DATA REPORT ON DRILLED SHAFT LOAD TESTING (OSTERBERG METHOD)

I-235 over UP RR - Polk Co., IA

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

Attention: Mike Kemery
Fax: 641-336-2387

PROJECT NUMBER: LT-8998, February 7, 2004

LOADTEST INC.

Head Office:
2631-D NW 41st Street, Gainesville, Florida 32606
Telephone: (352) 378-3717, 1-800-368-1138
Fax: (352) 378-3934

Regional Offices:
785 The Kingsway, Peterborough, Ontario, Canada K9J 6W7
Telephone: (705) 749-0076
Fax: (705) 743-6854

5420 S. Klee Mill Road, Ste. 4, Sykesville, Maryland 21784
Telephone: (410) 552-1979, 1-800-436-2355
Fax: (410) 552-1843

February 7, 2004

Longfellow Drilling
1209 County Highway J23
Clearfield, IA 50840

Attention: Mike Kemery

Data Report: I-235 over UP RR - Polk Co., IA
Location: Test Shaft 1

The enclosed report contains the data and analysis summary for the O-cell™ test performed on production Test Shaft 1 (LTI project LT-8998) on February 3, 2004. For your convenience, we have included an executive summary of the test results in addition to our standard detailed data report.

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

Best Regards,

D. Tilson
for Robert Simpson
For LOADTEST, Inc.

EXECUTIVE SUMMARY

Loadtest Inc. tested a 48-inch (1,220-mm) production shaft on February 3, 2004. The shaft was constructed by Longfellow Drilling on January 23, 2004. Mr. Denton Kort and John Graman of LOADTEST, Inc. carried out the test. Longfellow Drilling excavated the 79.33 feet (24.18 meters) long shaft under polymer slurry. Excavation proceeded by employing a 54-inch (1,370-mm) O.D. temporary surface casing to stabilize the upper soils. An auger was used for drilling the shaft and the shaft bottom was cleaned with a clean-out bucket. After allowing the shaft to sit for one hour, a final cleanout was performed by air lift. After base cleaning and installation of the reinforcing and O-cell™ assembly, concrete was delivered into the base of the shaft through a tremie pipe. The temporary casing was removed when the concrete level approached cut-off. The Iowa Department of Transportation observed construction of the shaft.

The maximum bi-directional load applied to the shaft was 4793 kips (21.3 MN). At the maximum load, the displacements above and below the O-cell were 0.14 inches (3.5 mm) and 1.16 inches (29.5 mm), respectively. Average unit shear data calculated from strain gages included a maximum calculated net unit side shear of 7.47 ksf (358 kPa), occurring between the Level 1 Strain Gages and the O-cell. Using this maximum side shear value, we calculate a corrected maximum applied end bearing pressure of 176 ksf (8,440 kPa).

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.

TABLE OF CONTENTS

SITE CONDITIONS AND SHAFT CONSTRUCTION

Site Sub-surface Conditions: Boring logs of conditions in the vicinity of the shaft, are presented in Appendix G. The subsurface material consisted primarily of sandy lean clay underlain by clay shale. Detailed geologic information can be obtained from the Iowa Department of Transportation.

Shaft Instrumentation: Test shaft instrumentation and assembly were carried out under the direction of John Graman of LOADTEST Inc. The test assembly included a single 21-inch (530-mm) O-cell™. The base of the O-cell™ assembly was located 2.76 feet (0.84 meters) above the tip of shaft. A pressure vs. load calibration of the O-cell™ was carried out to 2,550 kips (11.3 MN) by American Equipment and Fabricating Corporation prior to delivery to the test site (see Appendix B). Standard O-cell™ instrumentation included three LVWDTs (Linear Vibrating Wire Displacement Transducers - Geokon Model 4450 series) positioned between the lower and upper plates to measure O-cell™ expansion (Appendix A, Page 3 and 4). Two lengths of ½-inch (13 mm) steel pipe (180 degrees opposed) were attached to the test shaft assembly to measure compression of the shaft between the cell and the top of the shaft with traditional telltales that were installed later.

Five levels of two sister bar vibrating wire strain gages were installed in the shaft above the base of the O-cell™ assembly. Details concerning the strain gage placement appear in Table B and Figure A and B. The strain gages were used to assess the side shear load transfer of the shaft above the Osterberg cell. The strain gages were positioned as directed by the Iowa Department of Transportation.

The test shaft assembly also included two lines of steel pipe, starting at the top-of-shaft and terminating at the top of the bottom plate to vent the break in the shaft between upward and downward movement and the resulting annular void. If desired it permits the application of excess fluid pressure to reduce the possibility of soil entering the void. It also provides access for the final grouting to fill the void after completing the testing.

Test Shaft Construction: Longfellow Drilling excavated the production test shaft on January 23, 2004. The shaft was constructed with a total length of 79.33 feet (24.18 meters). The test shaft was constructed wet using polymer to a tip elevation of +734.32 feet (+223.82 meters). Excavation proceeded by employing a 54-inch (1,370-mm) O.D. temporary surface casing to stabilize the upper soils. An auger was used for drilling the shaft and the shaft bottom was cleaned with a clean-out bucket and air lift. After allowing the shaft to sit for one hour, a final cleanout was performed by air lift. After base cleaning and installation of the reinforcing and O-cell™ assembly, concrete was delivered into the base of the shaft through a tremie pipe. The temporary casing was removed when the concrete level approached cut-off. The Iowa Department of Transportation observed construction of the shaft. Table B contains a summary of dimensions, elevations and shaft properties used in the data evaluations.

OSTERBERG CELL TESTING

Test Arrangement: Telltales were provided and inserted from the cell to the top of shaft in pre-installed steel pipe (see above). LVWDTs at the top of shaft were attached to the traditional telltales. An LVWDT attached to a reference beam was provided to measure the top of shaft movement. The reference beam consisted of a 20-foot (6-meter) wide flange beam. The beam was supported at each end by concrete Jersey barriers placed perpendicular to the reference beam. Both ends of the reference beam were free to move horizontally. The beam was fully shaded by a tarp throughout the duration of the test. An automated Leica surveying level (NA3003) was used to monitor the reference beam to a precision of 0.0004 inches (0.01 mm).

Both a Bourdon-type pressure gage (0-10,000 psi) 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 of the movement indicators, LVWDTs and strain gages were connected to a data logger (Data Electronics - Model 615 Datataker®). The logger, in turn was connected to a laptop computer. This arrangement allowed movement indicator, LVWDT, strain gage and thermistor readings to be recorded and stored automatically at 30 second intervals during the test. It also allowed the automatic importation of all test data into a laptop computer for real-time display and additional data back-up. The Leica (NA3003) data was imported in real-time directly to the same lap top computer used to acquire the data logger data.

Note: Required calibrations are included in Appendix B.

Testing Procedures: We applied the load increments using the Quick Load Test Method (ASTM D1143), holding each successive load increment constant for eight minutes by manually adjusting the O-cell™ pressure. We used approximately 15 seconds to move between increments. The data logger automatically recorded the instrument readings every 30 seconds, but herein we report only the one, two, four and eight minute readings during each increment of maintained load. The various plotted results generally use the one, two, four and eight minute readings, but the creep results use the difference between the four and eight minute readings.

As with all our tests, we begin the load test by pressurizing the O-cell™ in order to break the tack welds that hold the cell closed (for handling and construction of 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 test. 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 900 psi (6.21 MPa).

The Osterberg cell load test was conducted as follows: The 21-inch (530-mm) diameter O-cell™, with its base located 2.76 feet (0.84 meters) above the tip of shaft was pressurized to assess the base resistance below the O-cell™ assembly and the side shear above the O-cell™ assembly. The O-cell™ was pressurized in 16 loading increments to 9,600 psi (66.2 MPa) resulting in a bi-directional load of 2,474 kips (11.00 MN). The loading was halted after load interval 1L-16 because O-cell had exceeded its maximum capacity. The O-cell™ was then reloaded in 3 loading increments to a bi-directional O-cell™ load of 1,550 kips (6.89 MN) at 2L-3 in order to demonstrate that no significant weakening of the production shaft occurred as a result of the load test.

TEST RESULTS AND ANALYSES

General: The loads applied by the O-cell™ act in two opposing directions, resisted by side shear above the O-cell™ and by base resistance below the O-cell™. Gross, or applied O-cell™ load is defined as load applied above and below the O-cell™ as calculated from the cell's calibration. Net load is defined as the O-cell™ load minus the buoyant weight of the shaft above the cell for upward movements. Net load is used in this report when analyzing average net unit shear values above the cell and also when reconstructing an equivalent top load curve for top loaded compression shafts. For this test we calculated a buoyant weight of 154 kips (0.69 MN).

The top of shaft movement depends on the reference beam movement. The beam was monitored during the test. The maximum range of movement for the center of the beam was less than 0.01 inches (0.25 mm) over the duration of the test. The top of shaft measurements have therefore not been adjusted herein.

Side Shear Resistance: The maximum upward net load applied to the side shear was 2,320 kips (10.3 MN) which occurred at load interval 1L-16 (Appendix A, Page 3 and 4, Figure 1). At this loading, the total upward movement of the top of O-cell™ assembly was 0.14 inches (3.5 mm). The following net unit side shear estimates are based on the strain gage data which appear in Appendix A, Pages 5 through 8 and the shaft stiffnesses computed below.

At the time of testing, the concrete unconfined compressive strength was estimated to be 3,900 psi (26.9 MPa). We used the ACI formula ($E_c=57{,}000\sqrt{f'c}$) to calculate an elastic modulus for the concrete. This, combined with the area of reinforcing steel, was used to determine a weighted average shaft stiffness of 7,200,000 kips (32,100 MN) for the nominal shaft. The unit stiffnesses vary somewhat throughout the shaft due to diameter and percent steel variations. Therefore different stiffnesses are used when computing load from strain gages. The various stiffnesses are given in Table B. Estimated net unit side shear values for the shaft based on the strain gage data, estimated shaft stiffnesses and shaft area are as follows:

Table A: Net Unit Side Shear Values (Based on Net Loads)

Load Transfer Zone	Direction* of Loading	Load Increment	Net Unit Side* Shear
Top of Shaft to Strain Gage Level 5	↑	1L-16	0.00 ksf (0 kPa)
Strain Gage Level 5 to Strain Gage Level 4	↑	1L-16	1.02 ksf (49 kPa)
Strain Gage Level 4 to Strain Gage Level 3	↑	1L-16	2.61 ksf (125 kPa)
Strain Gage Level 3 to Strain Gage Level 2	↑	1L-16	4.13 ksf (198 kPa)
Strain Gage Level 2 to Strain Gage Level 1	↑	1L-16	8.73 ksf (418 kPa)
O-cell™ to Strain Gage Level 1	↑	1L-16	7.47 ksf (358 kPa)

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

Note: Net unit shear values derived from the strain gages above the O-cell™ assembly may not be ultimate values. See Appendix E for net unit shear vs. displacement plots.

Side shear load distribution curves generated from strain gage data are shown in Figure 3. A unit side shear value for the shaft between the Level 1 Strain Gages and the O-cell™ was calculated for 1L-16 to obtain an estimate of the base shear component of resistance to the downward movement below the O-cell™. Note that the unit side shear below the cell may be slightly higher than that derived from 1L-16 since the upward and downward movements were not the same at the same loads.

Base Resistance: The maximum O-cell™ load applied to the base of the shaft was 2,474 kips (11.00 MN) which occurred at load interval 1L-16 (Appendix A, Page 4, Figure 1). At this loading, the total downward movement of the O-cell™ base was 1.16 inches (29.5 mm). The base resistance includes a small component of base shear which must be subtracted to obtain unit end bearing values. The shear component of resistance for the 2.76 feet (0.84 meter) shaft base below the O-cell™ is calculated to be 259 kips (1.15 MN) assuming a unit side shear value of 7.47 ksf (358 kPa) and a shaft diameter of 48 inches (1220 mm). The applied load to end bearing is then 2215 kips (9.90 MN) and the end-bearing pressure applied at the tip of the shaft is calculated to be 176 ksf (8,440 kPa).

Creep Limit: See Appendix D for our O-cell™ method for determining creep limit. The side shear creep data (Appendix A, Page 3 and 4, Figure 1) indicate that no creep limit was reached at a movement of 0.14 inches (3.5 mm) (Figure 4). The combined end bearing and lower side shear creep data (Appendix A, Page 3 and 4, Figure 1) indicate that a creep limit of 1,480 kips (6.6 MN) was reached at a movement of 0.32 inches (8.1 mm) (Figure 5). A top loaded shaft will begin significant creep when 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 3,820 kips (17.0 MN) by some unknown amount.

Equivalent Top Load: Figure 2 presents the equivalent top load-settlement curve. The unadjusted 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 can be an important component of the settlements involved, the equivalent top load curve includes an adjustment for the additional elastic compression which would occur in a top-load test. The darker curve as described in Procedure Part II of Appendix C includes such an adjustment. It should be noted however, that since the shaft side shear did not approach ultimate the additional movement may be over-estimated by some amount.

The test shaft was successfully loaded to a combined side shear and end bearing of more than 4,800 kips (21.4 MN). For a top loading of 3,210 kips (14.3 MN), the adjusted test data indicate this shaft would settle approximately 0.32 inches (8.2 mm) of which 0.27 inches (6.8 mm) is estimated elastic compression. The equivalent top load curve is shown in Figure 2. Note: as explained previously, the equivalent top load curve applies to a loading duration of eight minutes. Creep effects will reduce the ultimate resistance of both components and increase pile 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 above.

Shaft Compression Comparison: The measured maximum shaft compression, averaged from 2 telltales, is 0.11 inches (2.8 mm). Using the shaft nominal diameters (Table B and Figure A) and a weighted average shaft stiffness of 7,200,000 kips (32,100 MN) for the shaft and the load distribution in Figure 3, we calculated an elastic compression of 0.057 inches (1.4 mm) over the length of the compression telltales. We believe this lack of agreement in conjunction with a measured differential compression indicates a possible small area of poor concrete near the cell. This did not effect the data or analysis herein in any substantive way.

Bottom Plate Tilt: The three LVWDTs measuring O-cell™ expansion allow us to evaluate the tilt of the bottom plate. Appendix A, Page 3 and 4, Figure 1 shows these measurements. We calculate a maximum tilt angle of 0.6 degrees and a total tilt of 0.52 inches (13.6 mm) across the nominal 48-inch (1220-mm) diameter of the bottom of the shaft at the 1L-16 maximum loading.

POST-TEST O-CELL™ GROUTING

Since the test shaft is intended to carry structural loading (a "production shaft"), the contractor needs to fill the annular void in the shaft created outside the cell as a result of the expansion of the cell. The O-cell™ itself should also be filled. The shaft includes the piping to permit filling the O-cell™ and void with grout. If not already grouted, we recommend that this be done as soon as possible according to the procedures in Appendix F.

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. Wilson

for Robert Simpson
For LOADTEST Inc.

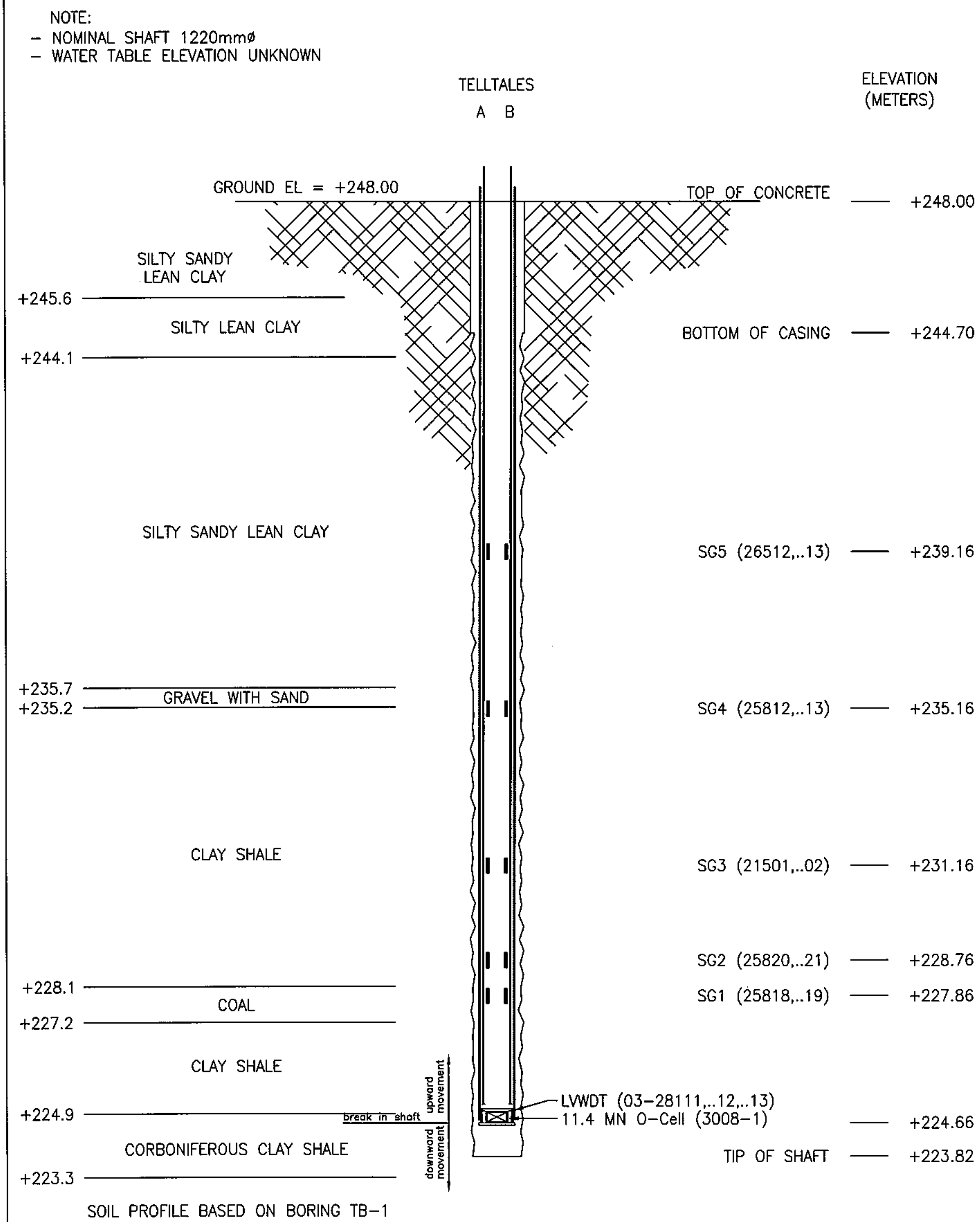
Reviewed by

Anita Cannon

FOR Shing ~~K.~~ K. Pang, P.E.
Geotechnical Engineer / LOADTEST Inc.

