.576	0.731	0.721
1 L - 2	8	11:33:30	2,000	1,240	0.746	0.868	0.670	0.807	0.798
1 L - 3	1	11:41:00	3,000	1,858	1.263	1.443	1.267	1.353	1.342
1 L - 3	2	11:42:00	3,000	1,858	1.287	1.475	1.297	1.381	1.369
1 L - 3	4	11:44:00	3,000	1,858	1.329	1.519	1.339	1.424	1.412
1 L - 3	8	11:48:00	3,000	1,858	1.386	1.591	1.405	1.488	1.479
1 L - 4	1	12:06:00	4,000	2,476	1.713	1.966	1.784	1.839	1.834
1 L - 4	2	12:07:00	4,000	2,476	1.729	1.986	1.804	1.857	1.852
1 L - 4	4	12:09:00	4,000	2,476	1.764	2.017	1.841	1.891	1.882
1 L - 4	8	12:13:00	4,000	2,476	1.805	2.061	1.888	1.933	1.929
1 L - 5	1	12:20:00	5,000	3,094	1.991	2.254	2.111	2.123	2.124
1 L - 5	2	12:21:00	5,000	3,094	2.009	2.270	2.130	2.140	2.140
1 L - 5	4	12:23:00	5,000	3,094	2.033	2.292	2.158	2.163	2.164
1 L - 5	8	12:27:00	5,000	3,094	2.067	2.321	2.195	2.194	2.197
1 L - 6	1	12:32:00	6,000	3,712	2.193	2.442	2.343	2.317	2.323
1 L - 6	2	12:33:00	6,000	3,712	2.203	2.452	2.358	2.328	2.336
1 L - 6	4	12:35:00	6,000	3,712	2.225	2.469	2.381	2.347	2.357
1 L - 6	8	12:39:00	6,000	3,712	2.253	2.493	2.412	2.373	2.385
1 L - 7	1	12:44:30	7,000	4,330	2.369	2.607	2.548	2.488	2.502
1 L - 7	2	12:45:30	7,000	4,330	2.379	2.618	2.563	2.499	2.515
1 L - 7	4	12:47:30	7,000	4,330	2.395	2.634	2.585	2.515	2.532
1 L - 7	8	12:51:30	7,000	4,330	2.415	2.654	2.610	2.535	2.553
1 L - 8	1	12:57:00	8,000	4,949	2.519	2.751	2.725	2.635	2.654
1 L - 8	2	12:58:00	8,000	4,949	2.531	2.761	2.739	2.646	2.665
1 L - 8	4	13:00:00	8,000	4,949	2.549	2.777	2.757	2.663	2.683
1 L - 8	8	13:04:00	8,000	4,949	2.569	2.793	2.778	2.681	2.697
1 L - 9	1	13:09:00	9,000	5,567	2.664	2.882	2.881	2.773	2.781
1 L - 9	2	13:10:00	9,000	5,567	2.674	2.891	2.892	2.782	2.790
1 L - 9	4	13:12:00	9,000	5,567	2.688	2.905	2.909	2.797	2.805
1 L - 9	8	13:16:00	9,000	5,567	2.706	2.922	2.927	2.814	2.824
1 L - 10	1	13:20:30	10,000	6,185	2.783	3.003	3.017	2.893	2.907
1 L - 10	2	13:21:30	10,000	6,185	2.793	3.015	3.029	2.904	2.913
1 L - 10	4	13:23:30	10,000	6,185	2.808	3.029	3.045	2.918	2.923
1 L - 10	8	13:27:30	10,000	6,185	2.826	3.048	3.065	2.937	2.934
1 L - 11	1	13:33:30	11,000	6,803	2.911	3.139	3.159	3.025	3.013
1 L - 11	2	13:34:30	11,000	6,803	2.919	3.148	3.169	3.033	3.022
1 L - 11	4	13:36:30	11,000	6,803	2.932	3.162	3.184	3.047	3.032
1 L - 11	8	13:40:30	11,000	6,803	2.951	3.182	3.204	3.066	3.044
1 L - 12	1	13:46:00	12,000	7,421	3.032	3.277	3.296	3.155	3.138
1 L - 12	2	13:47:00	12,000	7,421	3.044	3.286	3.308	3.165	3.151
1 L - 12	4	13:49:00	12,000	7,421	3.059	3.306	3.327	3.183	3.171
1 L - 12	8	13:53:00	12,000	7,421	3.080	3.330	3.351	3.205	3.195
1 L - 13	1	13:57:30	13,000	8,039	3.164	3.423	3.440	3.294	3.287
1 L - 13	2	13:58:30	13,000	8,039	3.171	3.435	3.452	3.303	3.301
1 L - 13	4	14:00:30	13,000	8,039	3.185	3.458	3.472	3.321	3.321
1 L - 13	8	14:04:30	13,000	8,039	3.206	3.487	3.497	3.347	3.348
1 L - 14	1	14:12:00	14,000	8,657	3.292	3.590	3.603	3.441	3.461
1 L - 14	2	14:13:00	14,000	8,657	3.300	3.602	3.617	3.451	3.472
1 L - 14	4	14:15:00	14,000	8,657	3.311	3.634	3.629	3.472	3.487
1 L - 14	8	14:19:00	14,000	8,657	3.326	3.651	3.648	3.488	3.512
1 L - 15	1	14:25:30	15,000	9,275	3.416	3.779	3.765	3.597	3.626
1 L - 15	2	14:26:30	15,000	9,275	3.424	3.795	3.776	3.609	3.638
1 L - 15	4	14:28:30	15,000	9,275	3.446	3.818	3.796	3.632	3.659
1 L - 15	8	14:32:30	15,000	9,275	3.469	3.851	3.824	3.660	3.689
1 U - 1	1	14:35:00	8,000	4,949	3.318	3.696	3.667	3.507	3.536
1 U - 1	2	14:36:00	8,000	4,949	3.315	3.695	3.668	3.505	3.533
1 U - 1	4	14:38:00	8,000	4,949	3.314	3.691	3.660	3.503	3.531
1 U - 2	1	14:40:30	4,000	2,476	3.148	3.535	3.508	3.342	3.377
1 U - 2	2	14:41:30	4,000	2,476	3.144	3.530	3.502	3.337	3.371
1 U - 2	4	14:43:30	4,000	2,476	3.142	3.528	3.500	3.335	3.369
1 U - 3	1	14:45:30	2,000	1,240	3.030	3.405	3.379	3.217	3.249
1 U - 3	2	14:46:30	2,000	1,240	3.025	3.399	3.374	3.212	3.241
1 U - 3	4	14:48:30	2,000	1,240	3.022	3.397	3.371	3.210	3.235
1 U - 4	1	14:50:30	1,000	622	2.954	3.304	3.283	3.129	3.146
1 U - 4	2	14:51:30	1,000	622	2.940	3.287	3.269	3.113	3.131
1 U - 4	4	14:53:30	1,000	622	2.930	3.280	3.264	3.105	3.124
1 U - 5	1	14:55:30	0	0	2.698	2.999	2.993	2.848	2.861
1 U - 5	2	14:56:30	0	0	2.687	2.987	2.981	2.837	2.848
1 U - 5	4	14:58:30	0	0	2.675	2.974	2.968	2.824	2.835
1 U - 5	8	15:02:30	0	0	2.661	2.960	2.953	2.810	2.820

* LVWDT C is not included in the average due to its orientation. LVWDTs A and B are oriented 180° opposed.

Upward and Downward O-cell Plate Movement and Creep (calculated)
Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell Pressure (psi)	O-cell Load (kips)	Top of Shaft (in)	Elastic Comp. (in)	Top Plate Movement (in)	O-cell Expansion (in)	Bot. Plate Movement (in)	Creep Up Per Hold (in)	Creep Dn Per Hold (in)
1 L - 0	-	11:00:00	0	0	0.000	0.000	0.000	0.000	0.000		
1 L - 1	1	11:14:30	1,000	622	0.003	0.006	0.010	0.247	-0.238		
1 L - 1	2	11:15:30	1,000	622	0.000	0.006	0.007	0.269	-0.262	-0.003	0.025
1 L - 1	4	11:17:30	1,000	622	0.000	0.006	0.007	0.279	-0.272	0.000	0.010
1 L - 1	8	11:21:30	1,000	622	-0.001	0.007	0.006	0.290	-0.283	-0.001	0.011
1 L - 2	1	11:26:30	2,000	1,240	0.001	0.014	0.016	0.661	-0.646		
1 L - 2	2	11:27:30	2,000	1,240	-0.002	0.014	0.013	0.687	-0.674	-0.003	0.029
1 L - 2	4	11:29:30	2,000	1,240	-0.001	0.014	0.013	0.731	-0.718	0.000	0.044
1 L - 2	8	11:33:30	2,000	1,240	0.000	0.015	0.015	0.807	-0.792	0.002	0.074
1 L - 3	1	11:41:00	3,000	1,858	0.001	0.022	0.023	1.353	-1.330		
1 L - 3	2	11:42:00	3,000	1,858	-0.001	0.022	0.021	1.381	-1.360	-0.001	0.030
1 L - 3	4	11:44:00	3,000	1,858	0.002	0.023	0.025	1.424	-1.399	0.004	0.039
1 L - 3	8	11:48:00	3,000	1,858	0.000	0.023	0.024	1.488	-1.464	-0.002	0.066
1 L - 4	1	12:06:00	4,000	2,476	0.004	0.030	0.034	1.839	-1.805		
1 L - 4	2	12:07:00	4,000	2,476	0.005	0.031	0.035	1.857	-1.822	0.001	0.017
1 L - 4	4	12:09:00	4,000	2,476	0.003	0.031	0.034	1.891	-1.856	-0.001	0.034
1 L - 4	8	12:13:00	4,000	2,476	0.006	0.032	0.038	1.933	-1.895	0.004	0.039
1 L - 5	1	12:20:00	5,000	3,094	0.011	0.040	0.051	2.123	-2.072		
1 L - 5	2	12:21:00	5,000	3,094	0.010	0.040	0.050	2.140	-2.090	-0.001	0.018
1 L - 5	4	12:23:00	5,000	3,094	0.008	0.040	0.049	2.163	-2.114	-0.001	0.024
1 L - 5	8	12:27:00	5,000	3,094	0.006	0.041	0.047	2.194	-2.147	-0.002	0.033
1 L - 6	1	12:32:00	6,000	3,712	0.011	0.049	0.059	2.317	-2.258		
1 L - 6	2	12:33:00	6,000	3,712	0.009	0.049	0.059	2.328	-2.269	-0.001	0.011
1 L - 6	4	12:35:00	6,000	3,712	0.012	0.050	0.062	2.347	-2.285	0.003	0.016
1 L - 6	8	12:39:00	6,000	3,712	0.015	0.051	0.066	2.373	-2.307	0.004	0.023
1 L - 7	1	12:44:30	7,000	4,330	0.016	0.060	0.076	2.488	-2.412		
1 L - 7	2	12:45:30	7,000	4,330	0.011	0.060	0.071	2.499	-2.427	-0.004	0.015
1 L - 7	4	12:47:30	7,000	4,330	0.016	0.061	0.077	2.515	-2.438	0.006	0.010
1 L - 7	8	12:51:30	7,000	4,330	0.015	0.063	0.077	2.535	-2.458	0.000	0.020
1 L - 8	1	12:57:00	8,000	4,949	0.018	0.071	0.089	2.635	-2.546		
1 L - 8	2	12:58:00	8,000	4,949	0.019	0.073	0.092	2.646	-2.554	0.003	0.009
1 L - 8	4	13:00:00	8,000	4,949	0.020	0.073	0.093	2.663	-2.570	0.002	0.015
1 L - 8	8	13:04:00	8,000	4,949	0.021	0.075	0.096	2.681	-2.586	0.002	0.016
1 L - 9	1	13:09:00	9,000	5,567	0.024	0.085	0.109	2.773	-2.664		
1 L - 9	2	13:10:00	9,000	5,567	0.024	0.086	0.110	2.782	-2.673	0.000	0.009
1 L - 9	4	13:12:00	9,000	5,567	0.025	0.087	0.112	2.797	-2.684	0.002	0.012
1 L - 9	8	13:16:00	9,000	5,567	0.027	0.089	0.117	2.814	-2.697	0.004	0.013
1 L - 10	1	13:20:30	10,000	6,185	0.035	0.099	0.134	2.893	-2.759		
1 L - 10	2	13:21:30	10,000	6,185	0.033	0.100	0.134	2.904	-2.771	0.000	0.012
1 L - 10	4	13:23:30	10,000	6,185	0.035	0.102	0.137	2.918	-2.782	0.003	0.011
1 L - 10	8	13:27:30	10,000	6,185	0.034	0.104	0.138	2.937	-2.799	0.002	0.017
1 L - 11	1	13:33:30	11,000	6,803	0.032	0.116	0.148	3.025	-2.876		
1 L - 11	2	13:34:30	11,000	6,803	0.032	0.118	0.150	3.033	-2.884	0.001	0.007
1 L - 11	4	13:36:30	11,000	6,803	0.035	0.119	0.155	3.047	-2.892	0.005	0.008
1 L - 11	8	13:40:30	11,000	6,803	0.041	0.122	0.163	3.066	-2.903	0.008	0.011
1 L - 12	1	13:46:00	12,000	7,421	0.047	0.136	0.183	3.155	-2.971		
1 L - 12	2	13:47:00	12,000	7,421	0.045	0.138	0.183	3.165	-2.982	-0.001	0.011
1 L - 12	4	13:49:00	12,000	7,421	0.050	0.141	0.191	3.183	-2.992	0.008	0.010
1 L - 12	8	13:53:00	12,000	7,421	0.051	0.145	0.196	3.205	-3.009	0.005	0.017
1 L - 13	1	13:57:30	13,000	8,039	0.062	0.159	0.221	3.294	-3.072		
1 L - 13	2	13:58:30	13,000	8,039	0.064	0.161	0.226	3.303	-3.077	0.005	0.005
1 L - 13	4	14:00:30	13,000	8,039	0.063	0.165	0.228	3.321	-3.093	0.002	0.016
1 L - 13	8	14:04:30	13,000	8,039	0.064	0.170	0.234	3.347	-3.113	0.006	0.019
1 L - 14	1	14:12:00	14,000	8,657	0.071	0.187	0.259	3.441	-3.182		
1 L - 14	2	14:13:00	14,000	8,657	0.073	0.189	0.262	3.451	-3.189	0.003	0.007
1 L - 14	4	14:15:00	14,000	8,657	0.072	0.192	0.264	3.472	-3.209	0.002	0.019
1 L - 14	8	14:19:00	14,000	8,657	0.076	0.196	0.272	3.488	-3.216	0.008	0.008
1 L - 15	1	14:25:30	15,000	9,275	0.083	0.213	0.295	3.597	-3.302		
1 L - 15	2	14:26:30	15,000	9,275	0.082	0.215	0.297	3.609	-3.312	0.002	0.010
1 L - 15	4	14:28:30	15,000	9,275	0.082	0.217	0.300	3.632	-3.332	0.003	0.020
1 L - 15	8	14:32:30	15,000	9,275	0.084	0.222	0.307	3.660	-3.353	0.007	0.021
1 U - 1	1	14:35:00	8,000	4,949	0.068	0.191	0.259	3.507	-3.248		
1 U - 1	2	14:36:00	8,000	4,949	0.067	0.191	0.258	3.505	-3.247		
1 U - 1	4	14:38:00	8,000	4,949	0.066	0.191	0.257	3.503	-3.246		
1 U - 2	1	14:40:30	4,000	2,476	0.053	0.160	0.214	3.342	-3.128		
1 U - 2	2	14:41:30	4,000	2,476	0.051	0.159	0.210	3.337	-3.127		
1 U - 2	4	14:43:30	4,000	2,476	0.051	0.159	0.210	3.335	-3.126		
1 U - 3	1	14:45:30	2,000	1,240	0.043	0.138	0.182	3.217	-3.036		
1 U - 3	2	14:46:30	2,000	1,240	0.043	0.137	0.180	3.212	-3.032		
1 U - 3	4	14:48:30	2,000	1,240	0.045	0.137	0.182	3.210	-3.028		
1 U - 4	1	14:50:30	1,000	622	0.039	0.125	0.164	3.129	-2.965		
1 U - 4	2	14:51:30	1,000	622	0.040	0.123	0.163	3.113	-2.951		
1 U - 4	4	14:53:30	1,000	622	0.040	0.123	0.163	3.105	-2.942		
1 U - 5	1	14:55:30	0	0	0.040	0.105	0.144	2.848	-2.704		
1 U - 5	2	14:56:30	0	0	0.039	0.104	0.142	2.837	-2.695		
1 U - 5	4	14:58:30	0	0	0.039	0.103	0.141	2.824	-2.683		
1 U - 5	8	15:02:30	0	0	0.038	0.102	0.140	2.810	-2.671		