TABLE B: SUMMARY OF DIMENSIONS, ELEVATIONS, AREAS & PROPERTIES FOR ANALYSIS PURPOSES

Shaft:		
Nominal shaft diameter: EL 248.16 meters to 244.66 meters	=	1370 mm
Nominal shaft diameter: EL 244.86 meters to 223.82 meters	=	1220 mm
O-cell size: (Serial no.: 3008-1)	=	533 mm
Length of concrete from break at base of cell to tip	=	0.8 meters
Shaft shear area from break at base of cell to tip	=	3.22 $meters^2$
Shaft end area	=	1.17 $meters^2$
Weight of shaft from break at base of cell to top of shaft	=	0.69 MN
Estimated shaft unit stiffness: EL 248.16 meters to 244.66 meters	=	38.6 GN
Estimated shaft unit stiffness: EL 244.86 meters to 237.02 meters	=	33.4 GN
Estimated shaft unit stiffness: EL 237.02 meters to 234.26 meters	=	35.9 GN
Estimated shaft unit stiffness: EL 234.26 meters to 224.66 meters	=	33.4 GN
Elevation of top of shaft concrete	=	+248.00 meters
Elevation of ground surface	=	+248.00 meters
Elevation of break at base of O-cell™	=	+224.66 meters
Elevation of shaft tip	=	+223.82 meters
Elevation of top of temporary casing: 1370 mm O.D.	=	+248.36 meters
Elevation of bottom of temporary casing: 1370 mm O.D.	=	+244.70 meters
Compression Sections:		
Elevation of top of telltale used for shaft compression	=	+248.61 meters
Elevation of bottom of telltale used for shaft compression	=	+225.09 meters
Strain Gages:		
Elevation of strain gage Level 5	=	+239.16 meters
Elevation of strain gage Level 4	=	+235.16 meters
Elevation of strain gage Level 3	=	+231.16 meters
Elevation of strain gage Level 2	=	+228.76 meters
Elevation of strain gage Level 1	=	+227.86 meters
Miscellaneous:		
Top plate diameter	=	953 mm
Top plate thickness	=	50.8 mm
Bottom plate diameter	=	1029 mm
Bottom plate thickness	=	50.8 mm
Water elevation	=	+0.0 meters
LVWDT radii - no: 03-28111	=	521 mm
LVWDT orientation - no.: 03-28111	=	0 degrees
LVWDT radii - no: 03-28112	=	521 mm
LVWDT orientation - no.: 03-28112	=	180 degrees
LVWDT radii - no: 03-28113	=	521 mm
LVWDT orientation - no.: 03-28113	=	270 degrees
Vertical re-bar size	=	T-36
Hoop re-bar size	=	T-15
Number of vertical bars	=	14



LOADTEST INC

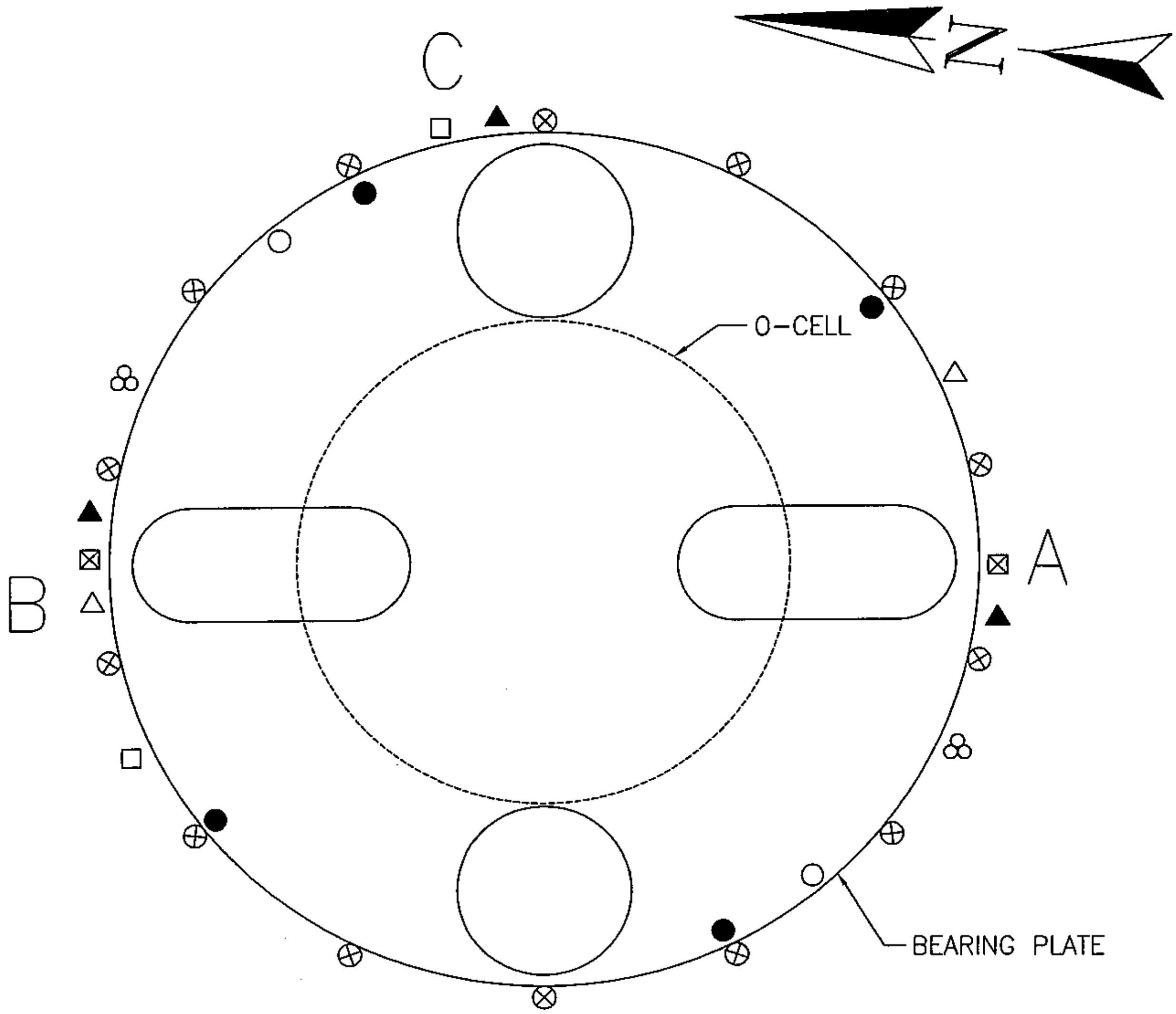
2631-D NW 41st St.
Gainesville, FL 32606
Phone 800-368-1138
FAX 352-378-3934

SCHEMATIC SECTION OF TEST SHAFT

LT-8998
I-235 over UP RR
Polk Co, IA

FIGURE A

2/10/2004 3:09:23 PM



LEGEND:

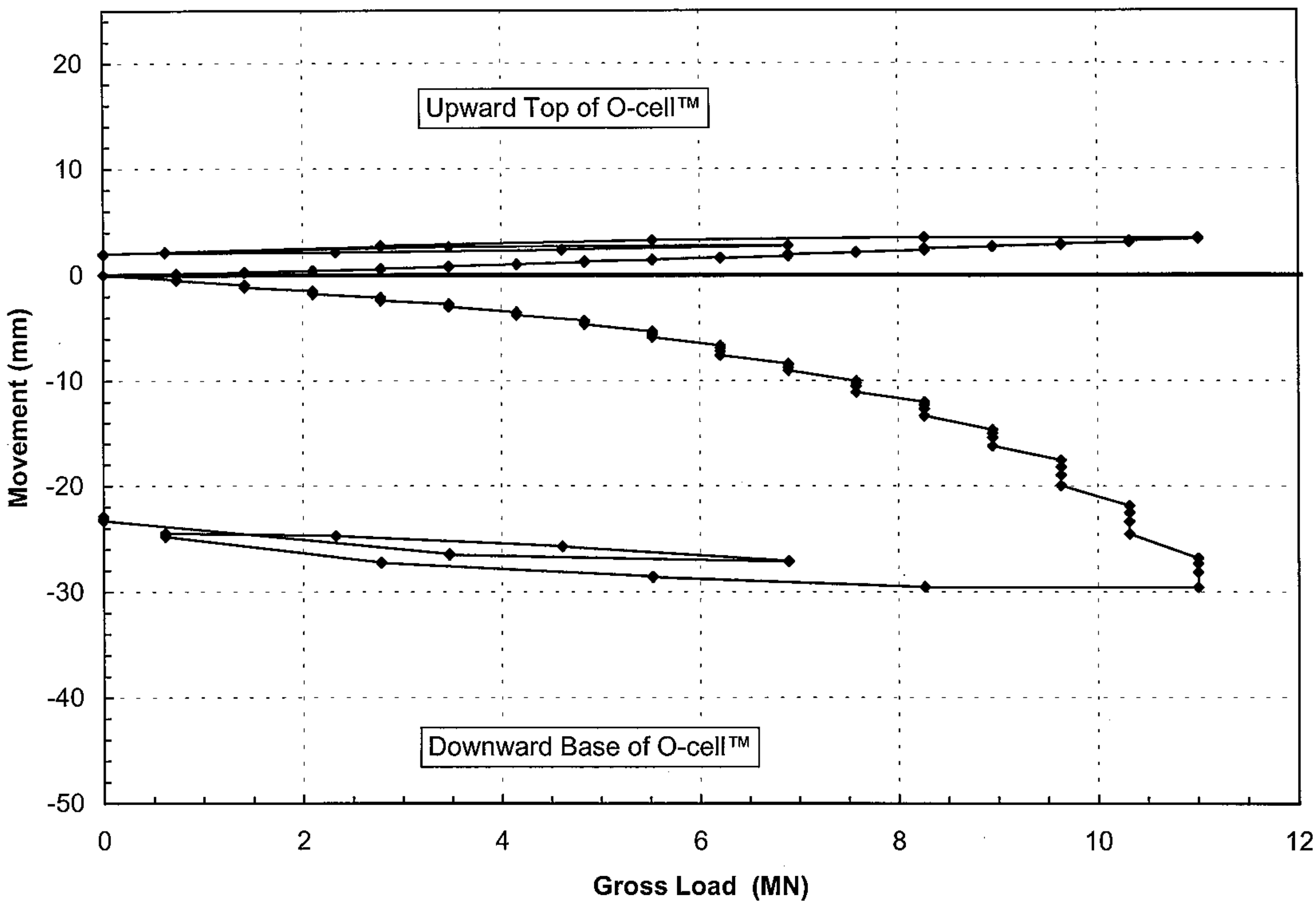
STRAIN GAGE	△
LVWDT	▲
TELLTALE	○
CSL PIPES	●
VENT PIPE	□
HYDRAULIC HOSES	⊠
REBAR	⊗
CABLE BUNDLE	∞

LOADTEST INC.	2631-D NW 41st St. Gainesville, FL 32606 Phone 800-368-1138 FAX 352-378-3934	INSTRUMENTATION LAYOUT	LT-8998 I-235 over UP RR Polk County, IA **FIGURE B**

2/10/2004 10:23:11 AM

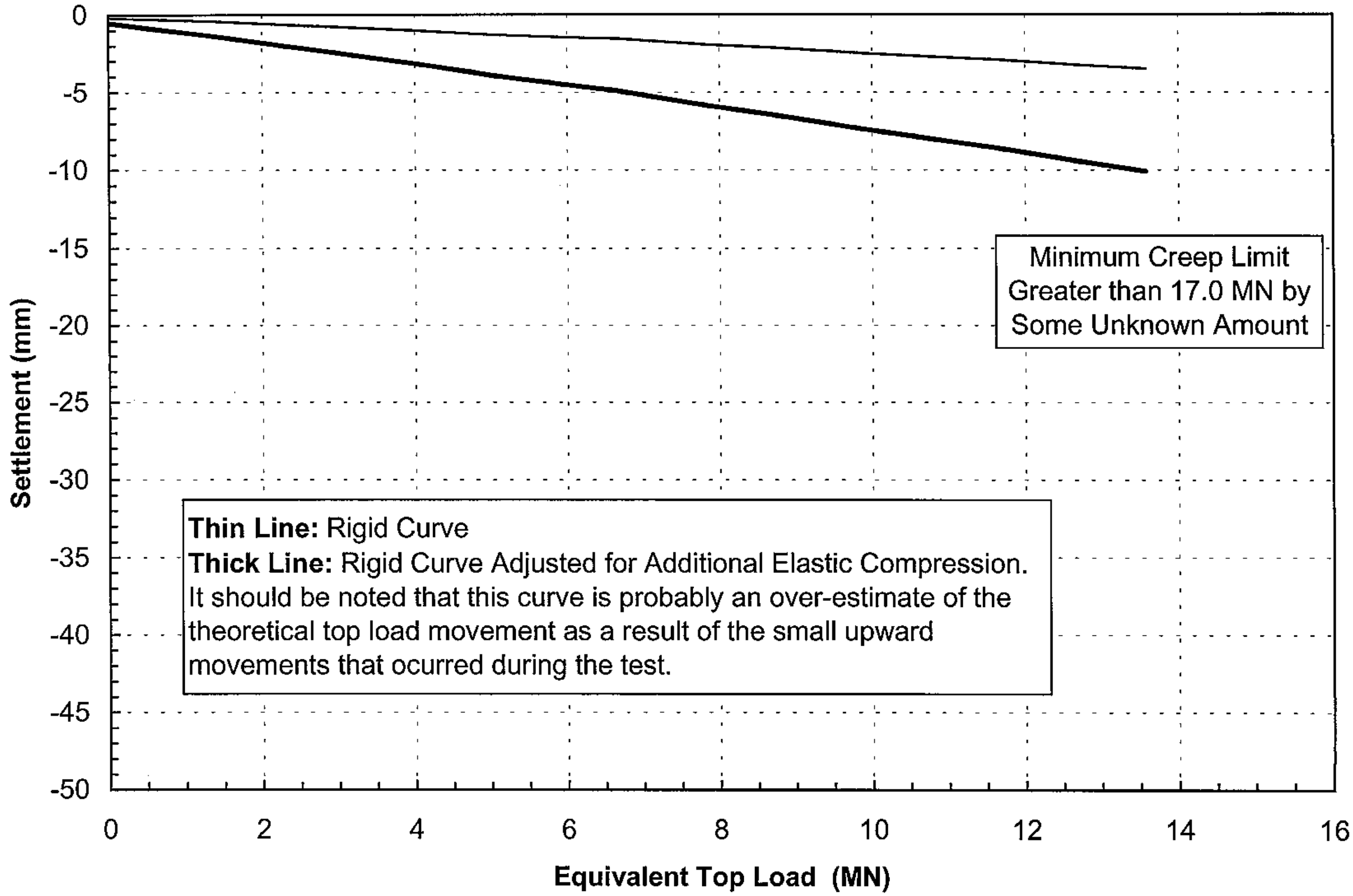
Osterberg Cell Load-Movement Curves

I-235 over UP RR - Polk Co., IA - Test Shaft 1



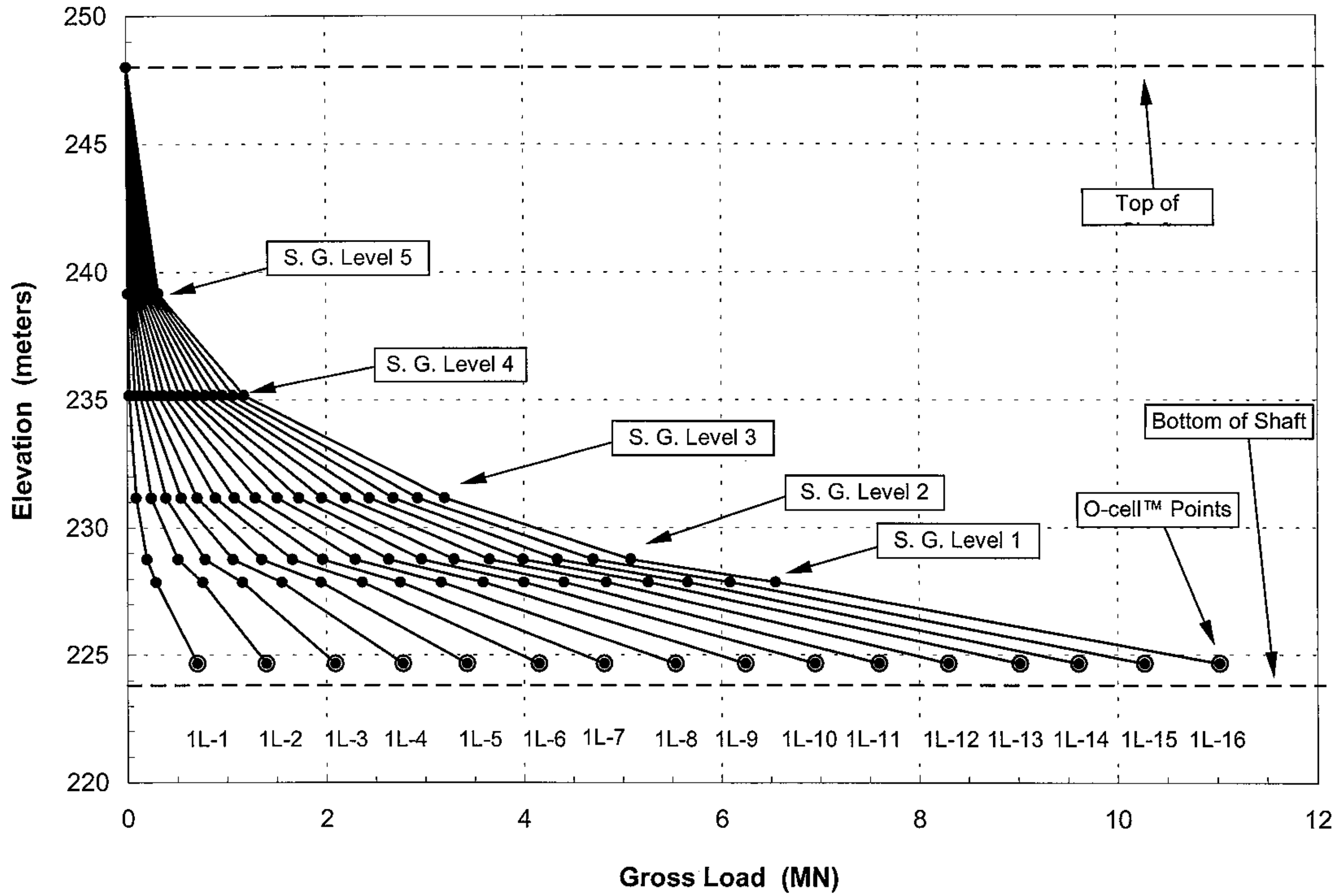
Equivalent Top Load-Movement Curves

I-235 over UP RR - Polk Co., IA - Test Shaft 1



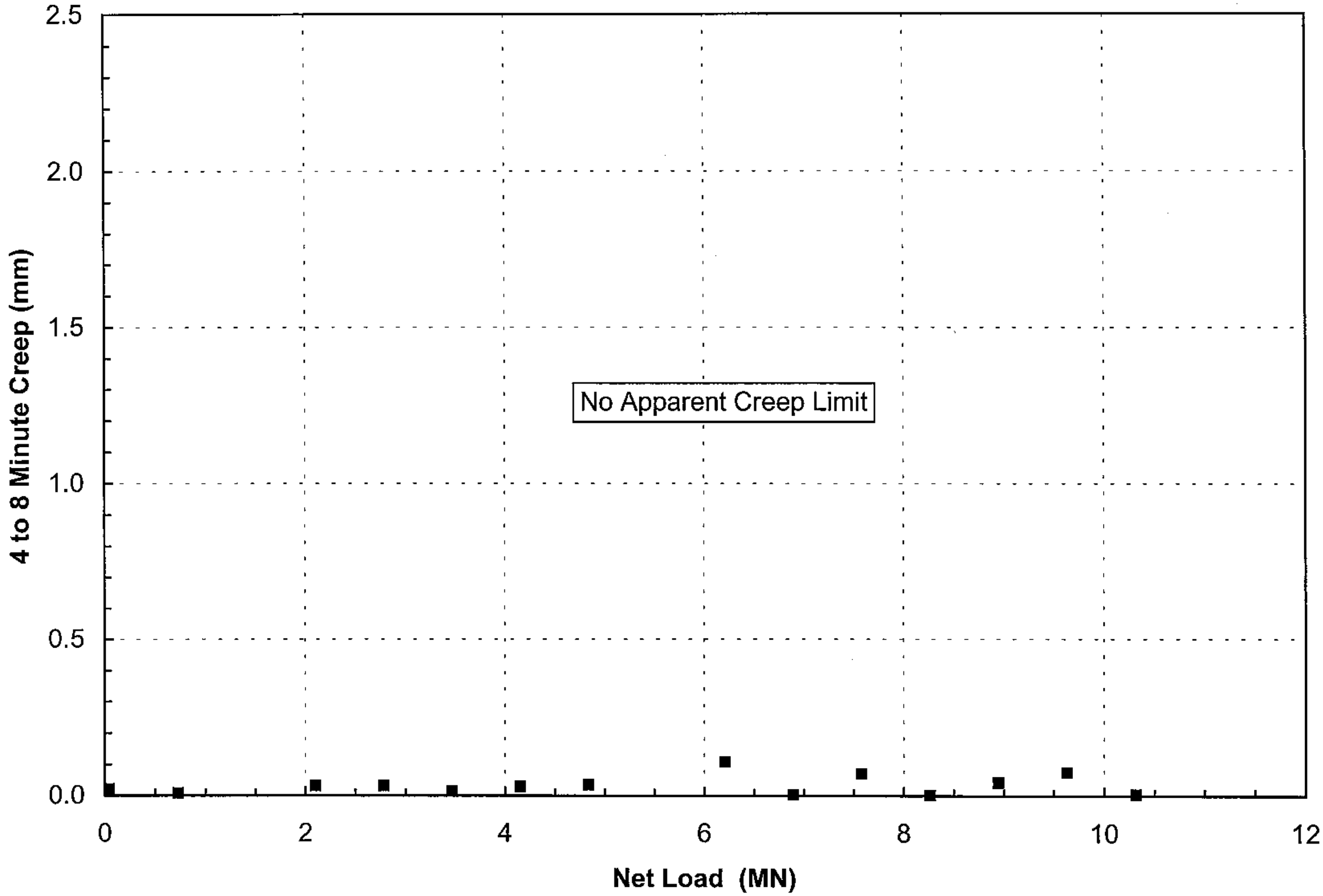
Strain Gage Load Distribution Curves

I-235 over UP RR - Polk Co., IA - Test Shaft 1



Side Shear Creep Limit

I-235 over UP RR - Polk Co., IA - Test Shaft 1

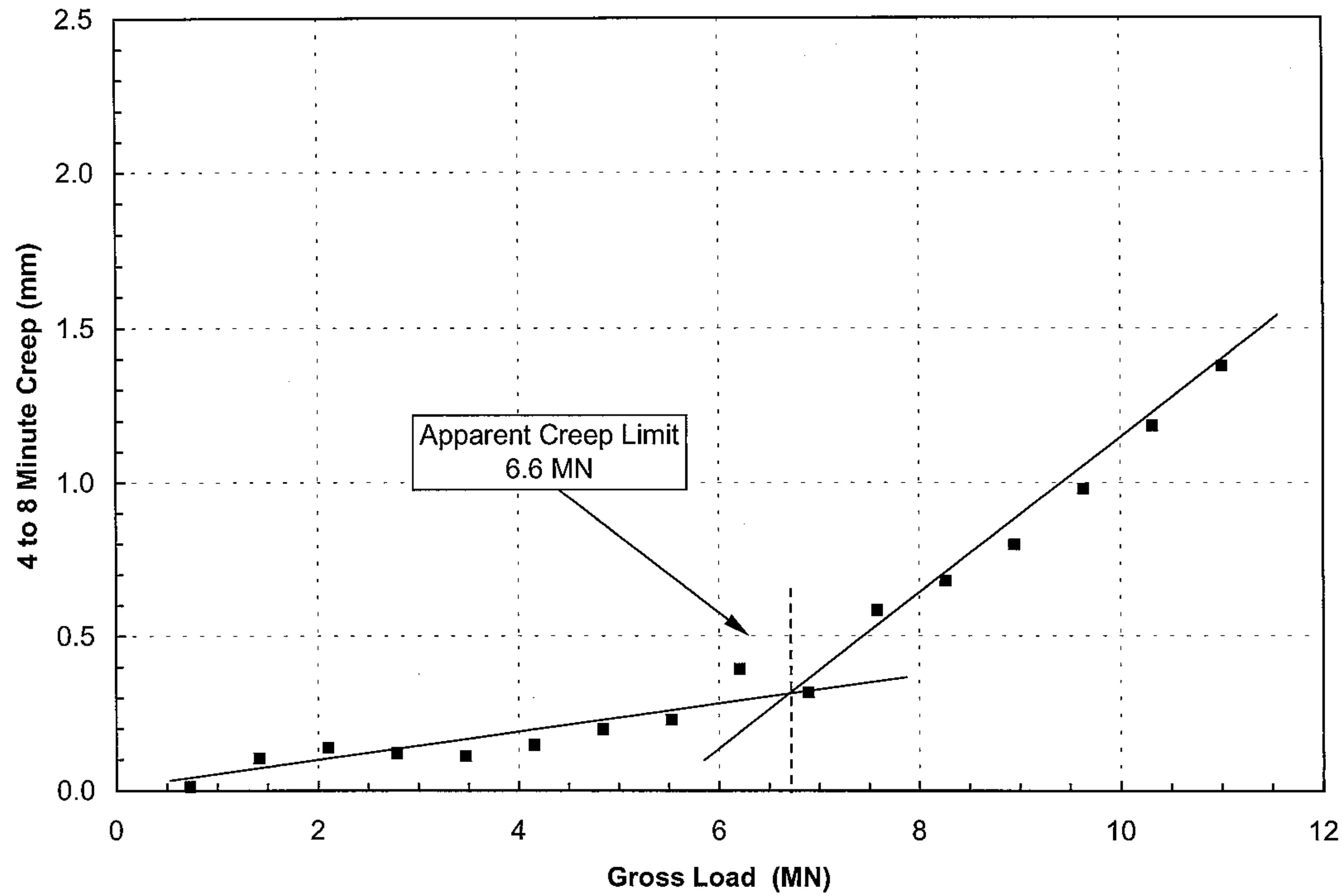


LOADTEST, Inc. Project No. LT-8998

Figure 4 of 5

Base Creep Limit

I-235 over UP RR - Polk Co., IA - Test Shaft 1



LOADTEST, Inc. Project No. LT-8998

Figure 5 of 5

APPENDIX A

FIELD DATA & DATA REDUCTION

Top of Shaft and Compression

I-235 over UP RR - Polk Co., IA - Test Shaft 1

Load Test Increment	Time (h:m:s)	Time After Start Minutes	O-cell™ Pressure (MPa)	Applied Load (MN)	Net Load (MN)	TOS Indicator Readings Side A (mm)	TOS Indicator Readings Average (mm)	Telltale Compression Side A (mm)	Telltale Compression Side B (mm)	Telltale Compression Average (mm)
1L -0	14:52:30	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1L -1	14:57:00	1	4.14	0.73	0.04	0.00	0.00	0.05	0.12	0.08
1L -1	14:58:00	2	4.14	0.73	0.04	0.00	0.00	0.05	0.12	0.08
1L -1	15:00:00	4	4.14	0.73	0.04	0.01	0.01	0.06	0.12	0.09
1L -1	15:04:00	8	4.14	0.73	0.04	0.02	0.02	0.07	0.12	0.09
1L -2	15:06:00	1	8.27	1.41	0.73	0.02	0.02	0.14	0.28	0.21
1L -2	15:07:00	2	8.27	1.41	0.73	0.02	0.02	0.15	0.30	0.22
1L -2	15:09:00	4	8.27	1.41	0.73	0.02	0.02	0.16	0.32	0.24
1L -2	15:13:00	8	8.27	1.41	0.73	0.02	0.02	0.17	0.33	0.25
1L -3	15:14:30	1	12.41	2.10	1.41	0.02	0.02	0.24	0.50	0.37
1L -3	15:15:30	2	12.41	2.10	1.41	0.03	0.03	0.24	0.51	0.37
1L -3	15:17:30	4	12.41	2.10	1.41	0.04	0.04	0.24	0.52	0.38
1L -3	15:21:30	8	12.41	2.10	1.41	0.02	0.02	0.24	0.54	0.39
1L -4	15:23:00	1	16.55	2.78	2.10	0.03	0.03	0.32	0.70	0.51
1L -4	15:24:00	2	16.55	2.78	2.10	0.04	0.04	0.33	0.70	0.52
1L -4	15:26:00	4	16.55	2.78	2.10	0.05	0.05	0.34	0.72	0.53
1L -4	15:30:00	8	16.55	2.78	2.10	0.06	0.06	0.37	0.75	0.56
1L -5	15:32:00	1	20.69	3.47	2.78	0.07	0.07	0.45	0.93	0.69
1L -5	15:33:00	2	20.69	3.47	2.78	0.07	0.07	0.46	0.94	0.70
1L -5	15:35:00	4	20.69	3.47	2.78	0.07	0.07	0.48	0.96	0.72
1L -5	15:39:00	8	20.69	3.47	2.78	0.09	0.09	0.50	0.97	0.74
1L -6	15:41:00	1	24.82	4.15	3.47	0.10	0.10	0.60	1.16	0.88
1L -6	15:42:00	2	24.82	4.15	3.47	0.10	0.10	0.61	1.17	0.89
1L -6	15:44:00	4	24.82	4.15	3.47	0.11	0.11	0.62	1.19	0.90
1L -6	15:48:00	8	24.82	4.15	3.47	0.10	0.10	0.63	1.20	0.92
1L -7	15:50:00	1	28.96	4.84	4.15	0.13	0.13	0.72	1.39	1.05
1L -7	15:51:00	2	28.96	4.84	4.15	0.16	0.16	0.72	1.40	1.06
1L -7	15:53:00	4	28.96	4.84	4.15	0.20	0.20	0.73	1.41	1.07
1L -7	15:57:00	8	28.96	4.84	4.15	0.21	0.21	0.75	1.43	1.09
1L -8	15:59:30	1	33.10	5.52	4.84	0.19	0.19	0.82	1.61	1.22
1L -8	16:00:30	2	33.10	5.52	4.84	0.18	0.18	0.83	1.63	1.23
1L -8	16:02:30	4	33.10	5.52	4.84	0.18	0.18	0.84	1.65	1.24
1L -8	16:06:30	8	33.10	5.52	4.84	0.19	0.19	0.85	1.67	1.26
1L -9	16:09:30	1	37.23	6.21	5.52	0.25	0.25	0.94	1.88	1.41
1L -9	16:10:30	2	37.23	6.21	5.52	0.23	0.23	0.94	1.88	1.41
1L -9	16:12:30	4	37.23	6.21	5.52	0.18	0.18	0.90	1.89	1.39
1L -9	16:16:30	8	37.23	6.21	5.52	0.17	0.17	0.88	1.92	1.40
1L -10	16:18:30	1	41.37	6.89	6.21	0.23	0.23	0.96	2.11	1.54
1L -10	16:19:30	2	41.37	6.89	6.21	0.24	0.24	0.98	2.13	1.55
1L -10	16:21:30	4	41.37	6.89	6.21	0.26	0.26	1.00	2.15	1.57
1L -10	16:25:30	8	41.37	6.89	6.21	0.34	0.34	1.03	2.18	1.61
1L -11	16:27:30	1	45.51	7.58	6.89	0.36	0.36	1.13	2.35	1.74
1L -11	16:28:30	2	45.51	7.58	6.89	0.36	0.36	1.13	2.37	1.75
1L -11	16:30:30	4	45.51	7.58	6.89	0.39	0.39	1.14	2.39	1.76
1L -11	16:34:30	8	45.51	7.58	6.89	0.39	0.39	1.12	2.41	1.76
1L -12	16:36:00	1	49.64	8.26	7.58	0.44	0.44	1.20	2.58	1.89
1L -12	16:37:00	2	49.64	8.26	7.58	0.47	0.47	1.22	2.61	1.92
1L -12	16:39:00	4	49.64	8.26	7.58	0.49	0.49	1.25	2.62	1.93
1L -12	16:43:00	8	49.64	8.26	7.58	0.53	0.53	1.27	2.66	1.97
1L -13	16:45:00	1	53.78	8.95	8.26	0.54	0.54	1.35	2.87	2.11
1L -13	16:46:00	2	53.78	8.95	8.26	0.56	0.56	1.36	2.88	2.12
1L -13	16:48:00	4	53.78	8.95	8.26	0.57	0.57	1.38	2.91	2.15
1L -13	16:52:00	8	53.78	8.95	8.26	0.56	0.56	1.38	2.95	2.16
1L -14	16:53:30	1	57.92	9.63	8.95	0.55	0.55	1.45	3.14	2.30
1L -14	16:54:30	2	57.92	9.63	8.95	0.56	0.56	1.47	3.17	2.32
1L -14	16:56:30	4	57.92	9.63	8.95	0.56	0.56	1.47	3.20	2.33
1L -14	17:00:30	8	57.92	9.63	8.95	0.59	0.59	1.46	3.24	2.35
1L -15	17:02:30	1	62.06	10.32	9.63	0.61	0.61	1.54	3.44	2.49
1L -15	17:03:30	2	62.06	10.32	9.63	0.62	0.62	1.56	3.46	2.51
1L -15	17:05:30	4	62.06	10.32	9.63	0.64	0.64	1.58	3.50	2.54
1L -15	17:09:30	8	62.06	10.32	9.63	0.68	0.68	1.60	3.54	2.57
1L -16	17:12:00	1	66.19	11.00	10.32	0.73	0.73	1.69	3.73	2.71
1L -16	17:13:00	2	66.19	11.00	10.32	0.75	0.75	1.70	3.75	2.73
1L -16	17:15:00	4	66.19	11.00	10.32	0.77	0.77	1.71	3.79	2.75
1L -16	17:19:00	8	66.19	11.00	10.32	0.75	0.75	1.72	3.84	2.78