Strain Gage Readings and Loads at Levels 1, 2 and 3
Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA

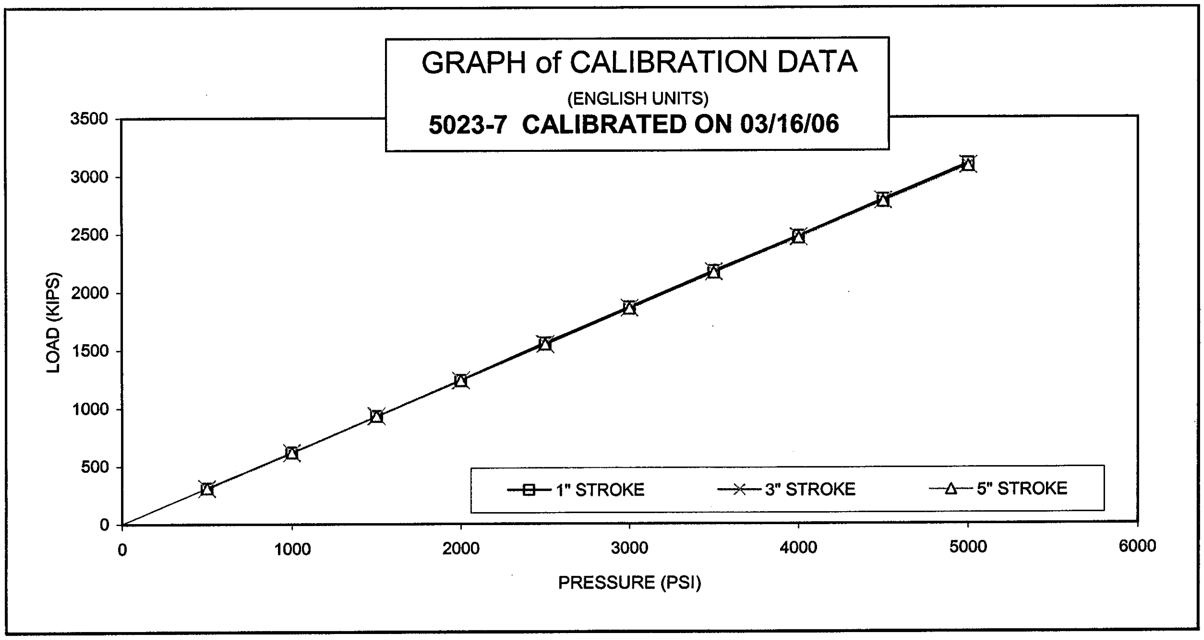
Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell Pressure (psi)	O-cell Load (kips)	Level 1 A - 6908 (με)	Level 1 B - 6909 (με)	Level 1 Av. Load (kips)	Level 2 A - 6910 (με)	Level 2 B - 6911 (με)	Level 2 Av. Load (kips)	Level 3 A - 6912 (με)	Level 3 B - 6913 (με)	Level 3 Av. Load (kips)
1 L - 0	-	11:00:00	0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0
1 L - 1	1	11:14:30	1,000	622	40.1	35.5	159	22.6	20.5	91	4.8	5.1	21
1 L - 1	2	11:15:30	1,000	622	41.5	37.2	166	23.3	21.6	95	4.4	5.2	20
1 L - 1	4	11:17:30	1,000	622	41.7	37.7	168	23.9	22.3	98	4.8	5.2	21
1 L - 1	8	11:21:30	1,000	622	43.0	38.7	172	24.5	23.1	100	4.9	5.3	22
1 L - 2	1	11:26:30	2,000	1,240	91.1	85.2	372	44.7	42.3	183	12.4	12.8	53
1 L - 2	2	11:27:30	2,000	1,240	93.2	86.4	379	44.9	42.8	185	12.6	13.1	54
1 L - 2	4	11:29:30	2,000	1,240	95.5	88.5	388	46.9	43.9	192	14.0	13.5	58
1 L - 2	8	11:33:30	2,000	1,240	98.0	90.8	398	47.9	44.9	196	13.3	13.6	57
1 L - 3	1	11:41:00	3,000	1,858	148.7	141.8	613	68.6	61.7	275	18.8	18.1	78
1 L - 3	2	11:42:00	3,000	1,858	150.8	144.1	622	69.5	62.0	278	18.7	18.2	78
1 L - 3	4	11:44:00	3,000	1,858	153.2	146.0	631	71.2	63.4	284	18.9	18.2	78
1 L - 3	8	11:48:00	3,000	1,858	156.3	149.4	645	73.1	64.8	291	19.3	18.3	80
1 L - 4	1	12:06:00	4,000	2,476	206.6	201.0	860	97.2	83.8	382	21.8	21.1	91
1 L - 4	2	12:07:00	4,000	2,476	209.2	203.5	871	99.2	85.0	389	21.5	21.1	90
1 L - 4	4	12:09:00	4,000	2,476	213.4	207.2	887	101.5	86.9	398	21.9	21.3	91
1 L - 4	8	12:13:00	4,000	2,476	218.3	212.0	908	105.0	89.7	411	22.5	21.6	93
1 L - 5	1	12:20:00	5,000	3,094	269.5	268.0	1134	131.9	110.7	512	24.1	24.0	102
1 L - 5	2	12:21:00	5,000	3,094	271.9	271.8	1147	133.6	111.6	517	24.2	24.1	102
1 L - 5	4	12:23:00	5,000	3,094	275.8	275.6	1164	136.4	114.1	529	24.5	24.4	103
1 L - 5	8	12:27:00	5,000	3,094	280.0	280.1	1182	139.9	116.7	541	24.4	24.6	103
1 L - 6	1	12:32:00	6,000	3,712	327.9	334.2	1397	165.3	136.7	637	26.8	26.9	113
1 L - 6	2	12:33:00	6,000	3,712	330.5	337.5	1410	167.2	138.4	645	26.9	26.7	113
1 L - 6	4	12:35:00	6,000	3,712	334.9	342.6	1430	170.6	140.9	657	27.2	27.0	114
1 L - 6	8	12:39:00	6,000	3,712	340.4	348.2	1453	175.0	144.5	674	27.5	27.3	116
1 L - 7	1	12:44:30	7,000	4,330	392.0	408.3	1689	203.2	166.2	779	30.5	30.4	128
1 L - 7	2	12:45:30	7,000	4,330	395.8	413.0	1706	205.5	168.4	789	30.9	30.4	129
1 L - 7	4	12:47:30	7,000	4,330	400.8	418.7	1729	209.7	171.2	804	30.7	30.4	129
1 L - 7	8	12:51:30	7,000	4,330	405.9	425.1	1754	213.8	175.0	820	31.1	31.1	131
1 L - 8	1	12:57:00	8,000	4,949	456.3	484.7	1986	240.5	196.8	923	34.7	33.6	144
1 L - 8	2	12:58:00	8,000	4,949	460.9	490.1	2007	243.3	199.5	934	35.0	33.8	145
1 L - 8	4	13:00:00	8,000	4,949	466.7	497.5	2035	247.4	203.2	951	35.3	34.1	146
1 L - 8	8	13:04:00	8,000	4,949	472.0	504.6	2061	252.2	207.4	970	35.7	34.4	148
1 L - 9	1	13:09:00	9,000	5,567	524.5	566.9	2303	281.0	230.4	1079	39.9	37.7	164
1 L - 9	2	13:10:00	9,000	5,567	529.4	572.7	2326	283.7	233.2	1091	40.4	37.8	165
1 L - 9	4	13:12:00	9,000	5,567	534.8	580.8	2354	287.7	237.0	1107	40.7	38.2	167
1 L - 9	8	13:16:00	9,000	5,567	540.5	588.4	2382	293.2	241.6	1128	41.5	38.8	169
1 L - 10	1	13:20:30	10,000	6,185	590.0	648.6	2613	320.3	263.6	1232	46.8	41.8	187
1 L - 10	2	13:21:30	10,000	6,185	594.8	654.6	2636	324.5	266.3	1247	47.2	42.0	188
1 L - 10	4	13:23:30	10,000	6,185	600.9	663.4	2668	328.3	270.8	1264	47.9	42.4	191
1 L - 10	8	13:27:30	10,000	6,185	609.1	674.5	2709	334.5	276.2	1289	48.7	43.3	194
1 L - 11	1	13:33:30	11,000	6,803	660.1	738.2	2950	363.4	300.5	1401	55.1	46.9	215
1 L - 11	2	13:34:30	11,000	6,803	664.9	744.0	2973	366.2	303.3	1413	55.4	47.1	216
1 L - 11	4	13:36:30	11,000	6,803	670.2	752.9	3003	370.4	307.3	1430	55.8	47.5	218
1 L - 11	8	13:40:30	11,000	6,803	680.9	763.8	3048	377.0	313.2	1456	56.5	47.7	220
1 L - 12	1	13:46:00	12,000	7,421	731.8	830.8	3297	406.6	338.3	1572	64.4	51.3	244
1 L - 12	2	13:47:00	12,000	7,421	738.8	838.9	3329	410.5	341.6	1587	65.1	51.9	247
1 L - 12	4	13:49:00	12,000	7,421	747.1	850.7	3371	415.5	346.9	1609	65.9	52.4	250
1 L - 12	8	13:53:00	12,000	7,421	759.3	866.9	3431	423.9	354.4	1642	67.5	53.3	255
1 L - 13	1	13:57:30	13,000	8,039	810.5	929.8	3672	452.4	377.8	1752	75.3	56.6	278
1 L - 13	2	13:58:30	13,000	8,039	815.2	936.1	3695	455.6	380.9	1765	75.8	56.8	280
1 L - 13	4	14:00:30	13,000	8,039	823.5	947.7	3737	460.8	385.7	1786	76.8	57.1	283
1 L - 13	8	14:04:30	13,000	8,039	834.3	963.3	3793	468.3	393.2	1818	78.0	58.5	288
1 L - 14	1	14:12:00	14,000	8,657	883.8	1026.1	4030	497.5	418.0	1932	85.4	61.7	310
1 L - 14	2	14:13:00	14,000	8,657	886.7	1030.6	4046	499.5	420.0	1940	85.9	61.8	312
1 L - 14	4	14:15:00	14,000	8,657	892.0	1037.9	4072	503.4	423.7	1956	86.1	62.4	313
1 L - 14	8	14:19:00	14,000	8,657	900.3	1049.6	4114	509.7	430.0	1983	87.5	62.9	317
1 L - 15	1	14:25:30	15,000	9,275	950.1	1111.6	4350	538.7	454.1	2095	95.1	66.1	340
1 L - 15	2	14:26:30	15,000	9,275	953.3	1116.3	4367	540.9	456.2	2104	95.5	66.2	341
1 L - 15	4	14:28:30	15,000	9,275	957.6	1123.8	4392	545.2	459.9	2121	96.0	66.7	343
1 L - 15	8	14:32:30	15,000	9,275	964.6	1135.1	4430	551.6	466.1	2148	97.3	67.3	347
1 U - 1	1	14:35:00	8,000	4,949	767.7	941.2	3606	460.7	401.3	1819	72.0	46.3	250
1 U - 1	2	14:36:00	8,000	4,949	766.5	940.3	3601	458.9	400.4	1813	72.2	46.7	251
1 U - 1	4	14:38:00	8,000	4,949	763.1	936.8	3587	456.1	398.8	1804	71.9	46.2	249
1 U - 2	1	14:40:30	4,000	2,476	574.3	740.0	2773	355.7	328.5	1444	52.8	30.9	177
1 U - 2	2	14:41:30	4,000	2,476	567.3	732.5	2743	351.0	324.8	1426	52.4	30.4	175
1 U - 2	4	14:43:30	4,000	2,476	566.0	730.7	2736	348.8	323.0	1417	52.3	30.7	175
1 U - 3	1	14:45:30	2,000	1,240	445.7	599.8	2206	285.9	279.4	1193	42.9	22.6	138
1 U - 3	2	14:46:30	2,000	1,240	441.7	595.6	2189	283.0	276.9	1181	42.3	22.6	137
1 U - 3	4	14:48:30	2,000	1,240	440.3	593.1	2180	280.3	274.9	1171	42.2	22.7	137
1 U - 4	1	14:50:30	1,000	622	381.3	523.5	1909	248.8	252.3	1057	38.7	19.4	123
1 U - 4	2	14:51:30	1,000	622	371.9	512.8	1867	242.9	248.1	1036	38.0	18.8	120
1 U - 4	4	14:53:30	1,000	622	369.3	508.4	1852	240.0	245.5	1024	37.8	18.6	119
1 U - 5	1	14:55:30	0	0	288.8	406.8	1468	196.8	212.0	863	31.5	15.1	98
1 U - 5	2	14:56:30	0	0	285.6	402.0	1451	194.3	210.3	854	31.4	15.1	98
1 U - 5	4	14:58:30	0	0	282.4	396.8	1433	190.8	207.7	841	31.3	15.2	98
1 U - 5	8	15:02:30	0	0	279.1	391.7	1415	186.6	204.3	825	30.8	15.5	98

Strain Gage Readings and Loads at Levels 4, 5 and 6
Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA

Load	Hold	Time	O-cell		Level 4			Level 5			Level 6		
Test Increment	Time (minutes)	(h:m:s)	Pressure (psi)	Load (kips)	A - 6914 (με)	B - 6915 (με)	Av. Load (kips)	A - 6916 (με)	B - 6917 (με)	Av. Load (kips)	A - 6918 (με)	B - 6919 (με)	Av. Load (kips)
1 L - 0	-	11:00:00	0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0
1 L - 1	1	11:14:30	1,000	622	2.9	2.6	12	1.5	1.1	6	0.1	0.0	0
1 L - 1	2	11:15:30	1,000	622	3.0	2.4	11	1.4	1.4	6	0.1	0.0	0
1 L - 1	4	11:17:30	1,000	622	2.9	2.5	11	1.5	1.2	6	0.0	-0.1	0
1 L - 1	8	11:21:30	1,000	622	2.9	2.4	11	1.5	1.2	6	-0.3	-0.2	-2
1 L - 2	1	11:26:30	2,000	1,240	7.7	7.0	31	3.6	3.7	15	-0.2	-0.1	-1
1 L - 2	2	11:27:30	2,000	1,240	7.6	7.0	31	3.7	3.7	16	-0.2	-0.2	-1
1 L - 2	4	11:29:30	2,000	1,240	7.9	7.2	32	3.7	4.0	16	-0.3	-0.4	-2
1 L - 2	8	11:33:30	2,000	1,240	8.0	7.3	32	3.7	3.8	16	-0.8	-0.8	-5
1 L - 3	1	11:41:00	3,000	1,858	12.3	11.3	50	6.8	6.2	27	-0.8	-1.8	-7
1 L - 3	2	11:42:00	3,000	1,858	13.0	12.7	54	7.0	6.1	28	-0.8	-2.0	-8
1 L - 3	4	11:44:00	3,000	1,858	13.1	11.4	52	7.0	6.0	28	-0.8	-2.5	-9
1 L - 3	8	11:48:00	3,000	1,858	13.3	11.2	52	7.2	6.0	28	-0.8	-3.0	-11
1 L - 4	1	12:06:00	4,000	2,476	15.7	12.5	59	9.2	7.7	36	-0.3	-2.4	-8
1 L - 4	2	12:07:00	4,000	2,476	15.7	12.5	60	9.4	7.7	36	-0.5	-2.3	-8
1 L - 4	4	12:09:00	4,000	2,476	15.9	13.7	62	9.5	7.8	37	-0.5	-2.4	-8
1 L - 4	8	12:13:00	4,000	2,476	16.0	12.8	61	9.6	8.1	37	-0.3	-2.1	-7
1 L - 5	1	12:20:00	5,000	3,094	18.0	14.5	69	11.6	9.2	44	0.1	-1.1	-3
1 L - 5	2	12:21:00	5,000	3,094	18.2	14.6	69	11.6	9.4	44	0.0	-1.2	-3
1 L - 5	4	12:23:00	5,000	3,094	18.3	14.7	70	11.8	9.5	45	0.1	-1.0	-2
1 L - 5	8	12:27:00	5,000	3,094	18.4	14.8	70	11.9	9.7	45	0.2	-0.7	-1
1 L - 6	1	12:32:00	6,000	3,712	19.9	15.6	75	13.3	10.6	50	0.6	0.2	2
1 L - 6	2	12:33:00	6,000	3,712	20.0	15.7	75	13.4	10.6	51	0.7	0.2	2
1 L - 6	4	12:35:00	6,000	3,712	20.2	15.7	76	13.5	10.8	51	0.8	0.4	3
1 L - 6	8	12:39:00	6,000	3,712	20.4	15.9	77	13.7	11.3	53	0.8	0.5	4
1 L - 7	1	12:44:30	7,000	4,330	22.0	17.4	83	15.2	12.0	57	1.3	1.0	6
1 L - 7	2	12:45:30	7,000	4,330	22.1	17.6	84	15.2	12.0	57	1.3	1.0	7
1 L - 7	4	12:47:30	7,000	4,330	22.2	17.7	84	15.3	12.0	58	1.3	1.0	6
1 L - 7	8	12:51:30	7,000	4,330	22.3	17.8	85	15.4	12.1	58	1.4	1.0	7
1 L - 8	1	12:57:00	8,000	4,949	23.8	19.0	90	16.4	12.7	61	1.8	1.4	9
1 L - 8	2	12:58:00	8,000	4,949	24.0	19.1	91	16.6	12.8	62	1.8	1.4	9
1 L - 8	4	13:00:00	8,000	4,949	24.1	19.2	91	16.6	12.9	62	1.8	1.5	9
1 L - 8	8	13:04:00	8,000	4,949	24.0	19.2	91	16.6	12.9	62	1.8	1.6	9
1 L - 9	1	13:09:00	9,000	5,567	25.9	20.6	98	17.7	13.5	66	2.3	2.0	12
1 L - 9	2	13:10:00	9,000	5,567	26.0	20.5	98	17.9	13.6	66	2.2	1.9	11
1 L - 9	4	13:12:00	9,000	5,567	26.2	20.6	99	17.9	13.6	67	2.3	2.2	12
1 L - 9	8	13:16:00	9,000	5,567	26.0	21.0	99	17.9	13.6	66	2.2	1.9	11
1 L - 10	1	13:20:30	10,000	6,185	28.1	22.2	106	19.0	14.5	71	2.7	2.4	14
1 L - 10	2	13:21:30	10,000	6,185	27.9	22.1	106	19.1	14.6	71	2.7	2.7	15
1 L - 10	4	13:23:30	10,000	6,185	28.1	22.5	107	19.2	14.7	71	2.6	2.4	14
1 L - 10	8	13:27:30	10,000	6,185	28.4	22.7	108	19.2	15.0	72	2.6	2.9	15
1 L - 11	1	13:33:30	11,000	6,803	30.1	24.0	114	20.2	15.5	75	3.0	3.3	18
1 L - 11	2	13:34:30	11,000	6,803	30.2	24.1	115	20.0	15.5	75	3.1	3.3	18
1 L - 11	4	13:36:30	11,000	6,803	30.3	23.9	114	20.2	15.6	76	3.2	2.9	17
1 L - 11	8	13:40:30	11,000	6,803	30.5	24.1	115	20.3	15.6	76	3.1	3.3	18
1 L - 12	1	13:46:00	12,000	7,421	32.6	25.3	122	21.0	16.5	79	3.5	3.8	20
1 L - 12	2	13:47:00	12,000	7,421	32.7	25.3	123	21.4	16.6	80	3.5	3.8	20
1 L - 12	4	13:49:00	12,000	7,421	32.9	25.5	123	21.4	16.7	80	3.4	3.8	20
1 L - 12	8	13:53:00	12,000	7,421	33.2	25.7	124	21.5	16.8	81	3.5	3.6	20
1 L - 13	1	13:57:30	13,000	8,039	35.3	27.0	131	22.2	17.8	84	3.9	4.0	22
1 L - 13	2	13:58:30	13,000	8,039	35.2	28.4	134	22.1	17.7	84	3.8	4.3	22
1 L - 13	4	14:00:30	13,000	8,039	35.5	27.7	133	22.2	17.9	85	3.8	4.0	22
1 L - 13	8	14:04:30	13,000	8,039	35.5	27.1	132	22.0	18.2	85	3.9	4.4	23
1 L - 14	1	14:12:00	14,000	8,657	37.2	31.1	144	22.6	19.2	88	4.0	4.7	24
1 L - 14	2	14:13:00	14,000	8,657	37.2	31.1	144	22.6	18.8	87	4.1	4.8	25
1 L - 14	4	14:15:00	14,000	8,657	37.3	31.1	144	22.6	18.8	87	4.0	4.7	24
1 L - 14	8	14:19:00	14,000	8,657	37.4	28.9	140	22.5	19.3	88	4.0	4.8	25
1 L - 15	1	14:25:30	15,000	9,275	38.8	30.6	146	22.8	20.0	90	4.1	5.3	26
1 L - 15	2	14:26:30	15,000	9,275	38.8	30.3	146	22.9	20.1	91	4.1	5.3	26
1 L - 15	4	14:28:30	15,000	9,275	38.9	30.5	146	22.8	20.3	91	4.1	5.1	26
1 L - 15	8	14:32:30	15,000	9,275	39.0	30.5	147	22.7	20.4	91	4.1	5.4	26
1 U - 1	1	14:35:00	8,000	4,949	30.1	23.2	112	18.5	15.5	72	2.5	3.8	17
1 U - 1	2	14:36:00	8,000	4,949	30.3	23.1	113	18.3	15.6	72	2.5	3.7	17
1 U - 1	4	14:38:00	8,000	4,949	30.2	23.4	113	18.5	15.5	72	2.5	3.8	17
1 U - 2	1	14:40:30	4,000	2,476	25.4	18.3	92	16.5	12.6	61	1.6	2.3	11
1 U - 2	2	14:41:30	4,000	2,476	25.3	18.1	92	16.5	12.5	61	1.6	1.9	10
1 U - 2	4	14:43:30	4,000	2,476	25.4	18.4	92	16.5	12.6	61	1.6	2.1	10
1 U - 3	1	14:45:30	2,000	1,240	23.1	15.9	82	15.4	11.2	56	1.4	1.4	8
1 U - 3	2	14:46:30	2,000	1,240	23.0	15.7	82	15.3	11.2	56	1.4	1.3	7
1 U - 3	4	14:48:30	2,000	1,240	22.9	16.0	82	15.3	11.1	56	1.3	0.8	6
1 U - 4	1	14:50:30	1,000	622	21.6	14.8	77	14.7	10.3	53	1.0	0.2	3
1 U - 4	2	14:51:30	1,000	622	21.4	14.7	76	14.6	10.0	52	1.0	0.0	3
1 U - 4	4	14:53:30	1,000	622	21.3	14.6	76	14.6	9.9	52	0.8	-0.6	0
1 U - 5	1	14:55:30	0	0	20.0	14.0	72	13.8	8.9	48	0.4	-1.3	-3
1 U - 5	2	14:56:30	0	0	20.0	13.4	70	13.8	8.9	48	0.4	-1.3	-2
1 U - 5	4	14:58:30	0	0	20.0	14.0	72	13.9	8.8	48	0.4	-1.6	-3
1 U - 5	8	15:02:30	0	0	20.0	13.4	70	13.8	9.0	48	0.2	-1.6	-4

APPENDIX B

O-CELL AND INSTRUMENTATION CALIBRATION SHEETS



STROKE:	1 INCH	3 INCH	5 INCH
PRESSURE PSI	LOAD KIPS	LOAD KIPS	LOAD KIPS
0	0	0	0
500	309	308	310
1000	620	618	620
1500	934	932	933
2000	1240	1238	1238
2500	1561	1550	1550
3000	1870	1861	1858
3500	2180	2170	2165
4000	2480	2470	2465
4500	2793	2783	2777
5000	3103	3088	3081

34" O-CELL, SERIAL # 5023-7

LOAD CONVERSION FORMULA

LOAD = PRESSURE * 0.6181 + (3.77)
{KIPS} {PSI}

Regression Output:

Constant	3.7710	kips
X Coefficient	0.6181	kip / psi
R Square	1.0000	
No. of Observations	30	
Degrees of Freedom	28	
Std Err of Y Est	6.41	
Std Err of X Coeff	0.0008	

CALIBRATION STANDARDS:

All data presented are derived from 6" dia. certified hydraulic pressure gauges and electronic load transducer, manufactured and calibrated by the University of Illinois at Champaign, Illinois. All calibrations and certifications are traceable through the Laboratory Master Deadweight Gauges directly to the National Institute of Standards and Technology. No specific guidelines exist for calibration of load test jacks and equipment but procedures comply with similar guidelines for calibration of gages, ANSI specifications B40.1.

* AE & FC CUSTOMER: LOADTEST Inc	* CONTRACTOR.: LONGFELLOW DRILLING
* AE & FC JOB NO: 8497	* JOB LOCATION: CLEARFIELD, IA
* CUSTOMER P.O. NO.: LT-9183	* DATED: 04/21/06

SERVICE ENGINEER: [signature] DATE: 21 Apr 2006

Certificate of Calibration

WIKA

Certificate No.:	**28554**	
Page 1 of 2		
Date of Calibration:	4/20/2005	
Customer	: FLOW TECHNOLOGY	
	P.O. BOX 8889	
	JACKSONVILLE, FL 32239-8889	

Pressure and Temperature Measurement
WIKA Instrument Corporation
Wiegand Boulevard
Lawrenceville, Georgia 30043

Tel 770-513-8200
Fax 770-338-5118
www.wika.com
info@wika.com

Order No. : 3261413

Specification of the device under test

Object	: Dial Gauge
Manufacturer	: WIKA
Model	: 232.50 6"
Serial No.	: -
Tag	: -
Pressure range	: 0 ... 15000 psi
Accuracy	: 1 % (of span)
Scale division / Resolution	: 200 psi
Method of measurement	: Gauge pressure
Output signal	: -

Working Standard (WS)

Name	: Electr. Gauge
Pressure range	: 0 ... 2750 bar
Calibration-number	: 56605 5-19-2004
Accuracy	: 0.025 % (of span)
Identity	: SS 205
Recal Interval	: 1 year

Calibration parameters

Place of calibration	: Cal-Lab (Lawrenceville)
Test temperature (in °F)	: 71.0
Humidity (in %)	: 30.0
Amb. pressure (in inHg)	: 28.9
Pressure medium	: water
Angle position	: vertical
local gravity (in m/s^2)	: 9.79541

Used auxiliary instruments

Multimeter	: -
Resistor	: -

Comments :

Kuldeep Patel

Quality Assurance : K. Patel

Calibration technician : C. Mathew

ISO 9001 Certified

WIKA

Certificate No.: 28554

Pressure and Temperature Measurement
WIKA Instrument Corporation
Wiegand Boulevard
Lawrenceville, Georgia 30043

Tel 770-513-8200
Fax 770-338-5118
www.wika.com
info@wika.com

Calibration results

Reading DUT *psi*	Reading WS *psi* *M 1*	*M 2*	Hysteresis *psi*	Deviation % *M 1*	Deviation % *M 2*	Pass/Fail
0.0	0.0	0.0	0.0	0.0	0.0	PASS
3000.0	3000.0	3040.0	40.0	0.0	-0.3	PASS
6000.0	5920.0	6000.0	80.0	0.5	0.0	PASS
9000.0	8920.0	9000.0	80.0	0.5	0.0	PASS
12000.0	11900.0	12000.0	100.0	0.7	0.0	PASS
15000.0	15000.0	15000.0	0.0	0.0	0.0	PASS

The DUT is labeled with a calibration sticker, which shows the date of calibration and the date for recalibration. The recommended cycle is one year from current calibration.

Declaration of conformity:

The device under test meets the specifications as required by the manufacturer.