Top of Shaft and Compression

I-235 over UP RR - Polk Co., IA - Test Shaft 1

Load Test Increment	Time (h:m:s)	Time After Start Minutes	O-cell™ Pressure (MPa)	Applied Load (MN)	Net Load (MN)	TOS Indicator Readings		Telltale Compression		
						Side A (mm)	Average (mm)	Side A (mm)	Side B (mm)	Average (mm)
1U -1	17:21:30	1	49.64	8.26	7.58	0.75	0.75	1.70	3.80	2.75
1U -1	17:22:30	2	49.64	8.26	7.58	0.76	0.76	1.70	3.80	2.75
1U -1	17:24:30	4	49.64	8.26	7.58	0.78	0.78	1.71	3.80	2.75
1U -2	17:26:30	1	33.10	5.52	4.84	0.79	0.79	1.62	3.39	2.51
1U -2	17:27:30	2	33.10	5.52	4.84	0.78	0.78	1.61	3.37	2.49
1U -2	17:29:30	4	33.10	5.52	4.84	0.78	0.78	1.60	3.36	2.48
1U -3	17:32:00	1	16.55	2.78	2.10	0.76	0.76	1.34	2.68	2.01
1U -3	17:33:00	2	16.55	2.78	2.10	0.75	0.75	1.32	2.66	1.99
1U -3	17:35:00	4	16.55	2.78	2.10	0.71	0.71	1.28	2.63	1.95
1U -4	17:37:00	1	3.45	0.62	0.00	0.69	0.69	0.95	1.97	1.46
1U -4	17:38:00	2	3.45	0.62	0.00	0.69	0.69	0.94	1.93	1.43
1U -4	17:40:00	4	3.45	0.62	0.00	0.69	0.69	0.91	1.87	1.39
2L -1	17:43:00	1	13.79	2.33	1.64	0.71	0.71	0.95	1.89	1.42
2L -1	17:44:00	2	13.79	2.33	1.64	0.72	0.72	0.97	1.90	1.43
2L -1	17:46:00	4	13.79	2.33	1.64	0.71	0.71	0.97	1.88	1.43
2L -2	17:48:00	1	27.58	4.61	3.92	0.71	0.71	1.07	2.23	1.65
2L -2	17:49:00	2	27.58	4.61	3.92	0.72	0.72	1.07	2.24	1.66
2L -2	17:51:00	4	27.58	4.61	3.92	0.74	0.74	1.07	2.25	1.66
2L -3	17:53:30	1	41.37	6.89	6.21	0.75	0.75	1.26	2.74	2.00
2L -3	17:54:30	2	41.37	6.89	6.21	0.75	0.75	1.27	2.75	2.01
2L -3	17:56:30	4	41.37	6.89	6.21	0.76	0.76	1.30	2.75	2.03
2U -1	17:58:30	1	20.69	3.47	2.78	0.76	0.76	1.23	2.59	1.91
2U -1	17:59:30	2	20.69	3.47	2.78	0.76	0.76	1.23	2.59	1.91
2U -1	18:01:30	4	20.69	3.47	2.78	0.76	0.76	1.23	2.58	1.90
2U -2	18:03:00	1	0.00	0.00	0.00	0.77	0.77	0.84	1.61	1.23
2U -2	18:04:00	2	0.00	0.00	0.00	0.77	0.77	0.82	1.56	1.19
2U -2	18:06:00	4	0.00	0.00	0.00	0.75	0.75	0.78	1.53	1.15

O-cell™ Expansion and Upward and Downward Movement

I-235 over UP RR - Polk Co., IA - Test Shaft 1

Load Test Increment	Time 0 (h:m:s)	Time After Start Minutes	O-cell™ Pressure (MPa)	Applied Load (MN)	Net Load (MN)	LVWDT Readings (Expansion)* 03-28111 (mm)	03-28112 (mm)	03-28113 (mm)	Average (mm)	Top of O-cell Movement (mm)	Upward Creep (mm)	Bottom of O-cell Movement (mm)	Downward Creep (mm)
1L -0	14:52:30	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	
1L -1	14:57:00	1	4.14	0.73	0.04	0.53	0.52	0.39	0.52	0.08		-0.44	
1L -1	14:58:00	2	4.14	0.73	0.04	0.56	0.55	0.40	0.55	0.08		-0.47	
1L -1	15:00:00	4	4.14	0.73	0.04	0.59	0.58	0.41	0.58	0.09		-0.49	
1L -1	15:04:00	8	4.14	0.73	0.04	0.62	0.62	0.43	0.62	0.12	0.02	-0.50	0.01
1L -2	15:06:00	1	8.27	1.41	0.73	1.07	1.25	0.82	1.16	0.23		-0.93	
1L -2	15:07:00	2	8.27	1.41	0.73	1.13	1.35	0.87	1.24	0.25		-1.00	
1L -2	15:09:00	4	8.27	1.41	0.73	1.20	1.47	0.91	1.33	0.26		-1.07	
1L -2	15:13:00	8	8.27	1.41	0.73	1.28	1.61	0.97	1.45	0.27	0.01	-1.18	0.10
1L -3	15:14:30	1	12.41	2.10	1.41	1.66	2.09	1.27	1.88	0.39		-1.49	
1L -3	15:15:30	2	12.41	2.10	1.41	1.72	2.19	1.30	1.95	0.40		-1.55	
1L -3	15:17:30	4	12.41	2.10	1.41	1.79	2.31	1.35	2.05	0.42		-1.63	
1L -3	15:21:30	8	12.41	2.10	1.41	1.89	2.47	1.41	2.18	0.41	-0.01	-1.77	0.14
1L -4	15:23:00	1	16.55	2.78	2.10	2.28	2.97	1.72	2.63	0.54		-2.09	
1L -4	15:24:00	2	16.55	2.78	2.10	2.34	3.06	1.75	2.70	0.55		-2.14	
1L -4	15:26:00	4	16.55	2.78	2.10	2.44	3.22	1.82	2.83	0.58		-2.25	
1L -4	15:30:00	8	16.55	2.78	2.10	2.56	3.42	1.90	2.99	0.62	0.03	-2.37	0.12
1L -5	15:32:00	1	20.69	3.47	2.78	3.00	3.93	2.27	3.47	0.76		-2.71	
1L -5	15:33:00	2	20.69	3.47	2.78	3.07	4.03	2.33	3.55	0.77		-2.78	
1L -5	15:35:00	4	20.69	3.47	2.78	3.16	4.14	2.41	3.65	0.79		-2.86	
1L -5	15:39:00	8	20.69	3.47	2.78	3.28	4.31	2.50	3.80	0.82	0.03	-2.97	0.11
1L -6	15:41:00	1	24.82	4.15	3.47	3.86	5.02	3.02	4.44	0.98		-3.46	
1L -6	15:42:00	2	24.82	4.15	3.47	3.90	5.10	3.07	4.50	0.99		-3.51	
1L -6	15:44:00	4	24.82	4.15	3.47	4.00	5.24	3.18	4.62	1.01		-3.61	
1L -6	15:48:00	8	24.82	4.15	3.47	4.13	5.43	3.31	4.78	1.02	0.01	-3.76	0.15
1L -7	15:50:00	1	28.96	4.84	4.15	4.73	6.16	3.84	5.44	1.18		-4.26	
1L -7	15:51:00	2	28.96	4.84	4.15	4.85	6.32	3.94	5.59	1.22		-4.37	
1L -7	15:53:00	4	28.96	4.84	4.15	4.95	6.44	4.04	5.69	1.27		-4.43	
1L -7	15:57:00	8	28.96	4.84	4.15	5.16	6.69	4.25	5.92	1.30	0.03	-4.62	0.20
1L -8	15:59:30	1	33.10	5.52	4.84	5.87	7.54	4.87	6.71	1.40		-5.30	
1L -8	16:00:30	2	33.10	5.52	4.84	6.00	7.68	4.99	6.84	1.40		-5.44	
1L -8	16:02:30	4	33.10	5.52	4.84	6.19	7.90	5.17	7.05	1.42		-5.63	
1L -8	16:06:30	8	33.10	5.52	4.84	6.45	8.18	5.42	7.31	1.45	0.04	-5.86	0.23
1L -9	16:09:30	1	37.23	6.21	5.52	7.34	9.27	6.23	8.31	1.66		-6.65	
1L -9	16:10:30	2	37.23	6.21	5.52	7.52	9.52	6.38	8.52	1.64		-6.88	
1L -9	16:12:30	4	37.23	6.21	5.52	7.75	9.78	6.61	8.77	1.58		-7.19	
1L -9	16:16:30	8	37.23	6.21	5.52	8.10	10.20	6.98	9.15	1.57	-0.01	-7.58	0.39
1L -10	16:18:30	1	41.37	6.89	6.21	8.99	11.26	7.79	10.12	1.76		-8.36	
1L -10	16:19:30	2	41.37	6.89	6.21	9.13	11.42	7.92	10.27	1.79		-8.48	
1L -10	16:21:30	4	41.37	6.89	6.21	9.39	11.74	8.20	10.56	1.83		-8.73	
1L -10	16:25:30	8	41.37	6.89	6.21	9.78	12.20	8.61	10.99	1.94	0.11	-9.05	0.32
1L -11	16:27:30	1	45.51	7.58	6.89	10.77	13.46	9.57	12.11	2.10		-10.02	
1L -11	16:28:30	2	45.51	7.58	6.89	10.94	13.68	9.76	12.31	2.11		-10.20	
1L -11	16:30:30	4	45.51	7.58	6.89	11.25	14.08	10.09	12.67	2.15		-10.51	
1L -11	16:34:30	8	45.51	7.58	6.89	11.76	14.75	10.67	13.26	2.16	0.00	-11.10	0.58
1L -12	16:36:00	1	49.64	8.26	7.58	12.71	15.99	11.65	14.35	2.33		-12.02	
1L -12	16:37:00	2	49.64	8.26	7.58	13.01	16.41	11.97	14.71	2.39		-12.32	
1L -12	16:39:00	4	49.64	8.26	7.58	13.36	16.85	12.37	15.10	2.43		-12.68	
1L -12	16:43:00	8	49.64	8.26	7.58	14.04	17.67	13.10	15.86	2.50	0.07	-13.36	0.68
1L -13	16:45:00	1	53.78	8.95	8.26	15.27	19.36	14.41	17.32	2.65		-14.66	
1L -13	16:46:00	2	53.78	8.95	8.26	15.57	19.78	14.74	17.68	2.68		-14.99	
1L -13	16:48:00	4	53.78	8.95	8.26	16.00	20.29	15.23	18.15	2.72		-15.43	
1L -13	16:52:00	8	53.78	8.95	8.26	16.71	21.18	16.04	18.95	2.72	0.00	-16.22	0.80
1L -14	16:53:30	1	57.92	9.63	8.95	17.93	22.88	17.37	20.41	2.85		-17.55	
1L -14	16:54:30	2	57.92	9.63	8.95	18.47	23.71	17.98	21.09	2.89		-18.21	
1L -14	16:56:30	4	57.92	9.63	8.95	19.14	24.62	18.73	21.88	2.90		-18.98	
1L -14	17:00:30	8	57.92	9.63	8.95	20.03	25.77	19.76	22.90	2.94	0.04	-19.96	0.98
1L -15	17:02:30	1	62.06	10.32	9.63	21.78	28.20	21.67	24.99	3.10		-21.89	
1L -15	17:03:30	2	62.06	10.32	9.63	22.37	28.93	22.23	25.65	3.13		-22.52	
1L -15	17:05:30	4	62.06	10.32	9.63	23.08	29.97	23.07	26.53	3.18		-23.35	
1L -15	17:09:30	8	62.06	10.32	9.63	24.18	31.39	24.32	27.79	3.25	0.07	-24.53	1.19
1L -16	17:12:00	1	66.19	11.00	10.32	26.19	34.29	26.63	30.24	3.44		-26.80	
1L -16	17:13:00	2	66.19	11.00	10.32	26.64	34.92	27.15	30.78	3.48		-27.31	
1L -16	17:15:00	4	66.19	11.00	10.32	27.41	35.93	28.01	31.67	3.52		-28.15	
1L -16	17:19:00	8	66.19	11.00	10.32	28.59	37.52	29.36	33.05	3.52	0.00	-29.53	1.38

O-cell™ Expansion and Upward and Downward Movement

I-235 over UP RR - Polk Co., IA - Test Shaft 1

Load Test Increment	Time 0 (h:m:s)	Time After Start Minutes	O-cell™ Pressure (MPa)	Applied Load (MN)	Net Load (MN)	LVWDT Readings (Expansion)* 03-28111 (mm)	03-28112 (mm)	03-28113 (mm)	Average (mm)	Top of O-cell Movement (mm)	Upward Creep (mm)	Bottom of O-cell Movement (mm)	Downward Creep (mm)
1U -1	17:21:30	1	49.64	8.26	7.58	28.45	37.61	29.11	33.03	3.50		-29.53	
1U -1	17:22:30	2	49.64	8.26	7.58	28.46	37.61	29.11	33.03	3.51		-29.52	
1U -1	17:24:30	4	49.64	8.26	7.58	28.46	37.61	29.11	33.04	3.53		-29.50	
1U -2	17:26:30	1	33.10	5.52	4.84	27.42	36.41	27.97	31.92	3.30		-28.62	
1U -2	17:27:30	2	33.10	5.52	4.84	27.37	36.35	27.93	31.86	3.27		-28.59	
1U -2	17:29:30	4	33.10	5.52	4.84	27.33	36.30	27.89	31.81	3.26		-28.55	
1U -3	17:32:00	1	16.55	2.78	2.10	25.64	34.42	26.09	30.03	2.76		-27.26	
1U -3	17:33:00	2	16.55	2.78	2.10	25.56	34.32	26.01	29.94	2.73		-27.21	
1U -3	17:35:00	4	16.55	2.78	2.10	25.48	34.25	25.92	29.87	2.67		-27.20	
1U -4	17:37:00	1	3.45	0.62	0.00	22.80	31.08	23.15	26.94	2.15		-24.79	
1U -4	17:38:00	2	3.45	0.62	0.00	22.65	30.93	23.00	26.79	2.12		-24.67	
1U -4	17:40:00	4	3.45	0.62	0.00	22.42	30.67	22.79	26.55	2.08		-24.47	
2L -1	17:43:00	1	13.79	2.33	1.64	22.77	30.92	23.15	26.85	2.13		-24.72	
2L -1	17:44:00	2	13.79	2.33	1.64	22.78	30.97	23.17	26.87	2.15		-24.73	
2L -1	17:46:00	4	13.79	2.33	1.64	22.78	30.97	23.17	26.88	2.14		-24.74	
2L -2	17:48:00	1	27.58	4.61	3.92	23.82	32.28	24.24	28.05	2.36		-25.69	
2L -2	17:49:00	2	27.58	4.61	3.92	23.86	32.36	24.27	28.11	2.38		-25.73	
2L -2	17:51:00	4	27.58	4.61	3.92	23.90	32.38	24.31	28.14	2.41		-25.73	
2L -3	17:53:30	1	41.37	6.89	6.21	25.41	34.18	25.90	29.79	2.75		-27.04	
2L -3	17:54:30	2	41.37	6.89	6.21	25.45	34.23	25.95	29.84	2.76		-27.08	
2L -3	17:56:30	4	41.37	6.89	6.21	25.52	34.30	26.02	29.91	2.78		-27.13	
2U -1	17:58:30	1	20.69	3.47	2.78	24.76	33.56	25.08	29.16	2.67		-26.49	
2U -1	17:59:30	2	20.69	3.47	2.78	24.77	33.56	25.07	29.16	2.67		-26.49	
2U -1	18:01:30	4	20.69	3.47	2.78	24.70	33.48	25.02	29.09	2.67		-26.42	
2U -2	18:03:00	1	0.00	0.00	0.00	21.29	29.24	21.49	25.26	1.99		-23.27	
2U -2	18:04:00	2	0.00	0.00	0.00	21.06	28.98	21.27	25.02	1.96		-23.07	
2U -2	18:06:00	4	0.00	0.00	0.00	20.85	28.73	21.07	24.79	1.90		-22.88	

* LVWDT 03-28113 not used in average due to its orientation.

Strain Gage Readings and Loads at Levels 1, 2 and 3

I-235 over UP RR - Polk Co., IA - Test Shaft 1

Load Test Increment	Time 0 (h:m:s)	Time After Start Minutes	O-cell™ Pressure (MPa)	Applied Load (MN)	Net Load (MN)	Level 1 25818 με	Level 1 25819 με	Level 1 Av. Load (MN)	Level 2 25820 με	Level 2 25821 με	Level 2 Av. Load (MN)	Level 3 21501 με	Level 3 21502 με	Level 3 Av. Load (MN)
1L -0	14:52:30	0	0.00	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
1L -1	14:57:00	1	4.14	0.73	0.04	10.2	8.8	0.29	5.5	7.4	0.20	3.1	2.7	0.09
1L -1	14:58:00	2	4.14	0.73	0.04	10.2	8.8	0.29	5.4	7.4	0.20	3.0	2.7	0.09
1L -1	15:00:00	4	4.14	0.73	0.04	10.0	8.7	0.29	5.4	7.4	0.20	3.1	2.6	0.09
1L -1	15:04:00	8	4.14	0.73	0.04	9.9	8.8	0.29	5.3	7.3	0.20	3.1	2.7	0.09
1L -2	15:06:00	1	8.27	1.41	0.73	22.4	20.9	0.67	12.5	16.6	0.45	7.2	6.3	0.21
1L -2	15:07:00	2	8.27	1.41	0.73	23.1	22.0	0.70	12.9	17.4	0.47	7.6	6.6	0.22
1L -2	15:09:00	4	8.27	1.41	0.73	23.5	23.2	0.72	13.3	18.1	0.49	7.9	6.9	0.23
1L -2	15:13:00	8	8.27	1.41	0.73	24.2	24.6	0.76	13.7	19.1	0.51	8.3	7.3	0.24
1L -3	15:14:30	1	12.41	2.10	1.41	34.2	35.0	1.07	19.5	27.3	0.73	12.1	10.7	0.35
1L -3	15:15:30	2	12.41	2.10	1.41	34.6	36.1	1.10	19.9	28.0	0.74	12.3	10.9	0.36
1L -3	15:17:30	4	12.41	2.10	1.41	35.4	37.6	1.13	20.2	29.0	0.76	12.9	11.4	0.38
1L -3	15:21:30	8	12.41	2.10	1.41	35.5	39.1	1.16	20.5	29.8	0.78	13.3	11.7	0.39
1L -4	15:23:00	1	16.55	2.78	2.10	45.3	49.3	1.47	26.4	38.2	1.00	17.1	15.1	0.50
1L -4	15:24:00	2	16.55	2.78	2.10	45.9	50.4	1.49	26.6	39.0	1.02	17.4	15.5	0.51
1L -4	15:26:00	4	16.55	2.78	2.10	46.2	51.9	1.52	27.0	39.9	1.04	17.9	15.8	0.52
1L -4	15:30:00	8	16.55	2.78	2.10	46.5	53.7	1.55	27.5	41.0	1.06	18.5	16.4	0.54
1L -5	15:32:00	1	20.69	3.47	2.78	56.2	64.7	1.88	33.2	50.1	1.29	22.6	20.2	0.66
1L -5	15:33:00	2	20.69	3.47	2.78	56.7	65.9	1.90	33.8	50.9	1.31	23.0	20.6	0.68
1L -5	15:35:00	4	20.69	3.47	2.78	56.8	67.3	1.93	34.0	51.8	1.33	23.5	21.0	0.69
1L -5	15:39:00	8	20.69	3.47	2.78	56.6	68.9	1.95	34.3	52.7	1.35	23.8	21.5	0.70
1L -6	15:41:00	1	24.82	4.15	3.47	66.3	81.6	2.29	40.9	62.6	1.61	28.6	25.9	0.84
1L -6	15:42:00	2	24.82	4.15	3.47	66.5	82.6	2.31	41.2	63.4	1.62	28.9	26.2	0.85
1L -6	15:44:00	4	24.82	4.15	3.47	67.0	84.0	2.34	41.7	64.2	1.64	29.4	26.8	0.87
1L -6	15:48:00	8	24.82	4.15	3.47	67.0	85.5	2.37	41.9	65.2	1.66	29.9	27.4	0.89
1L -7	15:50:00	1	28.96	4.84	4.15	76.0	97.3	2.69	48.4	74.4	1.90	34.5	31.6	1.03
1L -7	15:51:00	2	28.96	4.84	4.15	76.2	98.3	2.71	48.7	75.1	1.92	35.0	32.1	1.04
1L -7	15:53:00	4	28.96	4.84	4.15	76.3	99.3	2.72	49.1	75.9	1.94	35.4	32.6	1.06
1L -7	15:57:00	8	28.96	4.84	4.15	76.7	100.6	2.75	49.7	77.1	1.97	36.0	33.4	1.08
1L -8	15:59:30	1	33.10	5.52	4.84	85.4	112.4	3.07	56.3	86.2	2.21	40.7	37.9	1.22
1L -8	16:00:30	2	33.10	5.52	4.84	86.3	113.8	3.10	57.0	87.3	2.24	41.3	38.7	1.24
1L -8	16:02:30	4	33.10	5.52	4.84	86.9	115.1	3.13	57.7	88.3	2.26	42.0	39.3	1.26
1L -8	16:06:30	8	33.10	5.52	4.84	87.5	116.4	3.16	58.4	89.5	2.29	42.7	40.3	1.29
1L -9	16:09:30	1	37.23	6.21	5.52	96.6	129.1	3.50	65.6	99.2	2.56	47.8	45.5	1.45
1L -9	16:10:30	2	37.23	6.21	5.52	96.6	130.5	3.52	65.9	100.1	2.57	48.2	46.0	1.46
1L -9	16:12:30	4	37.23	6.21	5.52	97.2	131.6	3.55	66.5	101.1	2.60	48.9	46.8	1.48
1L -9	16:16:30	8	37.23	6.21	5.52	98.2	133.2	3.59	67.3	102.4	2.63	49.6	47.6	1.51
1L -10	16:18:30	1	41.37	6.89	6.21	107.4	145.0	3.92	74.5	111.7	2.89	54.6	52.7	1.66
1L -10	16:19:30	2	41.37	6.89	6.21	107.6	145.6	3.93	74.7	112.1	2.90	54.9	53.1	1.68
1L -10	16:21:30	4	41.37	6.89	6.21	108.5	146.7	3.96	75.4	113.1	2.92	55.7	53.9	1.70
1L -10	16:25:30	8	41.37	6.89	6.21	109.4	148.4	4.00	76.6	114.6	2.96	56.4	54.9	1.73
1L -11	16:27:30	1	45.51	7.58	6.89	119.1	160.5	4.34	84.0	124.2	3.23	61.8	60.4	1.89
1L -11	16:28:30	2	45.51	7.58	6.89	119.3	160.8	4.34	84.4	124.6	3.24	62.3	60.8	1.91
1L -11	16:30:30	4	45.51	7.58	6.89	119.8	162.1	4.37	85.0	125.6	3.27	62.8	61.6	1.93
1L -11	16:34:30	8	45.51	7.58	6.89	120.5	163.4	4.40	85.7	126.6	3.29	63.6	62.5	1.96
1L -12	16:36:00	1	49.64	8.26	7.58	130.5	175.2	4.74	93.7	136.1	3.57	68.8	67.9	2.12
1L -12	16:37:00	2	49.64	8.26	7.58	131.1	176.4	4.77	94.2	137.1	3.59	69.5	68.6	2.14
1L -12	16:39:00	4	49.64	8.26	7.58	131.8	177.0	4.79	94.8	137.8	3.61	70.2	69.4	2.16
1L -12	16:43:00	8	49.64	8.26	7.58	133.0	178.8	4.84	96.0	139.4	3.65	71.3	70.6	2.20
1L -13	16:45:00	1	53.78	8.95	8.26	142.6	190.2	5.16	103.7	148.6	3.91	76.4	76.0	2.36
1L -13	16:46:00	2	53.78	8.95	8.26	143.0	190.8	5.18	104.3	149.3	3.93	76.9	76.6	2.38
1L -13	16:48:00	4	53.78	8.95	8.26	144.4	192.0	5.22	105.2	150.3	3.96	77.8	77.6	2.41
1L -13	16:52:00	8	53.78	8.95	8.26	145.5	193.5	5.26	106.0	151.3	3.99	78.5	78.6	2.44
1L -14	16:53:30	1	57.92	9.63	8.95	155.3	204.6	5.58	113.9	160.6	4.26	83.7	83.7	2.60
1L -14	16:54:30	2	57.92	9.63	8.95	156.3	206.4	5.63	115.1	162.1	4.30	84.6	84.9	2.63
1L -14	16:56:30	4	57.92	9.63	8.95	156.6	207.4	5.65	115.8	162.8	4.32	85.4	85.6	2.65
1L -14	17:00:30	8	57.92	9.63	8.95	157.1	207.8	5.66	116.1	163.6	4.34	86.2	86.5	2.68
1L -15	17:02:30	1	62.06	10.32	9.63	168.3	219.8	6.02	124.9	173.4	4.63	91.8	92.2	2.85
1L -15	17:03:30	2	62.06	10.32	9.63	168.8	220.8	6.04	125.5	174.1	4.65	92.6	93.0	2.88
1L -15	17:05:30	4	62.06	10.32	9.63	169.4	221.5	6.06	126.3	174.9	4.67	93.1	93.8	2.90
1L -15	17:09:30	8	62.06	10.32	9.63	170.3	222.4	6.09	127.1	176.0	4.70	93.9	94.8	2.93
1L -16	17:12:00	1	66.19	11.00	10.32	181.9	234.1	6.45	136.1	185.7	4.99	99.9	100.9	3.11
1L -16	17:13:00	2	66.19	11.00	10.32	182.9	234.8	6.48	136.9	186.5	5.02	100.6	101.6	3.14
1L -16	17:15:00	4	66.19	11.00	10.32	184.2	235.8	6.52	137.9	187.6	5.05	101.5	102.6	3.16
1L -16	17:19:00	8	66.19	11.00	10.32	185.5	236.7	6.55	139.0	188.7	5.08	102.4	103.8	3.20

Strain Gage Readings and Loads at Levels 1, 2 and 3

I-235 over UP RR - Polk Co., IA - Test Shaft 1

Load Test Increment	Time 0 (h:m:s)	Time After Start Minutes	O-cell™ Pressure (MPa)	Applied Load (MN)	Net Load (MN)	Level 1			Level 2			Level 3		
						25818	25819	Av. Load	25820	25821	Av. Load	21501	21502	Av. Load
						με	με	(MN)	με	με	(MN)	με	με	(MN)
1U -1	17:21:30	1	49.64	8.26	7.58	171.8	226.6	6.18	132.0	180.4	4.84	98.6	99.9	3.08
1U -1	17:22:30	2	49.64	8.26	7.58	171.2	226.1	6.16	131.5	179.9	4.83	98.4	99.7	3.07
1U -1	17:24:30	4	49.64	8.26	7.58	170.2	225.2	6.13	130.8	179.1	4.81	98.0	99.4	3.06
1U -2	17:26:30	1	33.10	5.52	4.84	137.0	198.8	5.21	113.4	159.5	4.23	88.2	89.8	2.76
1U -2	17:27:30	2	33.10	5.52	4.84	136.0	197.7	5.18	113.0	158.7	4.21	87.8	89.3	2.75
1U -2	17:29:30	4	33.10	5.52	4.84	135.2	196.9	5.15	112.3	158.0	4.19	87.3	88.9	2.73
1U -3	17:32:00	1	16.55	2.78	2.10	90.7	162.0	3.92	88.8	133.2	3.44	73.7	76.3	2.33
1U -3	17:33:00	2	16.55	2.78	2.10	90.4	160.9	3.90	88.6	132.3	3.43	73.2	75.8	2.31
1U -3	17:35:00	4	16.55	2.78	2.10	89.5	159.5	3.86	88.3	131.0	3.40	72.6	75.2	2.29
1U -4	17:37:00	1	3.45	0.62	0.00	47.3	122.3	2.63	61.7	105.8	2.60	57.1	61.8	1.84
1U -4	17:38:00	2	3.45	0.62	0.00	45.4	119.4	2.56	60.7	103.3	2.54	56.1	60.6	1.81
1U -4	17:40:00	4	3.45	0.62	0.00	43.2	115.6	2.46	59.6	100.0	2.48	54.7	59.3	1.77
2L -1	17:43:00	1	13.79	2.33	1.64	56.2	124.7	2.81	66.0	105.8	2.66	57.6	61.9	1.85
2L -1	17:44:00	2	13.79	2.33	1.64	56.6	124.8	2.81	66.2	105.9	2.67	57.7	62.0	1.86
2L -1	17:46:00	4	13.79	2.33	1.64	56.8	125.0	2.82	66.2	105.8	2.67	57.6	61.8	1.85
2L -2	17:48:00	1	27.58	4.61	3.92	86.9	152.1	3.71	82.4	123.7	3.20	66.7	70.2	2.12
2L -2	17:49:00	2	27.58	4.61	3.92	86.6	152.0	3.70	82.2	123.7	3.19	66.6	70.0	2.12
2L -2	17:51:00	4	27.58	4.61	3.92	87.2	152.8	3.72	82.3	124.3	3.21	66.7	70.4	2.13
2L -3	17:53:30	1	41.37	6.89	6.21	120.4	182.7	4.70	100.6	145.6	3.82	77.9	80.8	2.46
2L -3	17:54:30	2	41.37	6.89	6.21	121.2	183.7	4.73	100.7	146.6	3.83	78.2	81.1	2.47
2L -3	17:56:30	4	41.37	6.89	6.21	121.9	184.5	4.75	101.2	147.4	3.86	78.5	81.5	2.48
2U -1	17:58:30	1	20.69	3.47	2.78	91.7	162.2	3.94	86.4	130.8	3.37	70.4	73.7	2.24
2U -1	17:59:30	2	20.69	3.47	2.78	91.7	162.2	3.94	86.4	130.8	3.37	70.4	73.6	2.23
2U -1	18:01:30	4	20.69	3.47	2.78	90.3	160.7	3.89	85.6	129.8	3.34	70.0	73.2	2.22
2U -2	18:03:00	1	0.00	0.00	0.00	29.4	100.1	2.01	47.9	88.7	2.12	47.8	53.0	1.56
2U -2	18:04:00	2	0.00	0.00	0.00	28.3	97.4	1.95	47.0	86.2	2.07	46.5	51.8	1.53
2U -2	18:06:00	4	0.00	0.00	0.00	27.5	94.6	1.89	46.3	84.1	2.02	45.6	50.7	1.49