WIKA Instrument Corporation certifies that the above named instrument has been calibrated by comparison to laboratory standards traceable to the National Institute of Standards and Technology (NIST)

Calibration is carried out according to the following procedures:

-
ISO 10012-1 Edition 15-0101992
ANSI / NCSL Z 540-1-1994
WIKA Procedure SOP 0.2

ISO 9001 Certified

Certificate of Calibration

Instrument: RDP Electronics LVDT

Model: DCW2000A/85B

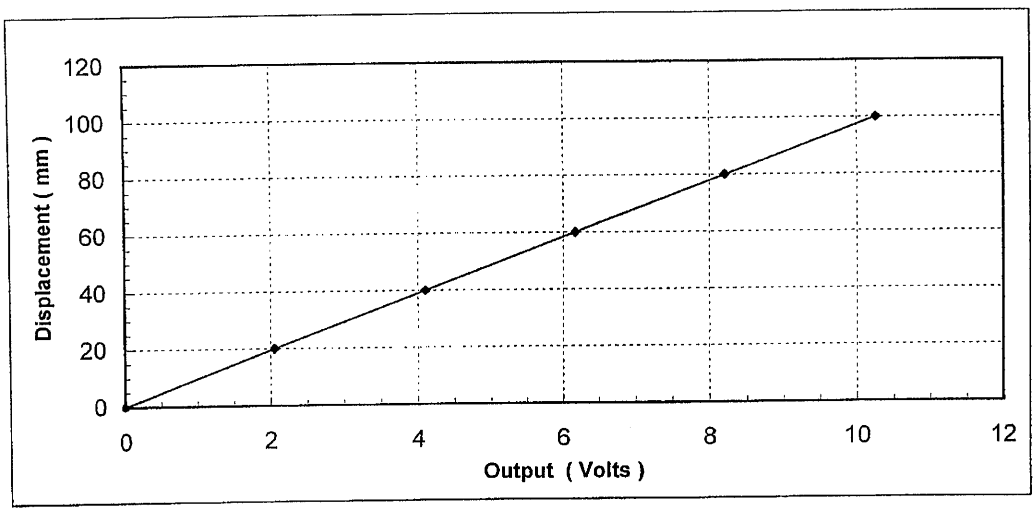
Serial Number: 2262

Calibration Date: February 6, 2006

Temperature: 18.9 °C

Linear Range: 100 mm

Displacement (mm)	1st Cycle (Volts)	2nd Cycle (Volts)	Average (Volts)	Linearity (% FS)
0	0.000	0.000	0.000	0.00
20	2.051	2.053	2.052	-0.01
40	4.104	4.106	4.105	-0.01
60	6.165	6.165	6.165	0.06
80	8.205	8.207	8.206	-0.05
100	10.266	10.263	10.265	0.01



Linear Gage Factor: 9.743 **mm/V** 0.3836 **in/V**

The above named instrument has been calibrated using Grade 3 steel rectangular gage blocks and was found to be in tolerance in all operating ranges.

Tested by: Michael D. Ahrens, P.E. Signed: [signature]

Approved by: David J. Jakstis, P.E. Signed: [signature]

Certificate of Calibration

Instrument: RDP Electronics LVDT

Model: DCW2000A/85B

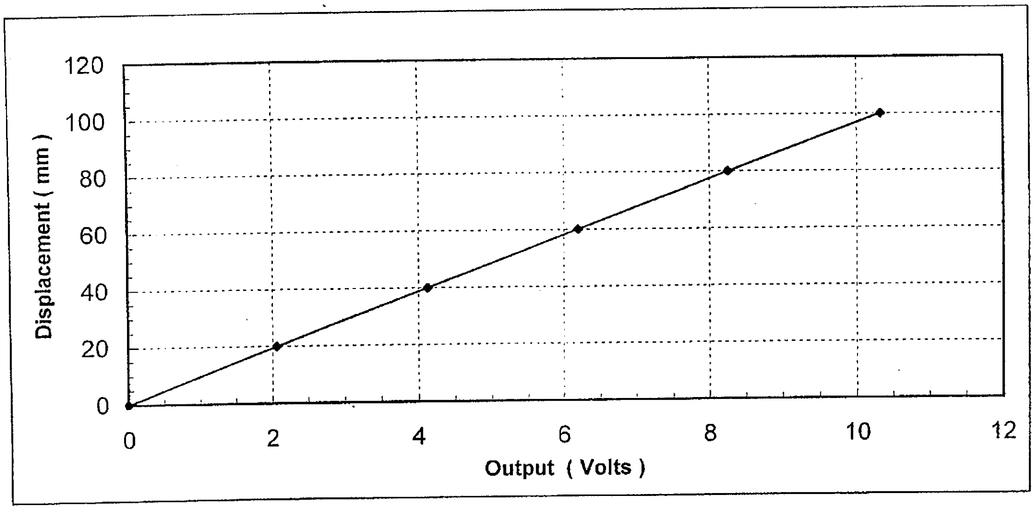
Serial Number: 2263

Calibration Date: February 6, 2006

Temperature: 18.9 °C

Linear Range: 100 mm

Displacement (mm)	1st Cycle (Volts)	2nd Cycle (Volts)	Average (Volts)	Linearity (% FS)
0	0.000	0.000	0.000	0.00
20	2.063	2.063	2.063	-0.02
40	4.127	4.127	4.127	-0.03
60	6.198	6.198	6.198	0.03
80	8.253	8.259	8.256	-0.04
100	10.325	10.330	10.328	0.03



Linear Gage Factor: 9.686 mm/V 0.3813 in/V

The above named instrument has been calibrated using Grade 3 steel rectangular gage blocks and was found to be in tolerance in all operating ranges.

Tested by: Michael D. Ahrens, P.E. Signed: Michael D. Ahrens

Approved by: David J. Jakstis, P.E. Signed:

Certificate of Calibration

Instrument: RDP Electronics LVDT

Model: DCW500A/85B

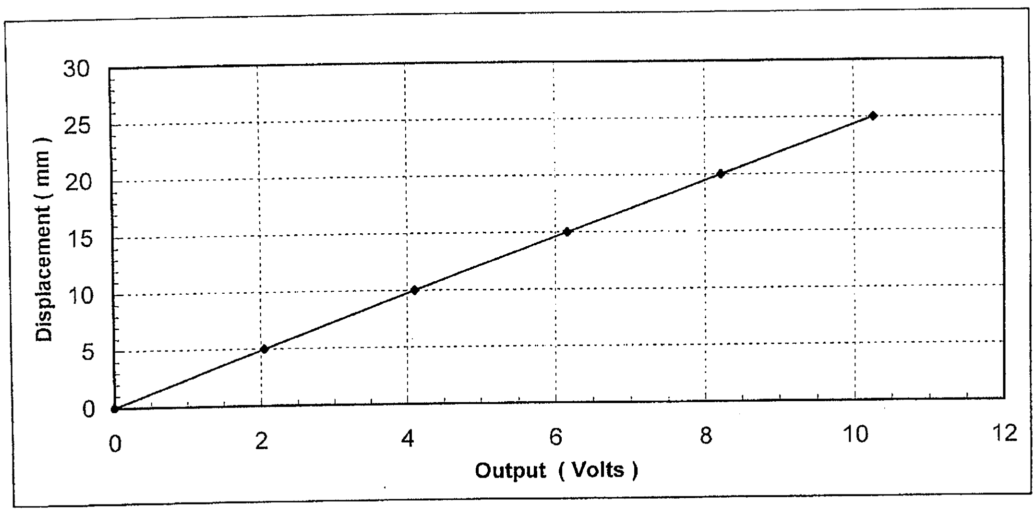
Serial Number: 3354

Calibration Date: February 6, 2006

Temperature: 18.9 °C

Linear Range: 25 mm

Displacement (mm)	1st Cycle (Volts)	2nd Cycle (Volts)	Average (Volts)	Linearity (% FS)
0	0.000	0.000	0.000	0.00
5	2.050	2.050	2.050	-0.03
10	4.105	4.106	4.105	-0.01
15	6.161	6.158	6.160	-0.01
20	8.216	8.214	8.215	0.01
25	10.269	10.266	10.268	0.00



Linear Gage Factor: **2.435** **mm/V** **0.09586** **in/V**

The above named instrument has been calibrated using Grade 3 steel rectangular gage blocks and was found to be in tolerance in all operating ranges.

Tested by: Michael D. Ahrens, P.E. Signed:

Approved by: David J. Jakstis, P.E. Signed:

Certificate of Calibration

Instrument: RDP Electronics LVDT

Model: DCW500A/85B

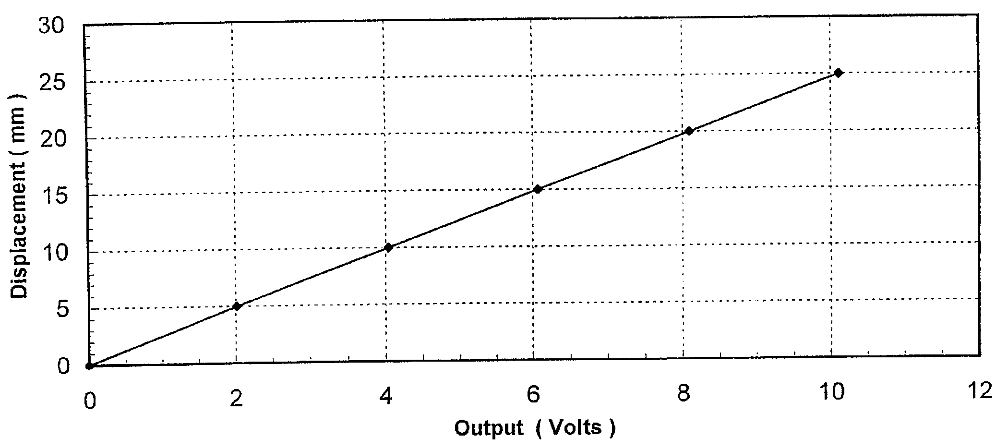
Serial Number: 3355

Calibration Date: February 6, 2006

Temperature: 18.9 °C

Linear Range: 25 mm

Displacement (mm)	1st Cycle (Volts)	2nd Cycle (Volts)	Average (Volts)	Linearity (% FS)
0	0.000	0.000	0.000	0.00
5	2.023	2.023	2.023	0.01
10	4.044	4.047	4.045	0.00
15	6.070	6.070	6.070	0.02
20	8.091	8.091	8.091	0.00
25	10.114	10.112	10.113	-0.01



Linear Gage Factor: 2.472 **mm/V** 0.09732 **in/V**

The above named instrument has been calibrated using Grade 3 steel rectangular gage blocks and was found to be in tolerance in all operating ranges.

Tested by: Michael D. Ahrens, P.E. Signed:

Approved by: David J. Jakstis, P.E. Signed:

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Vibrating Wire Displacement Transducer Calibration Report

Range: 150 mm

Serial Number: 06-3482

Cal. Std. Control Numbers: 529, 406, 344, 057

Calibration Date: April 03, 2006

Temperature: 21.9 °C

Calibration Instruction: CI-4400 Rev: C

Technician: Elice

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2623	2622	2623	-0.09	-0.06	0.03	0.02
30.0	3623	3621	3622	29.94	-0.04	29.91	-0.06
60.0	4628	4628	4628	60.16	0.11	60.06	0.04
90.0	5626	5624	5625	90.11	0.08	90.02	0.01
120.0	6620	6619	6620	119.99	-0.01	119.97	-0.02
150.0	7615	7614	7615	149.88	-0.08	150.01	0.01

(mm) Linear Gage Factor (G): 0.03004 (mm/ digit) **Regression Zero: 2626**

Polynomial Gage Factors: A: 3.68808E-08 B: 0.02967 C: -78.020

(inches) Linear Gage Factor (G): 0.001183 (inches/ digit)

Polynomial Gage Factors: A: 1.452E-09 B: 0.001168 C: -3.0717

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5110 Temp(T_0): 23.9 °C Date: April 26, 2006

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Vibrating Wire Displacement Transducer Calibration Report

Range: 150 mm

Calibration Date: April 03, 2006

Serial Number: 06-3483

Temperature: 21.9 °C

Cal. Std. Control Numbers: 529, 406, 344, 057

Calibration Instruction: CI-4400 Rev: C

Technician: Elise

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2676	2675	2676	-0.31	-0.21	-0.08	-0.05
30.0	3694	3692	3693	30.18	0.12	30.13	0.09
60.0	4697	4695	4696	60.23	0.15	60.05	0.03
90.0	5693	5693	5693	90.10	0.06	89.92	-0.05
120.0	6690	6690	6690	119.97	-0.02	119.92	-0.05
150.0	7688	7686	7687	149.84	-0.11	150.07	0.04

(mm) Linear Gage Factor (G): 0.02996 (mm/ digit) **Regression Zero: 2686**

Polynomial Gage Factors: A: 6.75388E-08 B: 0.02926 C: -78.852

(inches) Linear Gage Factor (G): 0.001180 (inches/ digit)

Polynomial Gage Factors: A: 2.65901E-09 B: 0.001152 C: -3.1044

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5195 Temp(T_0): 24.3 °C Date: April 26, 2006

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Vibrating Wire Displacement Transducer Calibration Report

Range: 150 mm

Calibration Date: April 03, 2006

Serial Number: 06-3484

Temperature: 21.9 °C

Cal. Std. Control Numbers: 529, 406, 344, 057

Calibration Instruction: CI-4400 Rev: C

Technician: Elise

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2596	2597	2597	-0.24	-0.16	-0.04	-0.02
30.0	3613	3611	3612	30.10	0.07	30.06	0.04
60.0	4617	4619	4618	60.17	0.11	60.00	0.00
90.0	5622	5621	5622	90.15	0.10	89.99	-0.01
120.0	6620	6620	6620	119.99	-0.01	119.95	-0.03
150.0	7618	7619	7619	149.83	-0.12	150.03	0.02

(mm) Linear Gage Factor (G): 0.02988 (mm/ digit) **Regression Zero: 2605**

Polynomial Gage Factors: A: 6.08905E-08 B: 0.02926 C: -76.421

(inches) Linear Gage Factor (G): 0.001176 (inches/ digit)

Polynomial Gage Factors: A: 2.39726E-09 B: 0.001152 C: -3.0087

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5150 Temp(T_0): 24.1 °C Date: April 26, 2006

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Calibration Date: April 25, 2006

Serial Number: 06-6908

Cal. Std. Control Numbers: 85888-1, 098

Prestress: 35,000 psi

Cable Length: 46 ft.

Temperature: 19.5 °C

Factory Zero Reading: 7577

Calibration Instruction: CI-VW Rebar Rev: C

Regression Zero: 7572

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7617	7631	7624		
1,500	8300	8315	8308	684	-0.19
3,000	9051	9064	9058	750	0.11
4,500	9794	9804	9799	742	0.13
6,000	10531	10537	10534	735	-0.07
100	7631				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.343 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6909

Prestress: 35,000 psi

Temperature: 19.7 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 46 ft.

Factory Zero Reading: 7509

Regression Zero: 7504

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7576	7577	7577		
1,500	8296	8298	8297	721	-0.30
3,000	9087	9093	9090	793	-0.59
4,500	9906	9911	9909	819	-0.09
6,000	10728	10729	10729	820	0.45
100	7578				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.324 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6910

Prestress: 35,000 psi

Temperature: 19.6 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 39 ft.

Factory Zero Reading: 7595

Regression Zero: 7601

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7654	7657	7656		
1,500	8327	8330	8329	673	-0.42
3,000	9086	9089	9088	759	0.23
4,500	9824	9824	9824	737	0.12
6,000	10554	10560	10557	733	-0.11
100	7658				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.343 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

<u>Users are advised to establish their own zero conditions.</u>

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6911

Prestress: 35,000 psi

Temperature: 19.5 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 39 ft.