Strain Gage Readings and Loads at Levels 4 and 5

I-235 over UP RR - Polk Co., IA - Test Shaft 1

Load Test Increment	Time 0 (h:m:s)	Time After Start Minutes	O-cell™ Pressure (MPa)	Applied Load (MN)	Net Load (MN)	Level 4			Level 5		
						25812	25813	Av. Load	26512	26513	Av. Load
						με	με	(MN)	με	με	(MN)
1L -0	14:52:30	0	0.00	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.00
1L -1	14:57:00	1	4.14	0.73	0.04	0.8	0.7	0.03	0.4	0.0	0.01
1L -1	14:58:00	2	4.14	0.73	0.04	0.8	0.6	0.02	0.4	0.0	0.01
1L -1	15:00:00	4	4.14	0.73	0.04	0.8	0.6	0.02	0.4	0.0	0.01
1L -1	15:04:00	8	4.14	0.73	0.04	0.8	0.6	0.02	0.4	0.0	0.01
1L -2	15:06:00	1	8.27	1.41	0.73	2.2	1.8	0.07	1.0	0.1	0.02
1L -2	15:07:00	2	8.27	1.41	0.73	2.4	2.0	0.07	1.1	0.1	0.02
1L -2	15:09:00	4	8.27	1.41	0.73	2.6	2.0	0.08	1.2	0.1	0.02
1L -2	15:13:00	8	8.27	1.41	0.73	2.6	2.1	0.08	1.2	0.1	0.02
1L -3	15:14:30	1	12.41	2.10	1.41	3.9	3.1	0.12	1.8	0.2	0.03
1L -3	15:15:30	2	12.41	2.10	1.41	3.9	3.3	0.12	1.8	0.2	0.03
1L -3	15:17:30	4	12.41	2.10	1.41	4.2	3.5	0.13	1.9	0.2	0.03
1L -3	15:21:30	8	12.41	2.10	1.41	4.2	3.7	0.13	1.9	0.2	0.03
1L -4	15:23:00	1	16.55	2.78	2.10	5.5	4.7	0.17	2.6	0.2	0.05
1L -4	15:24:00	2	16.55	2.78	2.10	5.6	4.8	0.17	2.6	0.3	0.05
1L -4	15:26:00	4	16.55	2.78	2.10	5.7	4.7	0.17	2.6	0.2	0.05
1L -4	15:30:00	8	16.55	2.78	2.10	5.8	5.0	0.18	2.9	0.3	0.05
1L -5	15:32:00	1	20.69	3.47	2.78	7.3	6.3	0.23	3.6	0.3	0.07
1L -5	15:33:00	2	20.69	3.47	2.78	7.3	6.4	0.23	3.5	0.3	0.06
1L -5	15:35:00	4	20.69	3.47	2.78	7.6	6.5	0.24	3.6	0.3	0.07
1L -5	15:39:00	8	20.69	3.47	2.78	7.6	6.5	0.23	3.7	0.4	0.07
1L -6	15:41:00	1	24.82	4.15	3.47	9.4	8.2	0.29	4.5	0.4	0.08
1L -6	15:42:00	2	24.82	4.15	3.47	9.4	8.2	0.29	4.5	0.4	0.08
1L -6	15:44:00	4	24.82	4.15	3.47	9.6	8.2	0.30	4.7	0.4	0.08
1L -6	15:48:00	8	24.82	4.15	3.47	9.9	8.7	0.31	4.7	0.4	0.09
1L -7	15:50:00	1	28.96	4.84	4.15	11.4	9.7	0.35	5.5	0.5	0.10
1L -7	15:51:00	2	28.96	4.84	4.15	11.6	10.0	0.36	5.6	0.5	0.10
1L -7	15:53:00	4	28.96	4.84	4.15	11.7	10.0	0.36	5.5	0.5	0.10
1L -7	15:57:00	8	28.96	4.84	4.15	12.1	10.2	0.37	5.8	0.5	0.11
1L -8	15:59:30	1	33.10	5.52	4.84	13.6	11.6	0.42	6.6	0.6	0.12
1L -8	16:00:30	2	33.10	5.52	4.84	13.9	11.8	0.43	6.8	0.6	0.12
1L -8	16:02:30	4	33.10	5.52	4.84	14.1	12.1	0.44	6.9	0.6	0.13
1L -8	16:06:30	8	33.10	5.52	4.84	14.6	12.2	0.45	7.0	0.7	0.13
1L -9	16:09:30	1	37.23	6.21	5.52	16.3	14.0	0.51	7.9	0.7	0.14
1L -9	16:10:30	2	37.23	6.21	5.52	16.4	14.1	0.51	7.9	0.8	0.14
1L -9	16:12:30	4	37.23	6.21	5.52	16.7	14.1	0.51	8.2	0.8	0.15
1L -9	16:16:30	8	37.23	6.21	5.52	17.0	14.5	0.53	8.2	0.8	0.15
1L -10	16:18:30	1	41.37	6.89	6.21	18.9	16.0	0.58	9.1	0.9	0.17
1L -10	16:19:30	2	41.37	6.89	6.21	18.9	16.1	0.58	9.2	0.9	0.17
1L -10	16:21:30	4	41.37	6.89	6.21	19.4	16.3	0.60	9.3	0.9	0.17
1L -10	16:25:30	8	41.37	6.89	6.21	19.5	16.7	0.60	9.5	0.9	0.17
1L -11	16:27:30	1	45.51	7.58	6.89	21.4	18.3	0.66	10.4	1.0	0.19
1L -11	16:28:30	2	45.51	7.58	6.89	21.7	18.5	0.67	10.5	1.0	0.19
1L -11	16:30:30	4	45.51	7.58	6.89	22.1	18.7	0.68	10.6	1.0	0.19
1L -11	16:34:30	8	45.51	7.58	6.89	22.4	18.9	0.69	10.7	1.0	0.20
1L -12	16:36:00	1	49.64	8.26	7.58	24.3	20.6	0.75	11.7	1.1	0.21
1L -12	16:37:00	2	49.64	8.26	7.58	24.7	20.7	0.76	11.9	1.1	0.22
1L -12	16:39:00	4	49.64	8.26	7.58	25.1	21.1	0.77	12.0	1.1	0.22
1L -12	16:43:00	8	49.64	8.26	7.58	25.5	21.5	0.78	12.1	1.2	0.22
1L -13	16:45:00	1	53.78	8.95	8.26	27.4	23.1	0.84	13.1	1.2	0.24
1L -13	16:46:00	2	53.78	8.95	8.26	27.7	23.1	0.85	13.2	1.3	0.24
1L -13	16:48:00	4	53.78	8.95	8.26	28.1	23.6	0.86	13.3	1.3	0.24
1L -13	16:52:00	8	53.78	8.95	8.26	28.5	23.7	0.87	13.4	1.3	0.25
1L -14	16:53:30	1	57.92	9.63	8.95	30.4	25.4	0.93	14.4	1.4	0.26
1L -14	16:54:30	2	57.92	9.63	8.95	30.8	25.8	0.94	14.6	1.4	0.27
1L -14	16:56:30	4	57.92	9.63	8.95	31.1	26.1	0.96	14.7	1.4	0.27
1L -14	17:00:30	8	57.92	9.63	8.95	31.5	26.1	0.96	14.8	1.4	0.27
1L -15	17:02:30	1	62.06	10.32	9.63	33.8	28.2	1.03	15.8	1.5	0.29
1L -15	17:03:30	2	62.06	10.32	9.63	34.3	28.4	1.05	15.9	1.5	0.29
1L -15	17:05:30	4	62.06	10.32	9.63	34.3	28.7	1.05	15.9	1.6	0.29
1L -15	17:09:30	8	62.06	10.32	9.63	35.0	28.7	1.06	15.9	1.6	0.29
1L -16	17:12:00	1	66.19	11.00	10.32	37.2	30.6	1.13	17.0	1.7	0.31
1L -16	17:13:00	2	66.19	11.00	10.32	37.6	31.0	1.14	17.1	1.7	0.31
1L -16	17:15:00	4	66.19	11.00	10.32	38.0	31.3	1.16	17.1	1.7	0.31
1L -16	17:19:00	8	66.19	11.00	10.32	38.5	31.7	1.17	17.0	1.8	0.31

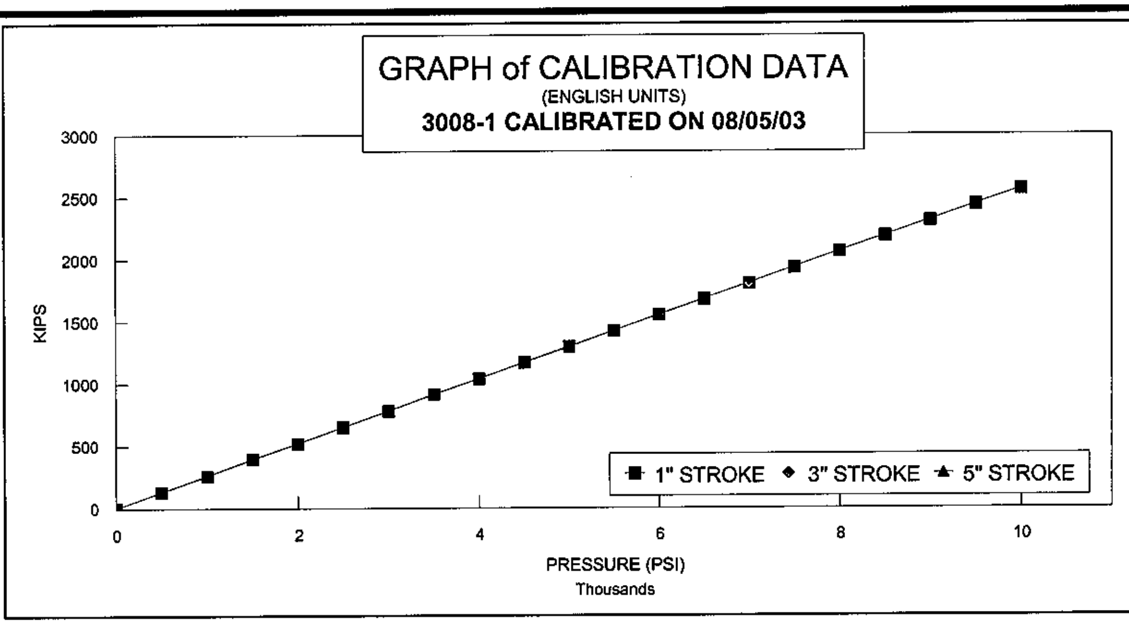
Strain Gage Readings and Loads at Levels 4 and 5

I-235 over UP RR - Polk Co., IA - Test Shaft 1

Load Test Increment	Time 0 (h:m:s)	Time After Start Minutes	O-cell™ Pressure (MPa)	Applied Load (MN)	Net Load (MN)	Level 4			Level 5		
						25812	25813	Av. Load	26512	26513	Av. Load
						με	με	(MN)	με	με	(MN)
1U -1	17:21:30	1	49.64	8.26	7.58	37.4	30.6	1.14	16.4	1.7	0.30
1U -1	17:22:30	2	49.64	8.26	7.58	37.3	30.5	1.13	16.4	1.7	0.30
1U -1	17:24:30	4	49.64	8.26	7.58	37.2	30.4	1.13	16.3	1.7	0.30
1U -2	17:26:30	1	33.10	5.52	4.84	34.1	27.6	1.03	14.8	1.5	0.27
1U -2	17:27:30	2	33.10	5.52	4.84	34.0	27.5	1.03	14.8	1.5	0.27
1U -2	17:29:30	4	33.10	5.52	4.84	33.9	27.3	1.02	14.8	1.5	0.27
1U -3	17:32:00	1	16.55	2.78	2.10	29.7	23.6	0.89	12.7	1.3	0.23
1U -3	17:33:00	2	16.55	2.78	2.10	29.5	23.7	0.89	12.6	1.3	0.23
1U -3	17:35:00	4	16.55	2.78	2.10	29.3	23.5	0.88	12.5	1.3	0.23
1U -4	17:37:00	1	3.45	0.62	0.00	25.0	19.3	0.74	10.2	1.1	0.19
1U -4	17:38:00	2	3.45	0.62	0.00	24.5	18.9	0.72	10.1	1.0	0.19
1U -4	17:40:00	4	3.45	0.62	0.00	24.0	18.7	0.71	9.8	1.0	0.18
2L -1	17:43:00	1	13.79	2.33	1.64	24.9	19.4	0.74	10.4	1.1	0.19
2L -1	17:44:00	2	13.79	2.33	1.64	25.1	19.5	0.74	10.4	1.1	0.19
2L -1	17:46:00	4	13.79	2.33	1.64	25.0	19.5	0.74	10.4	1.1	0.19
2L -2	17:48:00	1	27.58	4.61	3.92	27.8	22.2	0.83	11.9	1.2	0.22
2L -2	17:49:00	2	27.58	4.61	3.92	27.6	21.9	0.83	11.6	1.2	0.21
2L -2	17:51:00	4	27.58	4.61	3.92	27.6	22.2	0.83	11.9	1.2	0.22
2L -3	17:53:30	1	41.37	6.89	6.21	31.1	25.1	0.94	13.6	1.4	0.25
2L -3	17:54:30	2	41.37	6.89	6.21	31.3	25.2	0.94	13.7	1.4	0.25
2L -3	17:56:30	4	41.37	6.89	6.21	31.4	25.5	0.95	13.6	1.4	0.25
2U -1	17:58:30	1	20.69	3.47	2.78	28.9	23.0	0.87	12.1	1.3	0.22
2U -1	17:59:30	2	20.69	3.47	2.78	28.7	23.0	0.86	12.1	1.3	0.22
2U -1	18:01:30	4	20.69	3.47	2.78	28.6	22.7	0.86	12.1	1.3	0.22
2U -2	18:03:00	1	0.00	0.00	0.00	21.9	16.7	0.64	8.5	0.9	0.16
2U -2	18:04:00	2	0.00	0.00	0.00	21.6	16.4	0.63	8.4	0.9	0.15
2U -2	18:06:00	4	0.00	0.00	0.00	21.1	16.0	0.62	8.2	0.9	0.15

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	133	131	130
1000	262	258	260
1500	398	393	394
2000	523	521	521
2500	654	652	652
3000	783	783	781
3500	917	911	914
4000	1042	1039	1039
4500	1173	1170	1169
5000	1301	1297	1293
5500	1427	1426	1423
6000	1555	1552	1549
6500	1682	1680	1677
7000	1808	1805	
7500	1935		
8000	2063		
8500	2188		
9000	2313		
9500	2439		
10000	2564		

21" O-CELL, SERIAL # 3008-1

LOAD CONVERSION FORMULA

LOAD = PRESSURE * 0.2566 + (10.2)
{KIPS} {PSI}

Regression Output:

Constant	10.231
X Coefficient	0.257
R Squared	0.9999
No. of Observations	47
Degrees of Freedom	45
Std Err of Y Est	4.9021
Std Err of X Coef.	0.0003

CALIBRATION STANDARDS:

All data presented is 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 gauges, ANSI specifications B40.1.

*AE & FC CUSTOMER: LOADTEST INC. *AE & FC JOB NO.: 5047 *CUSTOMER P.O.NO.: LT-8998	*CONTRACTOR: LONGFELLOW DRILLING *JOB LOCATION: CLEARFIELD, IA *DATED: 12/19/03

SERVICE ENGINEER: [signature]   DATE: 23 Dec 2003

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

Vibrating Wire Displacement Transducer Calibration Report

Range: 150 mm

Calibration Date: November 17, 2003

Serial Number: 03-28111

Temperature: 21.7 °C

Cal. Std. Control Numbers: 344, 373, 529

Technician: gwo

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	2423	2422	2423	-0.236	-0.16	-0.032	-0.02
30.0	3422	3421	3422	30.09	0.06	30.05	0.03
60.0	4413	4414	4414	60.21	0.14	60.04	0.03
90.0	5396	5397	5397	90.05	0.03	89.89	-0.07
120.0	6387	6385	6386	120.1	0.06	120.1	0.03
150.0	7365	7364	7365	149.8	-0.14	150.0	0.00

(mm) Linear Gage Factor (G): 0.03036 (mm/ digit) **Regression Zero: 2430**

Polynomial Gage Factors: A: 6.2449E-08 B: 0.02975 C: -72.461

(inches) Linear Gage Factor (G): 0.001195 (inches/ digit)

Polynomial Gage Factors: A: 2.45862E-09 B: 0.001171 C: -2.8528

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

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5033 Temp(T_0): 25.6 °C Date: December 23, 2003

The above instrument was found to be in tolerance in all operating ranges.
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: November 17, 2003

Serial Number: 03-28112

Temperature: 21.7 °C

Cal. Std. Control Numbers: 344, 373, 529

Technician: gwo

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	2467	2465	2466	-0.272	-0.18	0.015	0.01
30.0	3496	3494	3495	30.03	0.02	29.97	-0.02
60.0	4523	4521	4522	60.27	0.18	60.04	0.03
90.0	5537	5535	5536	90.13	0.09	89.90	-0.06
120.0	6559	6553	6556	120.2	0.11	120.1	0.08
150.0	7559	7557	7558	149.7	-0.22	150.0	-0.03

(mm) Linear Gage Factor (G): 0.02945 (mm/ digit) **Regression Zero: 2475**

Polynomial Gage Factors: A: 8.2536E-08 B: 0.02862 C: -71.062

(inches) Linear Gage Factor (G): 0.001159 (inches/ digit)

Polynomial Gage Factors: A: 3.24945E-09 B: 0.001127 C: -2.7977

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

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5200 Temp(T_0): 25.5 °C Date: December 23, 2003

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: November 17, 2003

Serial Number: 03-28113

Temperature: 21.7 °C

Cal. Std. Control Numbers: 344, 373, 529

Technician: gwo

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	2400	2403	2402	-0.311	-0.21	0.022	0.01
30.0	3393	3391	3392	30.05	0.03	29.98	-0.01
60.0	4377	4377	4377	60.23	0.16	59.97	-0.02
90.0	5358	5356	5357	90.27	0.18	90.01	0.00
120.0	6332	6330	6331	120.1	0.08	120.1	0.04
150.0	7295	7293	7294	149.6	-0.24	150.0	-0.02

(mm) Linear Gage Factor (G): 0.03065 (mm/ digit) **Regression Zero: 2412**

Polynomial Gage Factors: A: 1.03659E-07 B: 0.02964 C: -71.763

(inches) Linear Gage Factor (G): 0.001207 (inches/ digit)

Polynomial Gage Factors: A: 4.08107E-09 B: 0.001167 C: -2.8253

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

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 4987 Temp(T_0): 25.8 °C Date: December 23, 2003

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: 26512

Customer: Loadtest, Inc.

Job Number: 22101

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 22.6 °C

Calibration Date: January 09, 2004

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 40 ft.

Factory Zero Reading: 6924

Regression Zero: 6942

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7000	6998	6999		
1,500	7668	7668	7668	669	-0.24
3,000	8406	8399	8403	735	-0.19
4,500	9145	9142	9144	741	0.09
6,000	9878	9876	9877	734	0.10
100	7001				

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

Gage Factor: 0.346 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: 26513

Customer: Loadtest, Inc.

Job Number: 22101

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 22.6 °C

Calibration Date: January 09, 2004

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 40 ft.

Factory Zero Reading: 6788

Regression Zero: 6798

Technician: KROB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6853	6852	6853		
1,500	7527	7527	7527	675	-0.18
3,000	8266	8265	8266	739	-0.04
4,500	8998	9001	9000	734	-0.05
6,000	9739	9738	9739	739	0.11
100	6852				

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

Gage Factor: 0.345 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: 25812

Customer: Loadtest Inc.

Job Number: 21237

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.0 °C

Calibration Date: August 12, 2003

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 55 ft.

Factory Zero Reading: 7070

Regression Zero: 7086

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7128	7132	7130		
1,500	7784	7784	7784	654	0.01
3,000	8484	8489	8487	703	0.18
4,500	9173	9185	9179	693	0.00
6,000	9873	9876	9875	696	-0.08
100	7132				

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

Gage Factor: 0.358 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: 25813

Customer: Loadtest Inc.

Job Number: 21237

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.1 °C

Calibration Date: August 12, 2003

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 55 ft.

Factory Zero Reading: 7010

Regression Zero: 7027

Technician: KDB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7081	7072	7077		
1,500	7733	7727	7730	654	-0.10
3,000	8442	8440	8441	711	0.08
4,500	9148	9147	9148	707	0.10
6,000	9848	9852	9850	703	-0.02
100	7075				

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

Gage Factor: 0.355 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 : 4911-4X

Calibration Date: September 25, 2001

Serial Number: 21501

Cal. Std. Control Numbers: 85888-1, 398

Customer: Loadtest Inc.

Cable Length: 189 ft.

Job Number: 17621

Factory Zero Reading: 6520

Cust. I.D. #: n/a

Regression Zero: 6533

Prestress: 2,460 kg./cm²

Technician: CMB

Temperature: 23.3 °C

Applied Load: (kilograms)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
45	6586	6587	6587		
680	7269	7271	7270	684	-0.19
1361	8012	8024	8018	748	-0.01
2041	8769	8762	8766	748	0.15
2722	9506	9499	9503	737	-0.04
45	6534				

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 per cent

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 : 4911-4X

Serial Number: 21502

Customer: Loadtest Inc.

Job Number: 17621

Cust. I.D. #: n/a

Prestress: 2,460 kg./cm²

Temperature: 23.5 °C

Calibration Date: September 25, 2001

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 189 ft.

Factory Zero Reading: 7006

Regression Zero: 7016

Technician: CMB

Applied Load: (kilograms)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
45	7072	7063	7068		
680	7758	7757	7758	690	-0.11
1361	8505	8515	8510	753	0.15
2041	9257	9251	9254	744	0.12
2722	9992	9995	9994	740	-0.06
45	7064				

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 per cent

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: 25818

Customer: Loadtest Inc.

Job Number: 21240

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 22.9 °C

Calibration Date: August 12, 2003

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 120 ft.

Factory Zero Reading: 6781

Regression Zero: 6792

Technician: KWB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6849	6846	6848		
1,500	7498	7498	7498	651	-0.29
3,000	8222	8217	8220	722	-0.05
4,500	8942	8934	8938	719	0.10
6,000	9653	9650	9652	714	0.07
100	6847				

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

Gage Factor: 0.352 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: 25819

Customer: Loadtest Inc.

Job Number: 21240

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.1 °C

Calibration Date: August 12, 2003

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 120 ft.

Factory Zero Reading: 6608

Regression Zero: 6623

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6685	6674	6680		
1,500	7333	7323	7328	649	-0.31
3,000	8049	8043	8046	718	-0.16
4,500	8771	8766	8769	723	0.15
6,000	9483	9477	9480	712	0.07
100	6674				

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

Gage Factor: 0.353 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: 25820

Customer: Loadtest Inc.

Job Number: 21240

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.2 °C

Calibration Date: August 12, 2003

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 115 ft.

Factory Zero Reading: 6745

Regression Zero: 6765

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6813	6812	6813		
1,500	7470	7467	7469	656	-0.18
3,000	8188	8187	8188	719	0.18
4,500	8896	8896	8896	709	0.17
6,000	9596	9594	9595	699	-0.17
100	6812				

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

Gage Factor: 0.354 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: 25821

Customer: Loadtest Inc.

Job Number: 21240

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.2 °C

Calibration Date: August 12, 2003

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 115 ft.

Factory Zero Reading: 7072

Regression Zero: 7083

Technician: KDB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7138	7133	7136		
1,500	7788	7787	7788	652	-0.21
3,000	8507	8503	8505	718	0.04
4,500	9220	9217	9219	714	0.15
6,000	9924	9925	9925	706	-0.01
100	7133				

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

Gage Factor: 0.354 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.

APPENDIX C

CONSTRUCTION OF EQUIVALENT
TOP-LOAD 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 the first converting gross to net loads. For our 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 $\ell_3 = 0$. 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 centriod 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 centriod 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

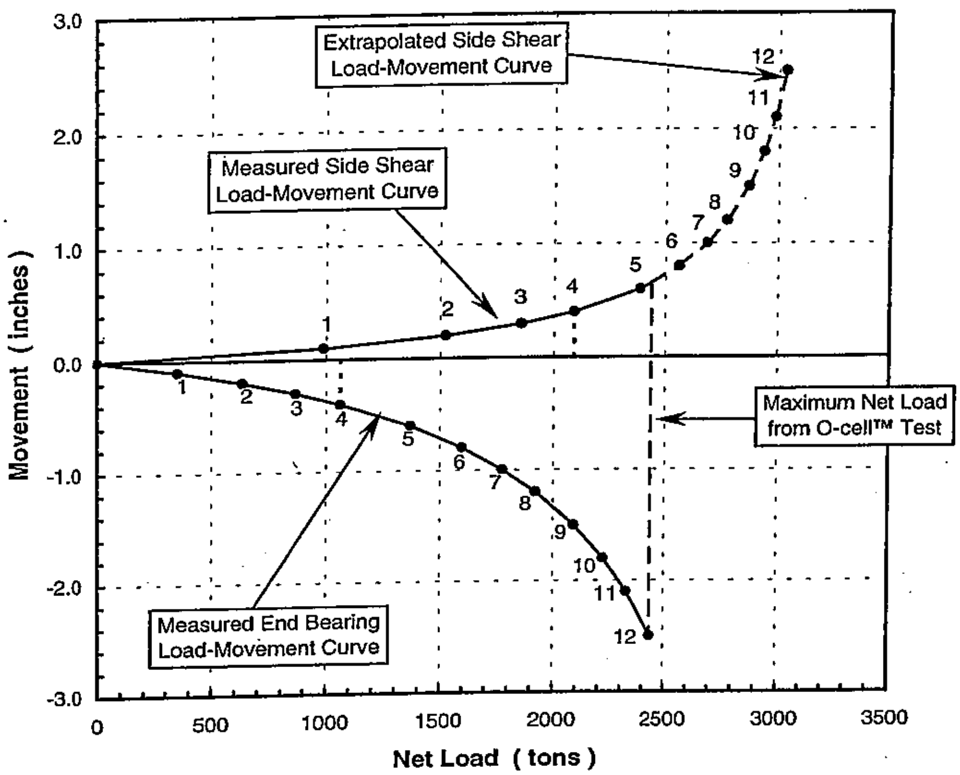
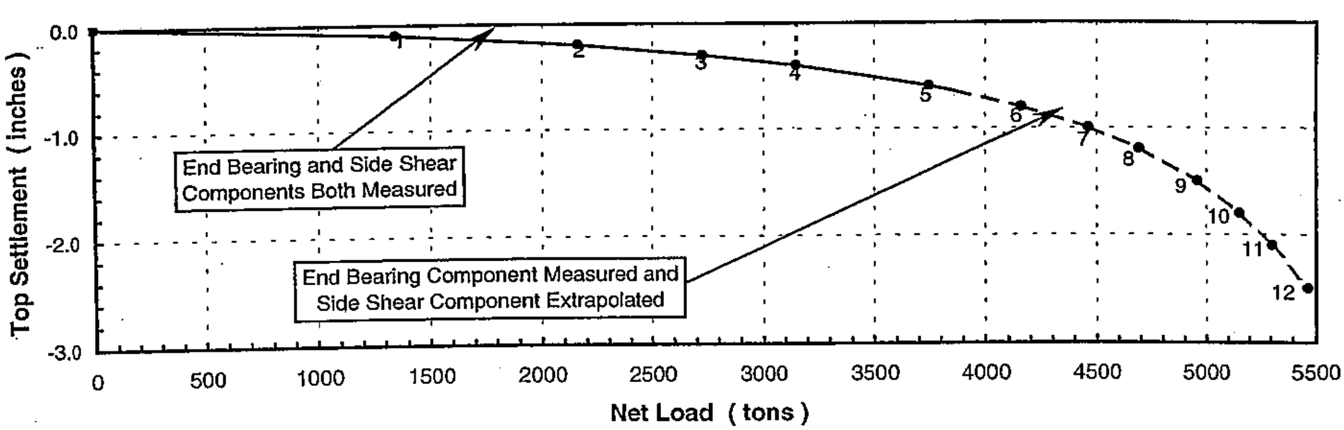
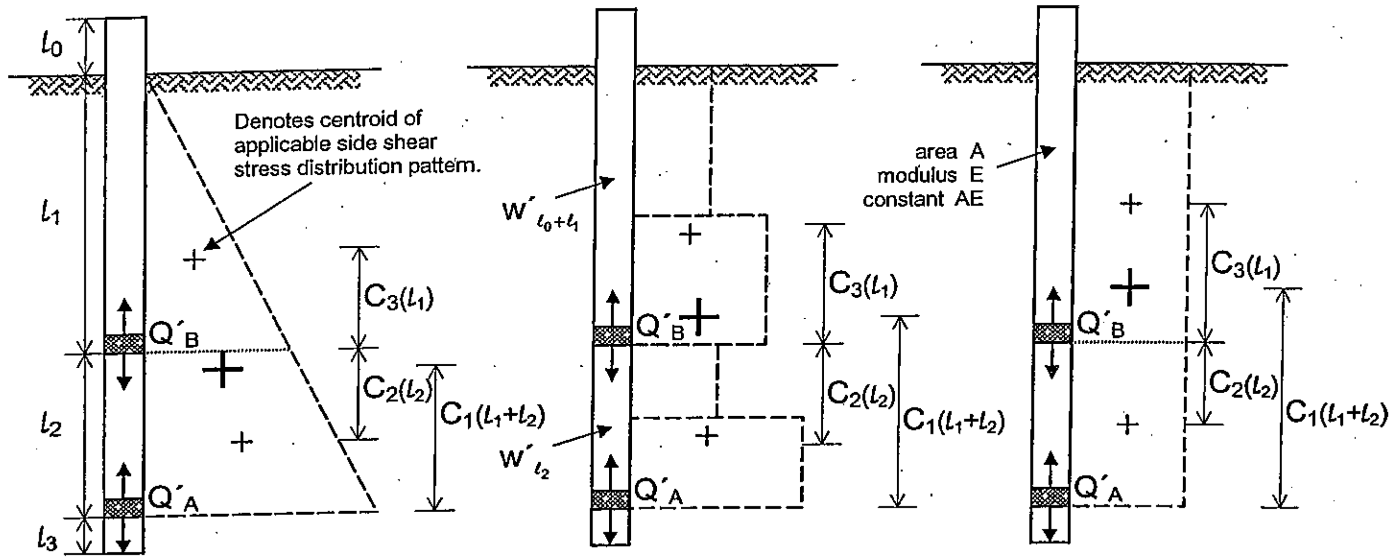


Figure B



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



1-Stage Single Level Test (Q´A only): $\delta_{OLT} = \delta_{\uparrow(\ell_1+\ell_2)}$

$C_1 = \frac{1}{3}$	Centroid Factor $= C_1$	$C_1 = \frac{1}{2}$
$\delta_{\uparrow(\ell_1+\ell_2)} = \frac{1}{3}\frac{Q'_{\uparrow A}(\ell_1+\ell_2)}{AE}$	$\delta_{\uparrow(\ell_1+\ell_2)} = C_1\frac{Q'_{\uparrow A}(\ell_1+\ell_2)}{AE}$	$\delta_{\uparrow(\ell_1+\ell_2)} = \frac{1}{2}\frac{Q'_{\uparrow A}(\ell_1+\ell_2)}{AE}$

3-Stage Multi Level Test (Q´A and Q´B): $\delta_{OLT} = \delta_{\uparrow\ell_1} + \delta_{\downarrow\ell_2}$

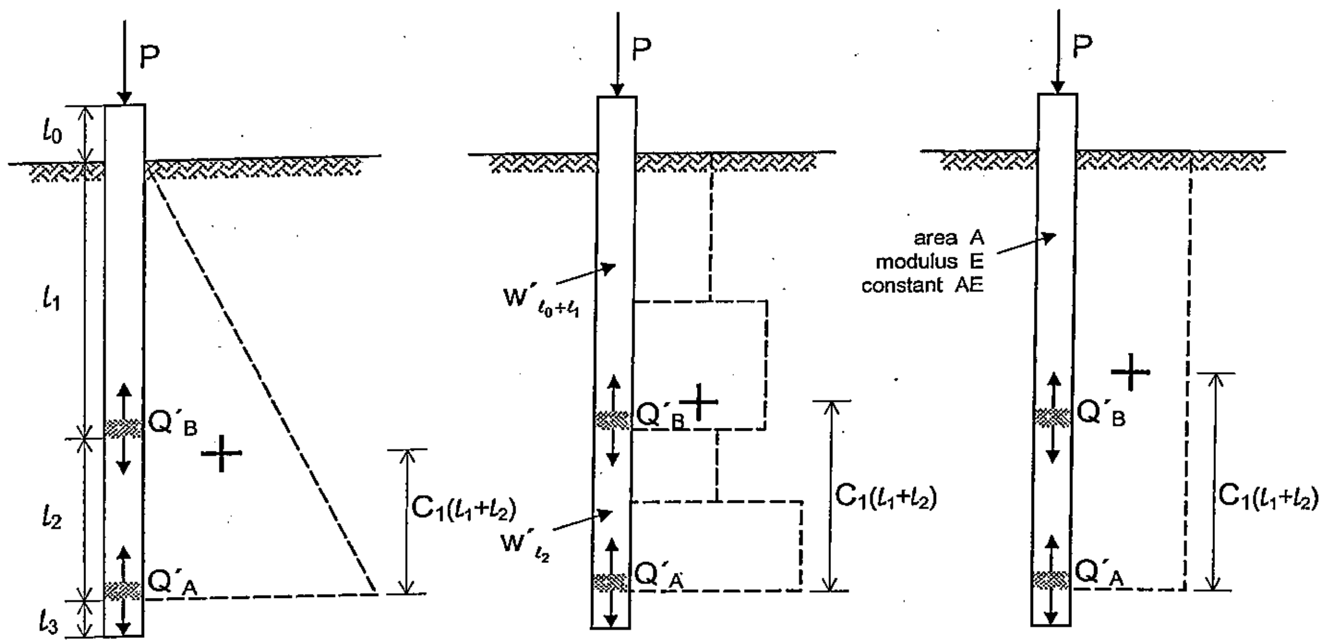
$C_3 = \frac{1}{3}$	Centroid Factor $= C_3$	$C_3 = \frac{1}{2}$
$\delta_{\uparrow\ell_1} = \frac{1}{3}\frac{Q'_{\uparrow B}\ell_1}{AE}$	$\delta_{\uparrow\ell_1} = C_3\frac{Q'_{\uparrow B}\ell_1}{AE}$	$\delta_{\uparrow\ell_1} = \frac{1}{3}\frac{Q'_{\uparrow B}\ell_1}{AE}$
$C_2 = \frac{1}{3}\left(\frac{3\ell_1+2\ell_2}{2\ell_1+\ell_2}\right)$	Centroid Factor $= C_2$	$C_2 = \frac{1}{2}$
$\delta_{\downarrow\ell_2} = \frac{1}{3}\left(\frac{3\ell_1+2\ell_2}{2\ell_1+\ell_2}\right)\frac{Q'_{\downarrow B}\ell_2}{AE}$	$\delta_{\downarrow\ell_2} = C_2\frac{Q'_{\downarrow B}\ell_2}{AE}$	$\delta_{\downarrow\ell_2} = \frac{1}{2}\frac{Q'_{\downarrow B}\ell_2}{AE}$

Net Loads:

$Q'_{\uparrow A} = Q_{\uparrow A} - W'_{\ell_0+\ell_1+\ell_2}$ $\quad$ $Q'_{\uparrow B} = Q_{\uparrow B} - W'_{\ell_0+\ell_1}$ $\quad$ $Q'_{\downarrow B} = Q'_{\downarrow B} + W'_{\ell_2}$

W´ = pile weight, bouyant where below water table

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



Top Loaded Test: $\delta_{TLT} = \delta_{\downarrow\ell_0} + \delta_{\downarrow\ell_1+\ell_2}$

$\delta_{\downarrow\ell_0} = \dfrac{P\ell_0}{AE}$	$\delta_{\downarrow\ell_0} = \dfrac{P\ell_0}{AE}$	$\delta_{\downarrow\ell_0} = \dfrac{P\ell_0}{AE}$
$C_1 = \dfrac{1}{3}$	$\text{Centroid Factor} = C_1$	$C_1 = \dfrac{1}{2}$
$\delta_{\downarrow\ell_1+\ell_2} = \dfrac{(Q'_{\downarrow A}+2P)}{3}\dfrac{(\ell_2+\ell_2)}{AE}$	$\delta_{\downarrow\ell_1+\ell_2} = [(C_1)Q'_{\downarrow A}+(1-C_1)P]\dfrac{(\ell_1+\ell_2)}{AE}$	$\delta_{\downarrow\ell_1+\ell_2} = \dfrac{(Q'_{\downarrow A}+P)}{2}\dfrac{(\ell_1+\ell_2)}{AE}$

Net and Equivalent Loads:

$Q'_{\downarrow A} = Q_{\downarrow A} - W'_{\ell_0+\ell_1+\ell_2}$ $\qquad P_{single} = Q'_{\downarrow A} + Q'_{\uparrow A}$ $\qquad P_{multi} = Q'_{\downarrow A} + Q'_{\uparrow B} + Q'_{\downarrow B}$

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

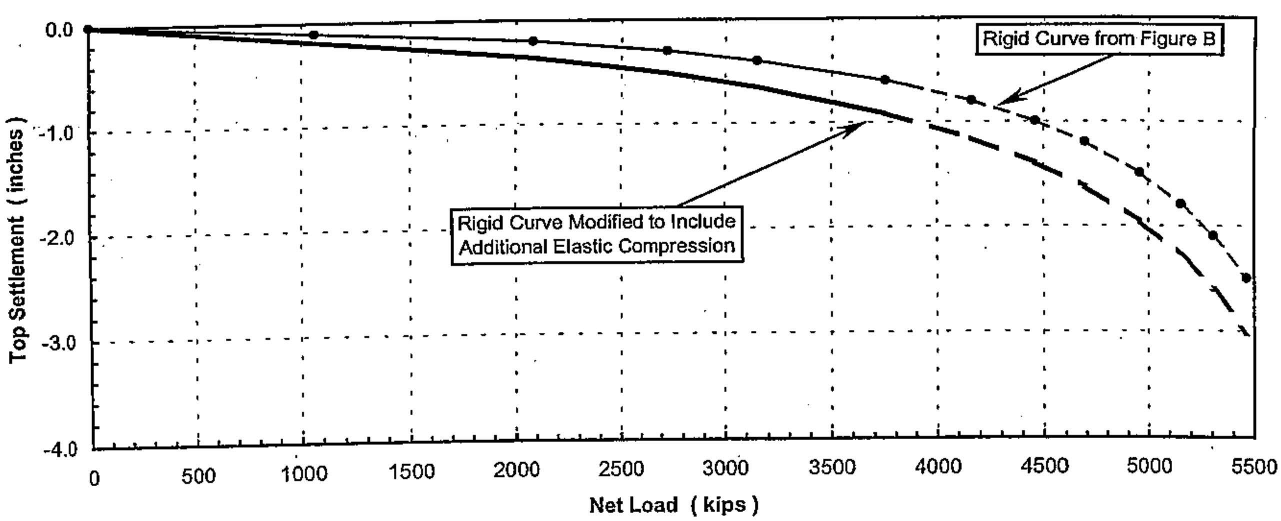
Example Calcuation for the Additional Elastic Compression Correction for Single Level Test (English Units)