Factory Zero Reading: 7491

Regression Zero: 7479

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7534	7541	7538		
1,500	8205	8215	8210	673	-0.31
3,000	8952	8965	8959	749	-0.03
4,500	9698	9704	9701	743	0.04
6,000	10443	10444	10444	743	0.12
100	7542				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.343 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6912

Prestress: 35,000 psi

Temperature: 19.7 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 34 ft.

Factory Zero Reading: 6651

Regression Zero: 6660

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6711	6711	6711		
1,500	7414	7416	7415	704	-0.11
3,000	8181	8182	8182	767	0.15
4,500	8936	8937	8937	755	0.04
6,000	9691	9693	9692	756	-0.06
100	6712				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.337 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6913

Prestress: 35,000 psi

Temperature: 20.2 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 34 ft.

Factory Zero Reading: 6569

Regression Zero: 6564

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6633	6635	6634		
1,500	7317	7317	7317	683	-0.34
3,000	8074	8076	8075	758	-0.52
4,500	8846	8843	8845	770	-0.33
6,000	9638	9633	9636	791	0.57
100	6636				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.336 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6914

Prestress: 35,000 psi

Temperature: 20.0 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 32 ft.

Factory Zero Reading: 6584

Regression Zero: 6614

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6678	6669	6674		
1,500	7359	7353	7356	683	-0.24
3,000	8114	8106	8110	754	-0.08
4,500	8854	8851	8853	743	-0.30
6,000	9626	9615	9621	768	0.33
100	6670				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.340 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6915

Prestress: 35,000 psi

Temperature: 20.4 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 32 ft.

Factory Zero Reading: 7689

Regression Zero: 7681

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7734	7745	7740		
1,500	8381	8393	8387	648	-0.45
3,000	9112	9122	9117	730	-0.06
4,500	9833	9843	9838	721	0.01
6,000	10555	10565	10560	722	0.12
100	7745				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.351 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

<u>Users are advised to establish their own zero conditions.</u>

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6916

Prestress: 35,000 psi

Temperature: 20.4 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 30 ft.

Factory Zero Reading: 6612

Regression Zero: 6623

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6685	6680	6683		
1,500	7364	7360	7362	680	-0.21
3,000	8107	8107	8107	745	-0.22
4,500	8855	8857	8856	749	-0.10
6,000	9612	9612	9612	756	0.26
100	6681				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.342 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6917

Prestress: 35,000 psi

Temperature: 20.1 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 30 ft.

Factory Zero Reading: 7035

Regression Zero: 7029

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7100	7102	7101		
1,500	7785	7790	7788	687	-0.34
3,000	8542	8551	8547	759	-0.66
4,500	9329	9335	9332	786	-0.12
6,000	10118	10123	10121	789	0.52
100	7103				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.334 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6918

Prestress: 35,000 psi

Temperature: 20.4 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 25 ft.

Factory Zero Reading: 7303

Regression Zero: 7303

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7359	7361	7360		
1,500	8048	8049	8049	689	-0.33
3,000	8818	8820	8819	771	0.16
4,500	9570	9569	9570	751	0.00
6,000	10327	10326	10327	757	0.04
100	7361				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.338 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 06-6919

Prestress: 35,000 psi

Temperature: 20.8 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: April 25, 2006

Cal. Std. Control Numbers: 85888-1, 098

Cable Length: 25 ft.

Factory Zero Reading: 7467

Regression Zero: 7466

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7537	7535	7536		
1,500	8222	8223	8223	687	-0.50
3,000	8996	9001	8999	776	-0.36
4,500	9777	9780	9779	780	-0.10
6,000	10565	10564	10565	786	0.36
100	7536				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor: 0.333 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

APPENDIX C

CONSTRUCTION OF THE EQUIVALENT TOP-LOADED LOAD-SETTLEMENT CURVE

CONSTRUCTION OF THE EQUIVALENT TOP-LOADED LOAD-SETTLEMENT CURVE FROM THE RESULTS OF AN O-CELL TEST (August, 2000)

Introduction: Some engineers find it useful to see the results of an O-cell load test in the form of a curve showing the load versus settlement of a top-loaded driven or bored pile (drilled shaft). We believe that an O-cell test can provide a good estimate of this curve when using the method described herein.

Assumptions: We make the following assumptions, which we consider both reasonable and usually conservative:

1. The end bearing load-movement curve in a top-loaded shaft has the same loads for a given movement as the net (subtract buoyant weight of pile above O-cell) end bearing load-movement curve developed by the bottom of the O-cell when placed at or near the bottom of the shaft.

2. The side shear load-movement curve in a top-loaded shaft has the same net shear, multiplied by an adjustment factor 'F', for a given downward movement as occurred in the O-cell test for that same movement at the top of the cell in the upward direction. The same applies to the upward movement in a top-loaded tension test. Unless noted otherwise, we use the following adjustment factors:
(a) F = 1.00 in all rock sockets and for primarily cohesive soils in compression
(b) F = 0.95 in primarily cohesionless soils
(c) F = 0.80 for all soils in top load tension tests.

3. We initially assume the pile behaves as a rigid body, but include the elastic compressions that are part of the movement data obtained from an O-cell test (OLT). Using this assumption, we construct an equivalent top-load test (TLT) movement curve by the method described below in Procedure Part I. We then use the following Procedure Part II to correct for the effects of the additional elastic compressions in a TLT.

4. Consider the case with the O-cell, or the bottom O-cell of more than one level of cells, placed some distance above the bottom of the shaft. We assume the part of the shaft below the cell, now top-loaded, has the same load-movement behavior as when top-loading the entire shaft. For this case the subsequent "end bearing movement curve" refers to the movement of the entire length of shaft below the cell.

Procedure Part I: Please refer to the attached Figure A showing O-cell test results and to Figure B, the constructed equivalent top loaded settlement curve. Note that each of the curves shown has points numbered from 1 to 12 such that the same point number on each curve has the same magnitude of movement. For example, point 4 has an upward and downward movement of 0.40 inches in Figure A and the same 0.40 inches downward in Figure B.

Note: This report shows the O-cell movement data in a Figure similar to Fig. A, but uses the gross loads as obtained in the field. Fig. A uses net loads to make it easier for the reader to convert Fig. A into Fig. B without the complication of first converting gross to net loads. For conservative reconstruction of the top loaded settlement curve we first convert both of the O-cell components to net load.

Using the above assumptions, construct the equivalent curve as follows: Select an arbitrary movement such as the 0.40 inches to give point 4 on the shaft side shear load movement curve in Figure A and record the 2,090 ton load in shear at that movement. Because we have initially assumed a rigid pile, the top of pile moves downward the same as the bottom. Therefore, find point 4 with 0.40 inches of upward movement on the end bearing load movement curve and record the corresponding load of 1,060 tons. Adding these two loads will give the total load of 3,150 tons due to side shear plus end bearing at the same movement and thus gives point 4 on the Figure B load settlement curve for an equivalent top-loaded test.

One can use the above procedure to obtain all the points in Figure B up to the component that moved the least at the end of the test, in this case point 5 in side shear. To take advantage of the fact that the test produced end bearing movement data up to point 12, we need to make an extrapolation of the side shear curve. We usually use a convenient and suitable hyperbolic curve fitting technique for this extrapolation. Deciding on the maximum number of data points to provide a good fit (a high r^2 correlation coefficient) requires some judgment. In this case we omitted point 1 to give an $r^2 = 0.999$ (including point 1 gave an $r^2 = 0.966$) with the result shown as points 6 to 12 on the dotted extension of the measured side shear curve. Using the same movement matching procedure described earlier we can then extend the equivalent curve to points 6 to 12. The results, shown in Figure B as a dashed line, signify that this part of the equivalent curve depends partly on extrapolated data.

Sometimes, if the data warrants, we will use extrapolations of both side shear and end bearing to extend the equivalent curve to a greater movement than the maximum measured (point 12). An appendix in this report gives the details of the extrapolation(s) used with the present O-cell test and shows the fit with the actual data.

Procedure Part II: The elastic compression in the equivalent top load test always exceeds that in the O-cell test. It not only produces more top movement, but also additional side shear movement, which then generates more side shear, which produces more compression, etc . . . An exact solution of this load transfer problem requires knowing the side shear vs. vertical movement (t-y) curves for a large number of pile length increments and solving the resulting set of simultaneous equations or using finite element or finite difference simulations to obtain an approximate solution for these equations. We usually do not have the data to obtain the many accurate t-y curves required. Fortunately, the approximate solution described below usually suffices.

The attached analysis p. 6 gives the equations for the elastic compressions that occur in the OLT with one or two levels of O-cells. Analysis p. 7 gives the equations for the elastic compressions that occur in the equivalent TLT. Both sets of equations do not include the elastic compression below the O-cell because the same compression takes place in both the OLT and the TLT. This is equivalent to taking $L_3 = 0$. Subtracting the OLT from the TLT compression gives the desired additional elastic compression at the top of the TLT. We then add the additional elastic compression to the 'rigid' equivalent curve obtained from Part I to obtain the final, corrected equivalent load-settlement curve for the TLT on the same pile as the actual OLT.

Note that the above pp. 6 and 7 give equations for each of three assumed patterns of developed side shear stress along the pile. The pattern shown in the center of the three applies to any approximately determined side shear distribution. Experience has shown the initial solution for the additional elastic compression, as described above, gives an adequate and slightly conservative (high) estimate of the additional compression versus more sophisticated load-transfer analyses as described in the first paragraph of this Part II.

The analysis p. 8 provides an example of calculated results in English units on a hypothetical 1-stage, single level OLT using the simplified method in Part II with the centroid of the side shear distribution 44.1% above the base of the O-cell. Figure C compares the corrected with the rigid curve of Figure B. Page 9 contains an example equivalent to that above in SI units.

The final analysis p. 10 provides an example of calculated results in English units on a hypothetical 3-stage, multi level OLT using the simplified method in Part II with the centroid of the combined upper and middle side shear distribution 44.1% above the base of the bottom O-cell. The individual centroids of the upper and middle side shear distributions lie 39.6% and 57.9% above and below the middle O-cell, respectively. Figure E compares the corrected with the rigid curve. Page 11 contains an example equivalent to that above in SI units.

Other Tests: The example illustrated in Figure A has the maximum component movement in end bearing. The procedures remain the same if the maximum test movement occurred in side shear. Then we would have extrapolated end bearing to produce the dashed-line part of the reconstructed top-load settlement curve.

The example illustrated also assumes a pile top-loaded in compression. For a pile top-loaded in tension we would, based on Assumptions 2. and 3., use the upward side shear load curve in Figure A, multiplied by the F = 0.80 noted in Assumption 2., for the equivalent top-loaded displacement curve.

Expected Accuracy: We know of only five series of tests that provide the data needed to make a direct comparison between actual, full scale, top-loaded pile movement behavior and the equivalent behavior obtained from an O-cell test by the method described herein. These involve three sites in Japan and one in Singapore, in a variety of soils, with three compression tests on bored piles (drilled shafts), one compression test on a driven pile and one tension test on a bored pile. The largest bored pile had a 1.2-m diameter and a 37-m length. The driven pile had a 1-m increment modular construction and a 9-m length. The largest top loading = 28 MN (3,150 tons).

The following references detail the aforementioned Japanese tests and the results therefrom:

Kishida H. et al., 1992, "Pile Loading Tests at Osaka Amenity Park Project," Paper by Mitsubishi Co., also briefly described in Schmertmann (1993, see bibliography). Compares one drilled shaft in tension and another in compression.

Ogura, H. et al., 1995, "Application of Pile Toe Load Test to Cast-in-place Concrete Pile and Precast Pile," special volume 'Tsuchi-to-Kiso' on Pile Loading Test, Japanese Geotechnical Society, Vol. 3, No. 5, Ser. No. 448. Original in Japanese. Translated by M. B. Karkee, GEOTOP Corporation. Compares one drilled shaft and one driven pile, both in compression.

We compared the predicted equivalent and measured top load at three top movements in each of the above four Japanese comparisons. The top movements ranged from ¼ inch (6 mm) to 40 mm, depending on the data available. The (equiv./meas.) ratios of the top load averaged 1.03 in the 15 comparisons with a coefficient of variation of less than 10%. We believe that these available comparisons help support the practical validity of the equivalent top load method described herein.

L. S. Peng, A. M. Koon, R. Page and C. W. Lee report the results of a class-A prediction by others of the TLT curve from an Osterberg cell test on a 1.2 m diameter, 37.2 m long bored pile in Singapore, compared to an adjacent pile with the same dimensions actually top-loaded by kentledge. They report about a 4% difference in ultimate capacity and less than 8% difference in settlements over the 1.0 to 1.5 times working load range -- comparable to the accuracy noted above. Their paper has the title "OSTERBERG CELL TESTING OF PILES", and was published in March 1999 in the Proceedings of the International Conference on Rail Transit, held in Singapore and published by the Association of Consulting Engineers Singapore.

B. H. Fellenius has made several finite element method (FEM) studies of an OLT in which he adjusted the parameters to produce good load-deflection matches with the OLT up and down load-deflection curves. He then used the same parameters to predict the TLT deflection curve. We compared the FEM-predicted curve with the equivalent load-deflection predicted by the previously described Part I and II procedures, with the results again comparable to the accuracy noted above. The ASCE has published a paper by Fellenius et. al. titled "O-Cell Testing and FE Analysis of 28-m-Deep Barrette in Manila, Philippines" in the Journal of Geotechnical and Geoenvironmental Engineering, Vol. 125, No. 7, July 1999, p. 566. It details one of his comparison studies.

Limitations: The engineer using these results should judge the conservatism, or lack thereof, of the aforementioned assumptions and extrapolation(s) before utilizing the results for design purposes. For example, brittle failure behavior may produce movement curves with abrupt changes in curvature (not hyperbolic). However, we believe the hyperbolic fit method and our assumptions used usually produce reasonable equivalent top load settlement curves.

August, 2000

Example of the Construction of an Equivalent Top-Loaded Settlement Curve (Figure B) From Osterberg Cell Test Results (Figure A)

Figure A

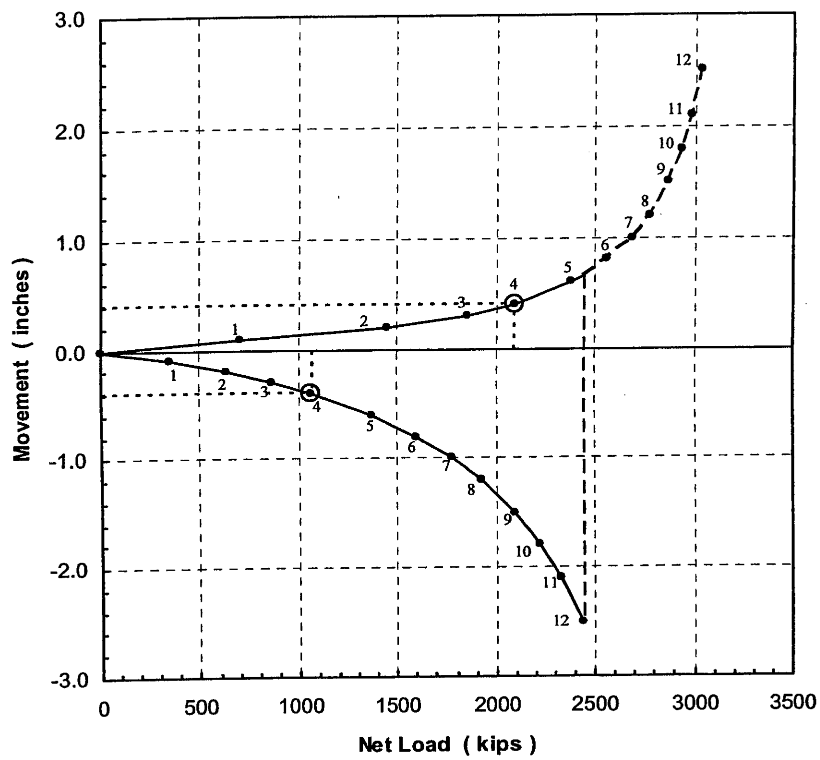
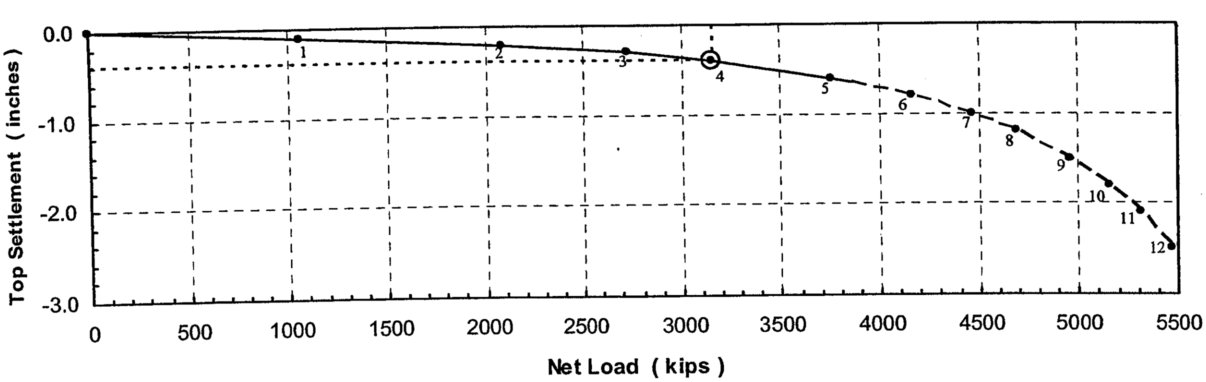
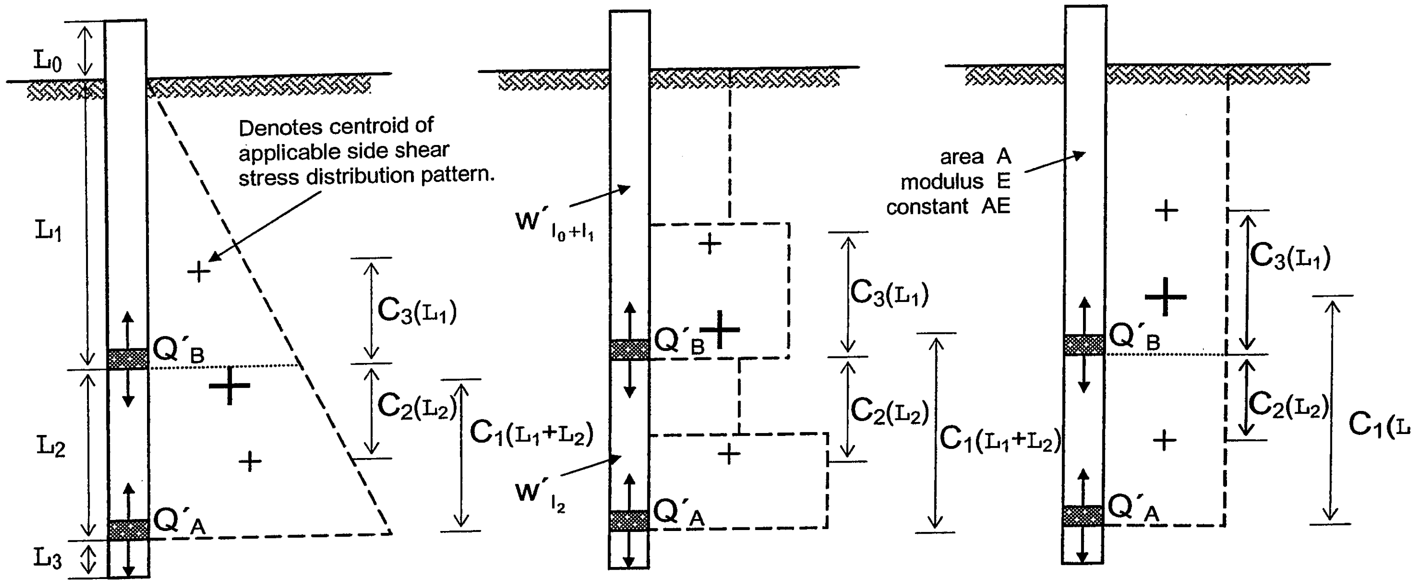


Figure B



Theoretical Elastic Compression in O-cell Test Based on Pattern of Developed Side Shear Stress



1-Stage Single Level Test (Q´A only): $\delta_{OLT} = \delta_{\uparrow(l_1+l_2)}$

$C_1 = \frac{1}{3}$	$\text{Centroid Factor} = C_1$	$C_1 = \frac{1}{2}$
$\delta_{\uparrow(l_1+l_2)} = \frac{1}{3}\frac{Q'_{\uparrow A}(l_1+l_2)}{AE}$	$\delta_{\uparrow(l_1+l_2)} = C_1\frac{Q'_{\uparrow A}(l_1+l_2)}{AE}$	$\delta_{\uparrow(l_1+l_2)} = \frac{1}{2}\frac{Q'_{\uparrow A}(l_1+l_2)}{AE}$

3-Stage Multi Level Test (Q´A and Q´B): $\delta_{OLT} = \delta_{\uparrow l_1} + \delta_{\downarrow l_2}$

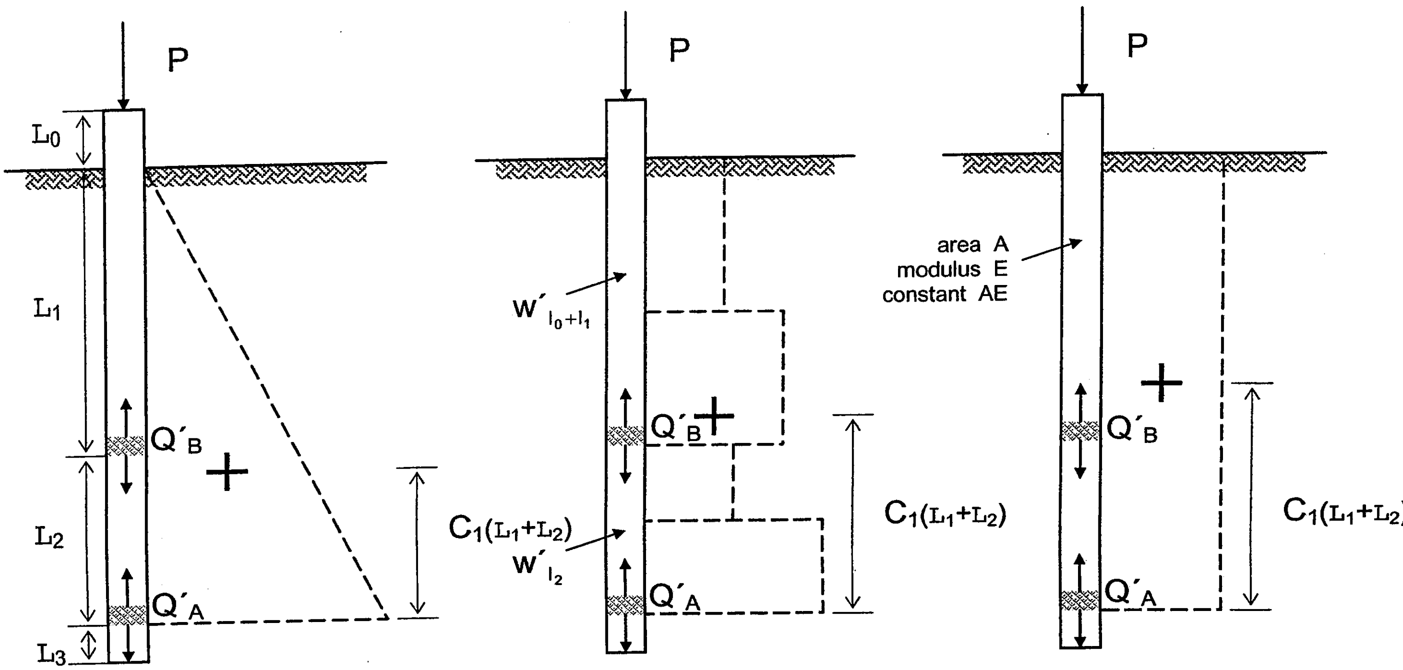
$C_3 = \frac{1}{3}$	$\text{Centroid Factor} = C_3$	$C_3 = \frac{1}{2}$
$\delta_{\uparrow l_1} = \frac{1}{3}\frac{Q'_{\uparrow B} l_1}{AE}$	$\delta_{\uparrow l_1} = C_3\frac{Q'_{\uparrow B} l_1}{AE}$	$\delta_{\uparrow l_1} = \frac{1}{3}\frac{Q'_{\uparrow B} l_1}{AE}$
$C_2 = \frac{1}{3}\left(\frac{3l_1+2l_2}{2l_1+l_2}\right)$	$\text{Centroid Factor} = C_2$	$C_2 = \frac{1}{2}$
$\delta_{\downarrow l_2} = \frac{1}{3}\left(\frac{3l_1+2l_2}{2l_1+l_2}\right)\frac{Q'_{\downarrow B} l_2}{AE}$	$\delta_{\downarrow l_2} = C_2\frac{Q'_{\downarrow B} l_2}{AE}$	$\delta_{\downarrow l_2} = \frac{1}{2}\frac{Q'_{\downarrow B} l_2}{AE}$

Net Loads:

$Q'_{\uparrow A} = Q_{\uparrow A} - W'_{l_0+l_1+l_2}$ $\quad Q'_{\uparrow B} = Q_{\uparrow B} - W'_{l_0+l_1}$ $\quad Q'_{\downarrow B} = Q'_{\downarrow B} + W'_{l_2}$

W' = pile weight, buoyant where below water table

Theoretical Elastic Compression in Top Loaded Test Based on Pattern of Developed Side Shear Stress



Top Loaded Test: $\delta_{TLT} = \delta_{\downarrow l_0} + \delta_{\downarrow l_1 + l_2}$

$\delta_{\downarrow l_0} = \dfrac{Pl_0}{AE}$	$\delta_{\downarrow l_0} = \dfrac{Pl_0}{AE}$	$\delta_{\downarrow l_0} = \dfrac{Pl_0}{AE}$
$C_1 = \dfrac{1}{3}$	$\text{Centroid Factor} = C_1$	$C_1 = \dfrac{1}{2}$
$\delta_{\downarrow l_1+l_2} = \dfrac{(Q'_{\downarrow A} + 2P)}{3}\dfrac{(l_2 + l_2)}{AE}$	$\delta_{\downarrow l_1+l_2} = [(C_1)Q'_{\downarrow A} + (1 - C_1)P]\dfrac{(l_1 + l_2)}{AE}$	$\delta_{\downarrow l_1+l_2} = \dfrac{(Q'_{\downarrow A} + P)}{2}\dfrac{(l_1 + l_2)}{AE}$

Net and Equivalent Loads:

$Q'_{\downarrow A} = Q_{\downarrow A} - W'_{l_0+l_1+l_2}$ $\quad P_{single} = Q'_{\downarrow A} + Q'_{\uparrow A}$ $\quad P_{multi} = Q'_{\downarrow A} + Q'_{\uparrow B} + Q'_{\downarrow B}$

Component loads Q selected at the same (±) Δ_{OLT}.

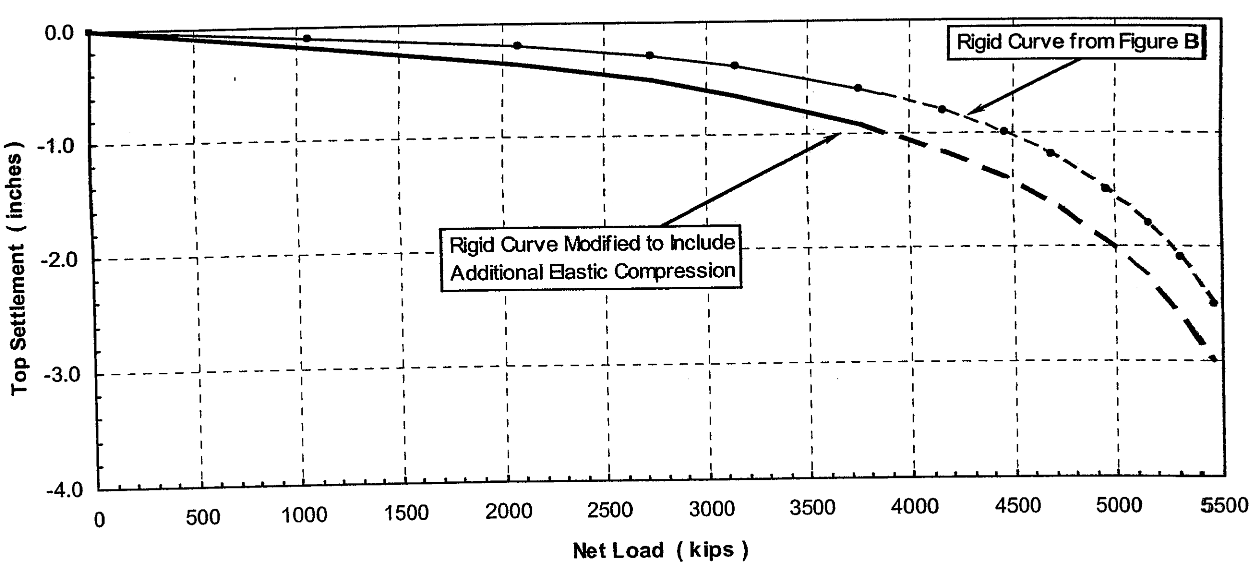
Example Calculation for the Additional Elastic Compression Correction For Single Level Test (English Units)

Given:

	C_1	=	0.441	
	AE	=	3,820,000	kips (assumed constant throughout test)
	I_0	=	5.9	ft
	I_1	=	30.0	ft (embedded length of shaft above O-cell)
	I_2	=	0.00	ft
	I_3	=	0.0	ft
Shear reduction factor		=	1.00	(cohesive soil)

Δ_{OLT} (in)	$Q'_{\downarrow A}$ (kips)	$Q'_{\uparrow A}$ (kips)	P (kips)	δ_{TLT} (in)	δ_{OLT} (in)	Δ_δ (in)	$\Delta_{OLT} + \Delta_\delta$ (in)
0.000	0	0	0	0.000	0.000	0.000	0.000
0.100	352	706	1058	0.133	0.047	0.086	0.186
0.200	635	1445	2080	0.257	0.096	0.160	0.360
0.300	867	1858	2725	0.339	0.124	0.215	0.515
0.400	1061	2088	3149	0.396	0.139	0.256	0.656
0.600	1367	2382	3749	0.478	0.159	0.319	0.919
0.800	1597	2563	4160	0.536	0.171	0.365	1.165
1.000	1777	2685	4462	0.579	0.179	0.400	1.400
1.200	1921	2773	4694	0.613	0.185	0.427	1.627
1.500	2091	2867	4958	0.651	0.191	0.460	1.960
1.800	2221	2933	5155	0.680	0.196	0.484	2.284
2.100	2325	2983	5308	0.703	0.199	0.504	2.604
2.500	2434	3032	5466	0.726	0.202	0.524	3.024

Figure C



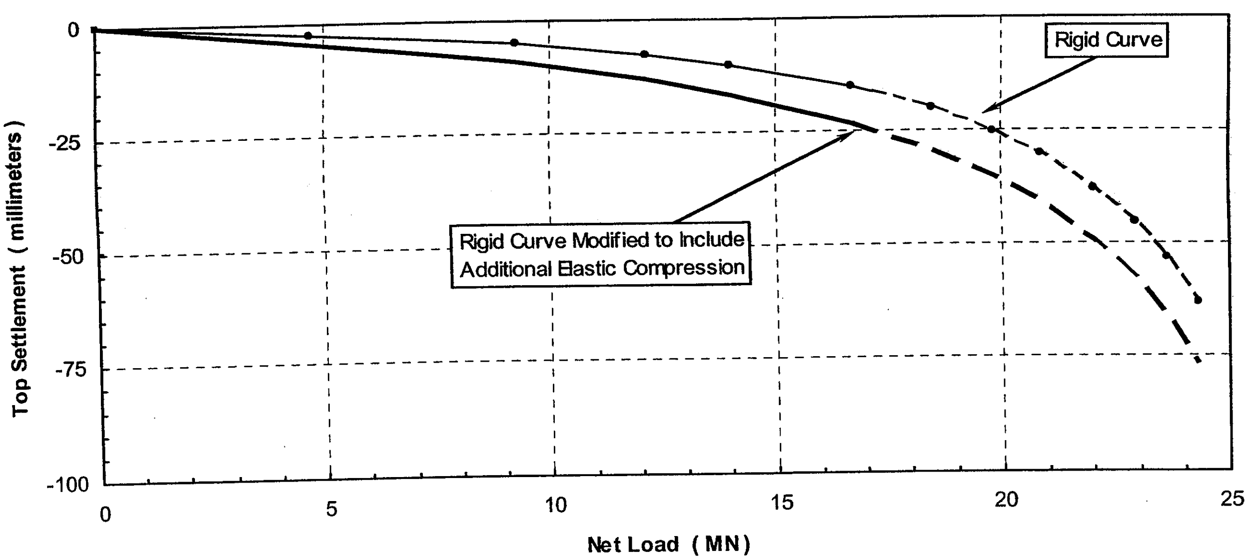
Example Calculation for the Additional Elastic Compression Correction For Single Level Test (SI Units)

Given:

C_1	=	0.441	
AE	=	17,000	MN (assumed constant throughout test)
I_0	=	1.80	m
I_1	=	14.69	m (embedded length of shaft above mid-cell)
I_2	=	0.00	m
I_3	=	0.0	m
Shear reduction factor	=	1.00	(cohesive soil)

Δ_{OLT} (mm)	$Q'_{\downarrow A}$ (MN)	$Q'_{\uparrow A}$ (mm)	P (MN)	δ_{TLT} (mm)	δ_{OLT} (mm)	Δ_δ (mm)	$\Delta_{OLT} + \Delta_\delta$ (mm)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.54	1.57	3.14	4.71	3.37	1.20	2.17	4.71
5.08	2.82	6.43	9.25	6.52	2.45	4.07	9.15
7.62	3.86	8.27	12.12	8.61	3.15	5.46	13.08
10.16	4.72	9.29	14.01	10.05	3.54	6.51	16.67
15.24	6.08	10.60	16.68	12.14	4.04	8.10	23.34
20.32	7.11	11.40	18.50	13.60	4.34	9.26	29.58
25.40	7.90	11.94	19.85	14.70	4.55	10.15	35.55
30.48	8.55	12.33	20.88	15.55	4.70	10.85	41.33
38.10	9.30	12.75	22.05	16.53	4.86	11.67	49.77
45.72	9.88	13.05	22.93	17.27	4.97	12.29	58.01
53.34	10.34	13.27	23.61	17.84	5.06	12.79	66.13
63.50	10.83	13.48	24.31	18.44	5.14	13.30	76.80

Figure D



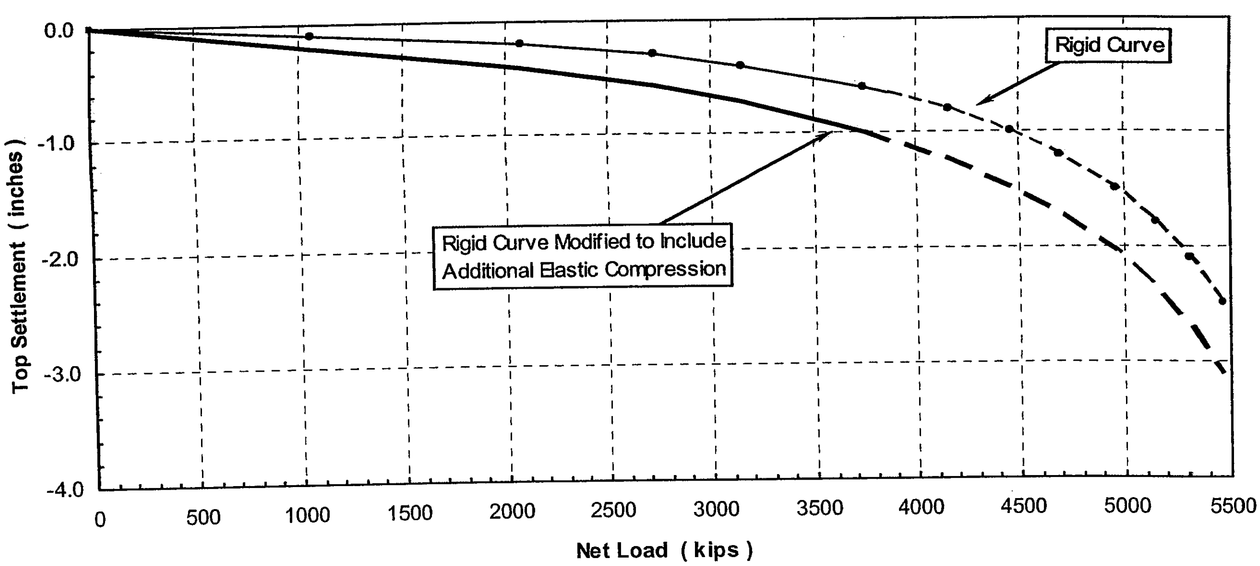
Example Calculation for the Additional Elastic Compression Correction For Multi Level Test (English Units)

Given:

C_1	=	0.441	
C_2	=	0.579	
C_3	=	0.396	
AE	=	3,820,000	kips (assumed constant throughout test)
I_0	=	5.9	ft
I_1	=	30.0	ft (embedded length of shaft above mid-cell)
I_2	=	18.2	ft (embedded length of shaft between O-cells)
I_3	=	0.0	ft
Shear reduction factor	=	1.00	(cohesive soil)

Δ_{OLT} (in)	$Q'_{\downarrow A}$ (kips)	$Q'_{\downarrow B}$ (kips)	$Q'_{\uparrow A}$ (kips)	P (kips)	δ_{TLT} (in)	δ_{OLT} (in)	Δ_δ (in)	$\Delta_{OLT} + \Delta_\delta$ (in)
0.000	0	0	0	0	0.000	0.000	0.000	0.000
0.100	352	247	459	1058	0.133	0.025	0.107	0.207
0.200	635	506	939	2080	0.257	0.052	0.205	0.405
0.300	867	650	1208	2725	0.339	0.067	0.272	0.572
0.400	1061	731	1357	3149	0.396	0.075	0.321	0.721
0.600	1367	834	1548	3749	0.478	0.085	0.393	0.993
0.800	1597	897	1666	4160	0.536	0.092	0.444	1.244
1.000	1777	940	1745	4462	0.579	0.096	0.483	1.483
1.200	1921	971	1802	4694	0.613	0.099	0.513	1.713
1.500	2091	1003	1864	4958	0.651	0.103	0.548	2.048
1.800	2221	1027	1907	5155	0.680	0.105	0.575	2.375
2.100	2325	1044	1939	5308	0.703	0.107	0.596	2.696
2.500	2434	1061	1971	5466	0.726	0.109	0.618	3.118

Figure E



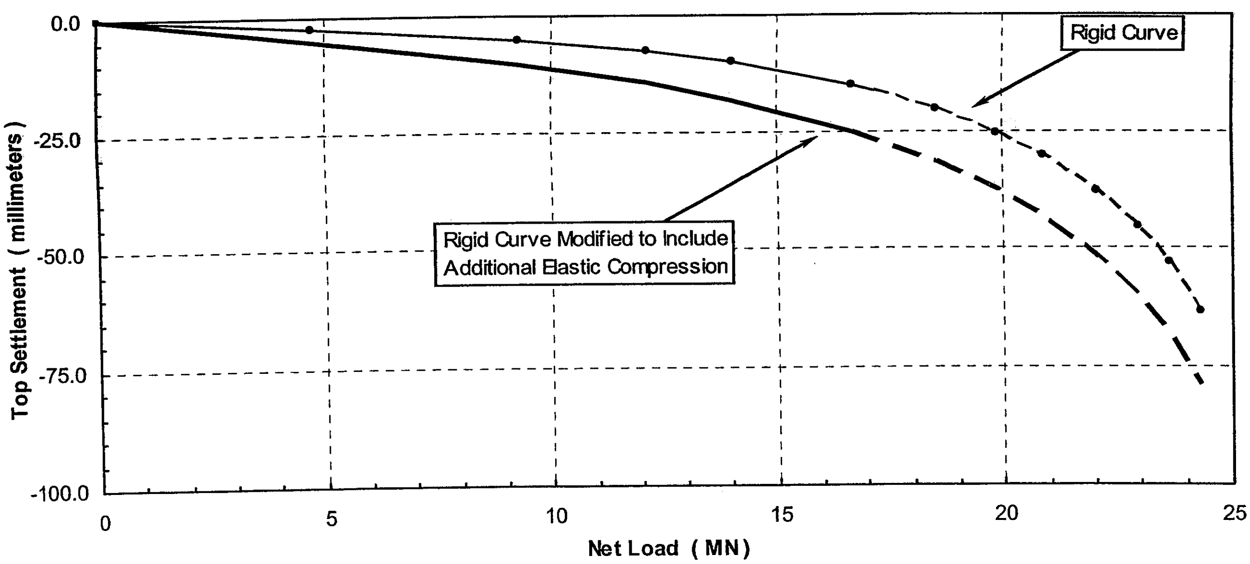
Example Calculation for the Additional Elastic Compression Correction For Multi Level Test (SI Units)

Given:

C_1	=	0.441	
C_2	=	0.579	
C_3	=	0.396	
AE	=	17,000	MN (assumed constant throughout test)
I_0	=	1.80	m
I_1	=	9.14	m (embedded length of shaft above mid-cell)
I_2	=	5.55	m (embedded length of shaft between O-cells)
I_3	=	0.00	m
Shear reduction factor	=	1.00	(cohesive soil)

Δ_{OLT} (mm)	$Q'_{\downarrow A}$ (MN)	$Q'_{\downarrow B}$ (MN)	$Q'_{\uparrow B}$ (mm)	P (MN)	δ_{TLT} (mm)	δ_{OLT} (mm)	Δ_δ (mm)	$\Delta_{OLT} + \Delta_\delta$ (mm)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.54	1.57	1.10	2.04	4.71	3.37	0.64	2.73	5.27
5.08	2.82	2.25	4.18	9.25	6.52	1.31	5.21	10.29
7.62	3.86	2.89	5.37	12.12	8.61	1.69	6.92	14.54
10.16	4.72	3.25	6.04	14.01	10.05	1.90	8.15	18.31
15.24	6.08	3.71	6.89	16.68	12.14	2.17	9.97	25.21
20.32	7.11	3.99	7.41	18.50	13.60	2.33	11.27	31.59
25.40	7.90	4.18	7.76	19.85	14.70	2.44	12.26	37.66
30.48	8.55	4.32	8.02	20.88	15.55	2.52	13.03	43.51
38.10	9.30	4.46	8.29	22.05	16.53	2.61	13.92	52.02
45.72	9.88	4.57	8.48	22.93	17.27	2.67	14.60	60.32
53.34	10.34	4.64	8.62	23.61	17.84	2.71	15.13	68.47
63.50	10.83	4.72	8.76	24.31	18.44	2.76	15.68	79.18

Figure F



APPENDIX D

O-CELL METHOD FOR DETERMINING CREEP LIMIT LOADING

O-CELL METHOD FOR DETERMINING A CREEP LIMIT LOADING ON THE EQUIVALENT TOP-LOADED SHAFT (September, 2000)

Background: O-cell testing provides a sometimes useful method for evaluating that load beyond which a top-loaded drilled shaft might experience significant unwanted creep behavior. We refer to this load as the "creep limit," also sometimes known as the "yield limit" or "yield load".

To our knowledge, Housel (1959) first proposed the method described below for determining the creep limit. Stoll (1961), Bourges and Levillian (1988), and Fellenius (1996) provide additional references. This method also follows from long experience with the pressuremeter test (PMT). Figure 8 and section 9.4 from ASTM D4719-94, reproduced below, show and describe the creep curve routinely determined from the PMT. The creep curve shows how the movement or strain obtained over a fixed time interval, 30 to 60 seconds, changes versus the applied pressure. One can often detect a distinct break in the curve at the pressure P_e in Figure 8. Plastic deformations may become significant beyond this break loading and progressively more severe creep can occur.

Definition: Similarly with O-cell testing using the ASTM Quick Method, one can conveniently measure the additional movement occurring over the final time interval at each constant load step, typically 4 to 8 minutes. A break in the curve of load vs. movement (as at P_e with the PMT) indicates the creep limit.

We usually indicate such a creep limit in the O-cell test for either one, or both, of the side shear and end bearing components, and herein designate the corresponding movements as M_{CL1} and M_{CL2}. We then combine the creep limit data to predict a creep limit load for the equivalent top loaded shaft.

Procedure if both M_{CL1} and M_{CL2} available: Creep cannot begin until the shaft movement exceeds the M_{CL} values. A conservative approach would assume that creep begins when movements exceed the lesser of the M_{CL} values. However, creep can occur freely only when the shaft has moved the greater of the two M_{CL} values. Although less conservative, we believe the latter to match behavior better and therefore set the creep limit as that load on the equivalent top-loaded movement curve that matches the greater M_{CL}.

Procedure if only M_{CL1} available: If we cannot determine a creep limit in the second component before it reaches its maximum movement M_x, we treat M_x as M_{CL2}. From the above method one can say that the creep limit load exceeds, by some unknown amount, that obtained when using $M_{CL2} = M_x$.

Procedure if no creep limit observed: Then, according to the above, the creep limit for the equivalent top-loaded shaft will exceed, again by some unknown amount, that load on the equivalent curve that matches the movement of the component with the maximum movement.

Limitations: The accuracy in estimating creep limits depends, in part, on the scatter of the data in the creep limit plots. The more scatter, the more difficult to define a limit. The user should make his or her own interpretation if he or she intends to make important use of the creep limit interpretations. Sometimes we obtain excessive scatter of the data and do not attempt an interpretation for a creep limit and will indicate this in the report.

Excerpts from ASTM D4719
"Standard Test Method for Pressuremeter Testing in Soils"

9.4 For Procedure A, plot the volume increase readings (V_{60}) between the 30 s and 60 s reading on a separate graph. Generally, a part of the same graph is used, see Fig. 8. For Procedure B, plot the pressure decrease reading between the 30 s and 60 s reading on a separate graph. The test curve shows an almost straight line section within the range of either low volume increase readings (V_{60}) for Procedure A or low pressure decrease for Procedure B. In this range, a constant soil deformation modulus can be measured. Past the so-called creep pressure, plastic deformations become prevalent.

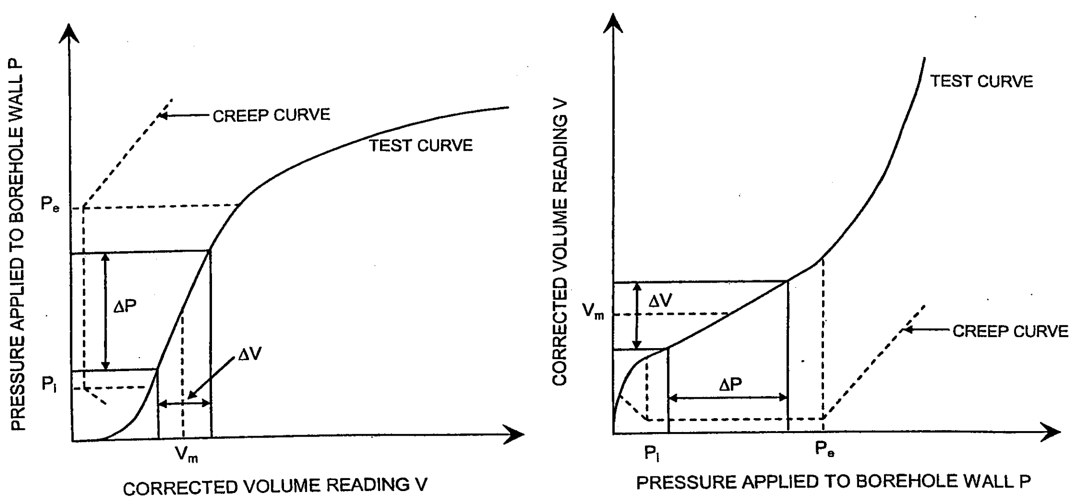


FIG. 8 Pressuremeter Test Curves for Procedure A

References

Housel, W.S. (1959), "Dynamic & Static Resistance of Cohesive Soils", ASTM STP 254, pp. 22-23.

Stoll, M.U.W. (1961, Discussion, Proc. 5th ICSMFE, Paris, Vol. III, pp. 279-281.

Bourges, F. and Levillian, J-P (1988), "force portante des rideaux plans metalliques charges verticalmement," Bull. No. 158, Nov.-Dec., des laboratoires des ponts et chaussees, p. 24.

Fellenius, Bengt H. (1996), Basics of Foundation Design, BiTech Publishers Ltd., p.79.

APPENDIX E

SOIL BORING LOG

BORING LOG No. TB 1

BORING NO.	LOCATION OF BORING	ELEVATION	DATUM	DRILLER	LOGGER
TB 1	Test Shaft by North Abutment	569.07 feet	Survey Stake	DAH	AMS

WATER LEVEL OBSERVATIONS				TYPE OF SURFACE	DRILL RIG
WHILE DRILLING	END OF DRILLING	24 HOURS AFTER DRILLING		Bare Soil	B-57
				DRILLING METHOD	TOTAL DEPTH
N/A	N/A	N/A		3.25" HSA and NQ2 Coring	47 feet

DEP. FT.	SAMPLE NO. & TYPE	"N" BLOWS (FT)	% REC.	COLOR, MOISTURE, CONSISTENCY / GEOLOGIC DESCRIPTION & OTHER REMARKS	USCS CLASS.	% MC	DRY DENS. pcf	Qu psi	DEP. FT.
				Dark gray and dark brown, Damp to moist LEAN CLAY	CL				
3	S1	20				19.2			3
				FILL — 4.0'					
				Dark gray, Moist LEAN CLAY with sand					
6									6
	S2	11		Dark brown below 7 feet		14.2			
9	S3	9			CL	19.9			9
12									12
				ALLUVIUM — 13.0'					
	S4	50/2"		Brown, Wet, MODERATELY WEATHERED LIMESTONE		11.6 9.1	139	3,860	
				Minor joints below 13.94 feet MISSISSIPPIAN BEDROCK — 14.1'		9.6	136	9,640	
15	NQ2-1		92	Light gray, Moist FRESH LIMESTONE RQD of Run 1 = 0.79					15
				Minor joints near 16.20 feet MISSISSIPPIAN BEDROCK — 16.4'					
				Light gray, Moist CALCAREOUS SANDSTONE		9.9	133	5,000	
18						7.6	142	6,980	18
	NQ2-2		100	RQD of Run 2 = 0.83					
				MISSISSIPPIAN BEDROCK — 20.7'					
21				Light gray and tan, Moist MODERATELY FRACTURED LIMESTONE with weathered shale inclusions		0.9	164	8,160	21
				MISSISSIPPIAN BEDROCK — 22.0'					
				Gray, Moist FRESH LIMESTONE 1" inclusions between 22.8 and 23.5 feet		3.1	158	7,780	
24				RQD of Run 3 = 0.93					24
	NQ2-3		108						

GSI Geotechnical Services, Inc.
2853 99th Street, Des Moines, IA 50322
(515) 270-6542 FAX (515) 270-1911

PROJECT: Test Shaft Location Investigation
LOCATION: Highway 1 at Des Moines River, Keosauqua, IA
JOB NO.: 066052
DATE: 3-7-2006

BORING LOG No. TB 1

BORING NO.	LOCATION OF BORING	ELEVATION	DATUM	DRILLER	LOGGER
TB 1	Test Shaft by North Abutment	569.07 feet	Survey Stake	DAH	AMS

WATER LEVEL OBSERVATIONS

WHILE DRILLING	END OF DRILLING	24 HOURS AFTER DRILLING	
N/A	N/A	N/A	

TYPE OF SURFACE	DRILL RIG
Bare Soil	B-57

DRILLING METHOD	TOTAL DEPTH
3.25" HSA and NQ2 Coring	47 feet

DEP. FT.	SAMPLE NO. & TYPE	"N" BLOWS (FT)	% REC.	SOIL DESCRIPTION: COLOR, MOISTURE, CONSISTENCY / GEOLOGIC DESCRIPTION & OTHER REMARKS	USCS CLASS.	% MC	DRY DENS. pcf	Qu psi	DEP. FT.
				Minor joints and dark gray weathered shale seams between 25.7 and 26.5 feet					
27									27
						2.5	160	6,150	
				Moderately jointed between 28.5 and 29.5 feet					
				RQD of Run 4 = 1.02					
30	NQ2-4		108			3.5	153	6,890	30
				Pale green mottled between 30 and 31 feet					
						2.8	152	5,490	
				Light gray and tan grains mixed between 32 and 37 feet					
33									33
				Dark gray shale seams between 33.30 and 33.80 feet					
				RQD of Run 5 = 0.92					
	NQ2-5		95						
						1.4	160	2,460	
36									36
						4.6	149	5,280	
				MISSISSIPPIAN BEDROCK — 37.0'					
				Light gray, Moist HEAVILY JOINTED LIMESTONE					
39									39
				RQD of Run 6 = 0.37					
	NQ2-6		88	MISSISSIPPIAN BEDROCK — 39.3'					
				Dark gray, Moist MODERATELY WEATHERED CLAY SHALE					
42				MISSISSIPPIAN BEDROCK — 42.0'					42
				Dark gray, Moist FRESH CLAY SHALE					
				Light gray fresh limestone between 43.35 and 43.95 feet		3.9	157	5,040	
				RQD of Run 7 = 0.98					
45	NQ2-7		95			8.9	139	360	45
				MISSISSIPPIAN BEDROCK — 47.0'					
				Bottom of Boring @ 47'					
48									48

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PROJECT: Test Shaft Location Investigation
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JOB NO.: 066052
DATE: 3-7-2006

APPENDIX F

NET UNIT SHEAR CURVES AND UNIT END BEARING CURVE

INCREMENTAL CURVES OF UNIT SIDE SHEAR VS. UPWARD SHAFT MOVEMENT

Engineers generally find that an estimate of unit side shear stress versus displacement is a useful deep foundation design parameter. Typically we will report these values for various shaft zones versus O-cell bearing plate displacement. In cases where significant movements occur and the ultimate capacity is approached, the displacement of each shear zone is very close to the measured O-cell plate movement. However, in cases with minimal movement, O-cell bearing plate displacement is primarily due to elastic compression of the shaft. In these cases, a more refined analysis is warranted to estimate the average displacement of each respective shear zone noting that the shear zone adjacent to the O-cell will displace more than subsequent zones. Plotting the unit shear values against the average shear zone displacement is more representative of the actual unit shear versus movement characteristics of the tested shaft.

The figure(s) in this Appendix provide information about the progressive mobilization of unit side shear stress as it developed during the upward shear movement between the shaft and the soil above the O-cell. Separate curves provide this information for the following shaft zones: Between the O-cell and the closest level of strain gages that provided usable data, between the levels of strain gages that provided usable data, and between the highest strain gage level with usable data and the level above which the side shear becomes negligible.

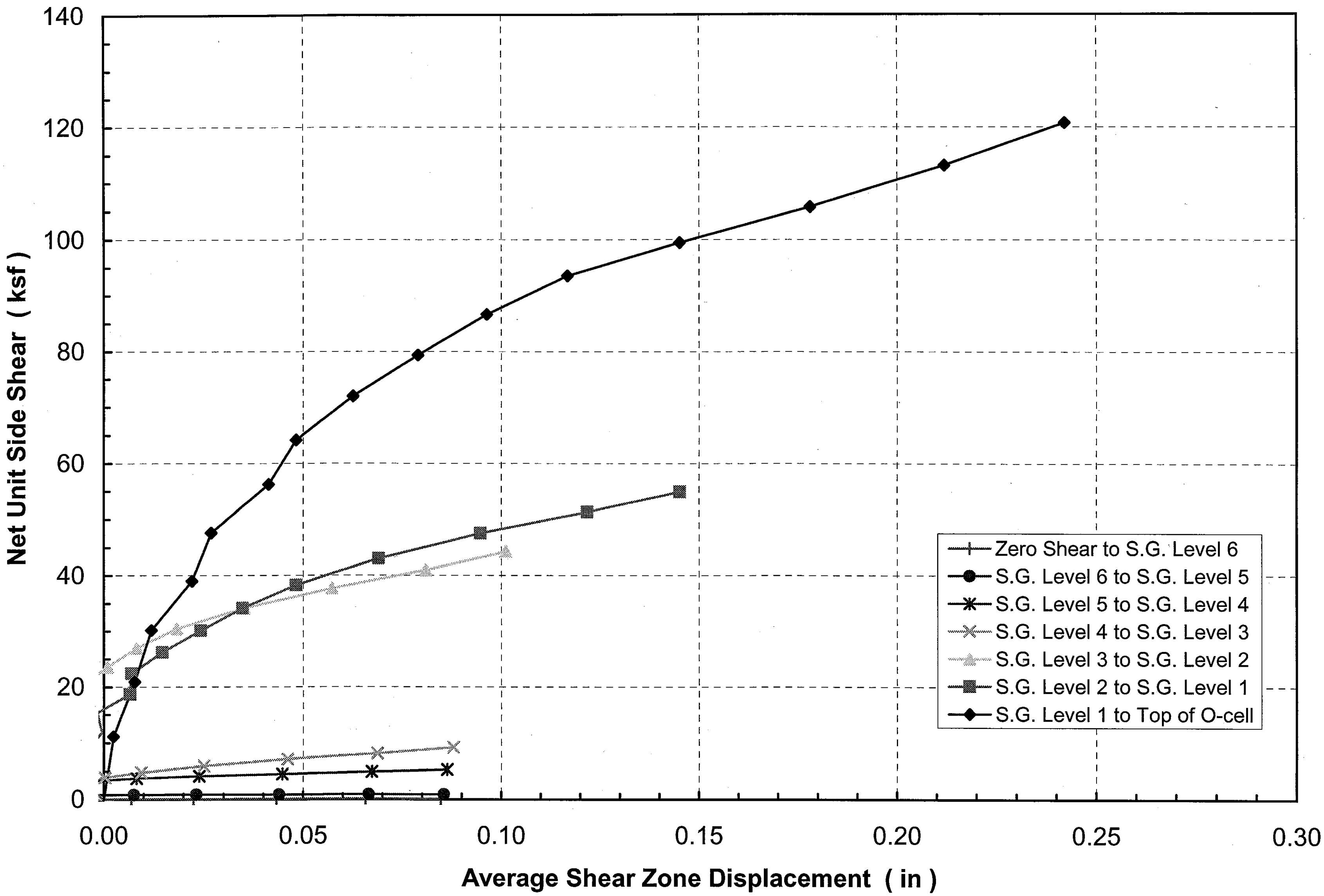
Our analysis assumes an average, constant unit side shear resistance along the above shaft zones, and that the movement represents the average for that zone.

The analysis uses the measured upward cell movement, the measured total elastic compression of the shaft, and with the computed elastic compression over each zone corrected to match the measured total. We also assume that the ground surface beside the shaft heaves only a negligible amount, and report the net unit side shears after correcting for the self weight of each respective shaft zone.

Based on tests and FE modeling, we suggest that the upward shear mobilization curves herein from the O-cell test also apply, approximately, to the downward movement shear mobilization from conventional top compression loading. We suggest a 0.95 shear correction factor for cohesionless soils. For top tension loading we suggest a 0.80 factor for all soils.

Net Unit Side Shear Curves

Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA



Unit End Bearing

Test Shaft #1 - Hwy 1 over Des Moines River - Keosauqua, IA