Given:

C_1 = 0.441
AE = 3820000 **kips** (assumed constant throughout test)
ℓ_0 = 5.9 **ft**
ℓ_1 = 48.2 **ft** (embedded length of shaft above O-cell™)
ℓ_2 = 0.0 **ft**
ℓ_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



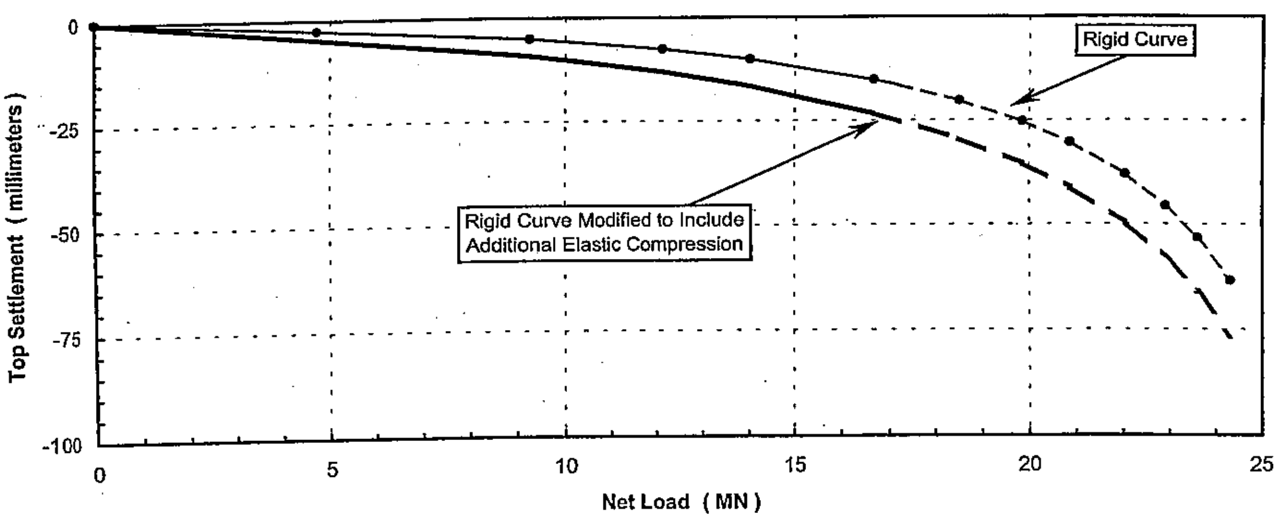
Example Calcuation for the Additional Elastic Compression Correction for Single Level Test (SI Units)

Given:

C_1 = 0.441
AE = 17000 MN (assumed constant throughout test)
ℓ_0 = 1.80 m
ℓ_1 = 14.69 m (embedded length of shaft above O-cell™)
ℓ_2 = 0.00 m
ℓ_3 = 0.00 m
Shear reduction factor = 1.00 (cohesive soil)

Δ_{OLT} (mm)	$Q'_{\downarrow A}$ (MN)	$Q'_{\uparrow A}$ (MN)	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



APPENDIX D

O-CELL^{TM} METHOD FOR DETERMINING CREEP LIMIT

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 2 to 4 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.

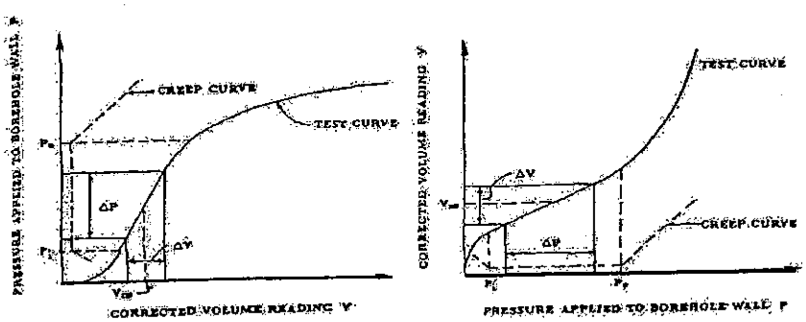


FIG. 8 Pressuremeter Test Curves for Procedure A

References

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

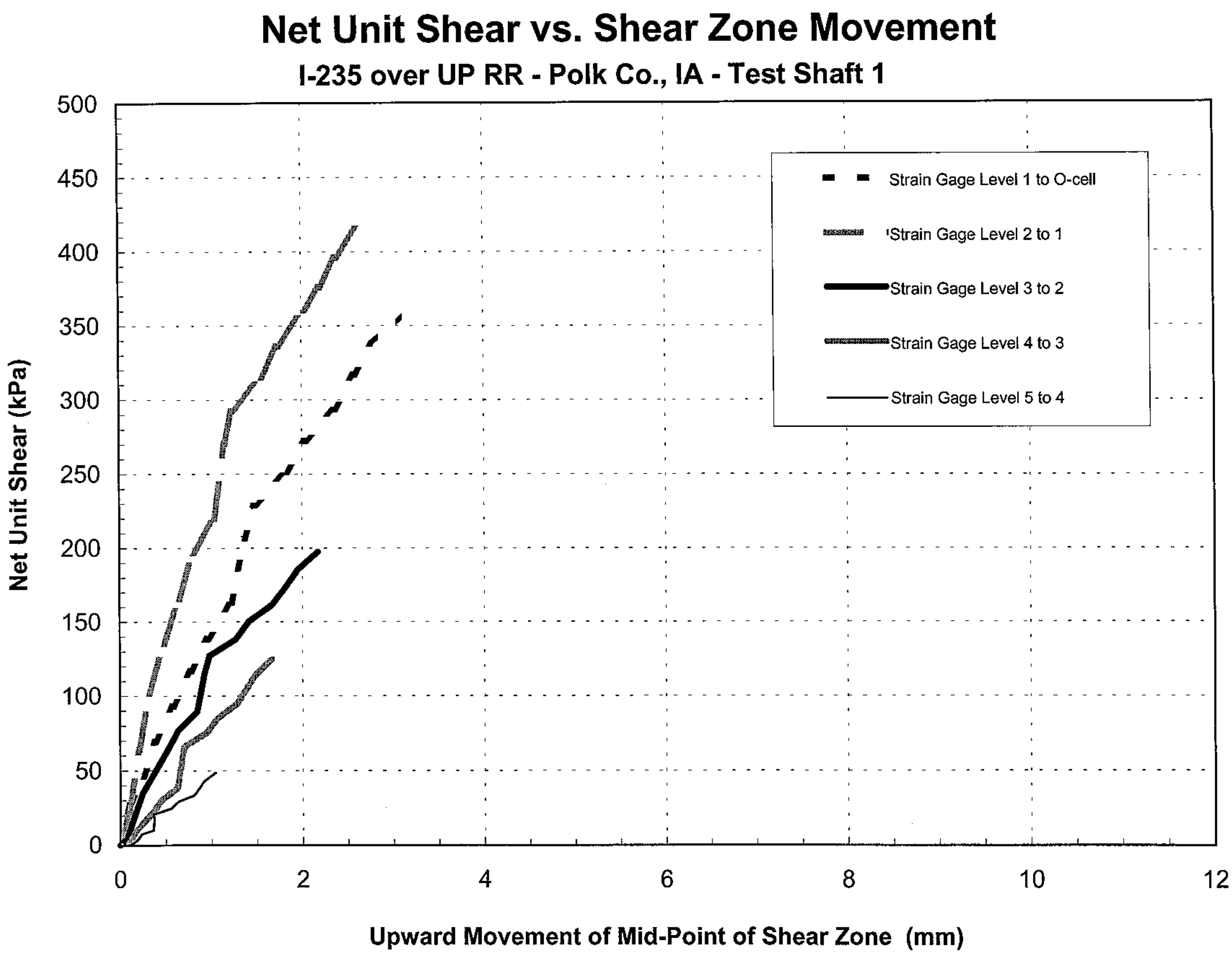
Stoll, M.U.W. (1961, Discussion, Proc. 5th ICSMFE, Paris, Vol. III, pp. 279-281.

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

NET UNIT SHEAR VERSUS UPWARD O-CELL™ MOVEMENT CURVES



Net Unit Shear vs. Shear Zone Movement
I-235 over UP RR - Polk Co., IA - Test Shaft 1
Net Unit Shear (kPa)
500
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Upward Movement of Mid-Point of Shear Zone (mm)
Strain Gage Level 1 to O-cell
Strain Gage Level 2 to 1
Strain Gage Level 3 to 2
Strain Gage Level 4 to 3
Strain Gage Level 5 to 4

Figure E-1

APPENDIX F

POST-TEST O-CELL™ GROUTING

POST-TEST GROUTING PROCEDURES FOR PRODUCTION DRILLED SHAFTS TESTED WITH AN OSTERBERG CELL

During the O-cell™ test the shaft breaks, on a horizontal plane, separating the upper section above the O-cell™ (upper side-shear) from the lower section below the O-cell™ (combined end bearing and lower side shear). This creates an annular space, the size of which depends on the shaft/O-cell™ geometry and the expansion of the O-cell™.

When a production shaft has been tested, the engineer may want to include the end bearing component from the lower section in order to obtain sufficient capacity of the production shaft. In such cases the contractor will be required to grout the O-cell™ and the annular space around the O-cell™ in order to allow load transfer to the lower side shear and end bearing.

POST-TEST GROUTING OF OSTERBERG CELLS

a) The grout shall consist of Portland cement and water only, **NO SAND**. The grout shall be fluid and pumpable. An initial mix consisting of 4 to 6 gallons of water per 95-lb bag of cement is recommended. Adjust water to obtain desired consistency.
b) The mixing shall be thorough to ensure that there are no lumps of dry cement. Pass the grout through a window screen mesh before pumping.
c) Connect the grout pump outlet to one hydraulic line of the O-cell™. Open the other line and establish a flow of water through the system.
d) Pump the grout through the O-cell™ hydraulic line while collecting the effluent from the bleed line. Monitor characteristics of effluent material and when it becomes equivalent to the grout being pumped, stop pumping.
e) Take three samples of the grout for compression testing @ 28 days, if required.

Recommended pre-mixed amount of grout for grouting of O-cell™:				
O-cell Diameter (Inches)	13	21	26	34
Grout Volume (Cubic Feet)	4	7	9	13

POST-TEST GROUTING OF ANNULAR SPACE AROUND OSTERBERG CELLS

a) Prepare a fluid grout mix consisting of Portland cement and water only, **NO SAND**. The mixing procedures should be as outlined for grouting the O-cells™. The quantity of grout should be at least three (3) times the theoretical volume required to fill the annular space and grout pipes.
b) Pump water and establish a flow through each of the PVC grout pipes (two or three per shaft).
c) Pump the fluid grout through one of the PVC pipes until the grout is observed flowing from the second grout pipe or until 1.5 times the theoretical volume has been pumped.
d) If no return of grout is observed from the second grout pipe, transfer the pump to the second pipe and pump grout through it until 1.5 times the theoretical volume has been pumped.
e) If higher strength grout is deemed necessary, immediately proceed with pumping the higher strength grout (which may be a sand mix). The pumping procedures for this grout will be the same as described above for the initial cement-water grout. **The entire grouting operation must be completed before the set time for the initial grout has elapsed.**
f) Take three (3) samples of each type of grout for compression testing @ 28 days.

Recommended pre-mix amount of grout for grouting of annular space:								
Shaft Diameter (Feet)	2	3	4	5	6	7	8	9
Grout Volume (Cubic Feet)	25	30	40	50	65	80	100	125

APPENDIX G

SOIL BORING LOG

BORING LOG No. TB-1

BORING NO.	LOCATION OF BORING	ELEVATION	DATUM	DRILLER	LOGGER
TB-1	Staked location by others	248 meters	Assumed	Dean Heldt	Aaron Smiley

WATER LEVEL OBSERVATIONS				TYPE OF SURFACE	DRILL RIG
WHILE DRILLING	END OF DRILLING	24 HOURS AFTER DRILLING		Grass	B-57
				DRILLING METHOD	**TOTAL DEPTH**
				8.26 cm Hollow stem augers	24.69 meters

DEPTH meters	SAMPLE No	SPT "N"	REC %	RQD %	SOIL DESCRIPTION: COLOR, MOISTURE, CONSISTENCY, MATERIAL DESCRIPTION & REMARKS, GEOLOGICAL ORIGIN	Layer depth	USCS CLASS	MC %	DRY DENSITY kg/m3	Qu kPa	DEPTH meters
					Light gray, CLAY SHALE						
15	NQ2-2		75	73							15
					Light gray, CALCAREOUS SILTSTONE	14.9					
					Light gray, CLAY SHALE	15.2		10.6	2090	996	
								12.3	1953	408	
16.5	NQ2-3		58	56							16.5
								14.9	1836	357	
18	NQ2-4		91	78				13.5	1897	278	18
								8.8	2066	693	
19.5	NQ2-5		85	53				5.4	2266	180	19.5
					Light gray, CALCAREOUS SILTSTONE	19.7					
					Black, COAL with vitreous texture	19.9					
21	NQ2-6		100	31	Light gray, CLAY SHALE	20.8		8.6			21
								10.3	2029	429	
22.5	NQ2-7		100	15				16.0	1823	126	22.5
					Black, CARBONIFEROUS CLAY SHALE	23.1		8.8	2114	4091	
24	NQ2-8		83	37				8.5	2087	9184	24
					PENNSYLVANIAN BEDROCK	24.7					
					Bottom of Boring at 24.69 meters						
25.5											25.5
27											27

GS Geotechnical Services Inc.
2853 99th Street, Des Moines, IA 50322-3858
(515) 270-6542 • FAX (515) 270-1911

PROJECT: Drilled shaft demonstration project for Osterberg
LOCATION: Interstate 235 over UP railroad tracks
JOB NO.: 036216
DATE: 1/06/04

BORING LOG No. TB-1

BORING NO.	LOCATION OF BORING	ELEVATION	DATUM	DRILLER	LOGGER
TB-1	Staked location by others	248 meters	Assumed	Dean Heldt	Aaron Smiley

WATER LEVEL OBSERVATIONS				TYPE OF SURFACE	DRILL RIG
WHILE DRILLING	END OF DRILLING	24 HOURS AFTER DRILLING		Grass	B-57
				DRILLING METHOD	**TOTAL DEPTH**
				8.26 cm Hollow stem augers	24.69 meters

DEPTH meters	SAMPLE DATA: SAMPLE No	SPT "N"	REC %	RQD %	SOIL DESCRIPTION: COLOR, MOISTURE, CONSISTENCY MATERIAL DESCRIPTION & REMARKS / GEOLOGICAL ORIGIN	USCS CLASS	LABORATORY DATA: MC %	DRY DENSITY kg/m3	Qu kPa	DEPTH meters
0					Light brownish gray, Mottled rust, Moist, Firm SILTY SANDY LEAN CLAY, trace fine gravel	CL				0
1.5	S1	5					16.7			1.5
					WISCONSINAN SUPRAGLACIAL TILL — 2.4					
					Dark gray, Moist, Stiff SILTY LEAN CLAY, trace white shell fragments	CL				
3	S2	11					25.9			3
					WISCONSINAN SUPRAGLACIAL TILL — 3.9					
					Dary gray, Moist, Very stiff SILTY SANDY LEAN CLAY, trace fine gravel	CL				
4.5	S3	16					20.3			4.5
6	S4	12					20.3			6
7.5	S5	13					21.3			7.5
9	S6	16					19.9			9
10.5	S7	19					20.6			10.5
12	S8	50/ 13cm			WISCONSINAN SUBGLACIAL TILL — 12.3		17.3			12
					Dark gray, Very moist, Very dense WELL GRADED GRAVEL WITH SAND	GW				
					WISCONSINAN GLACIAL DRIFT — 12.8					
					Light gray, CLAY SHALE — 13.2					
					— 13.5					
13.5	NQ2-1		74	30	Black, CARBONIFEROUS CLAY SHALE with traces of pyritization		12.9	2046	1906	13.5

Geotechnical Services Inc.

2853 99th Street, Des Moines, IA 50322-3858
(515) 270-6542 • FAX (515) 270-1911

PROJECT: Drilled shaft demonstration project for Osterberg
LOCATION: Interstate 235 over UP railroad tracks
JOB NO.: 036216
DATE: 1/06/04

BORING LOG No. TB-1

BORING NO.	LOCATION OF BORING	ELEVATION	DATUM	DRILLER	LOGGER
TB-1	Staked location by others	248 meters	Assumed	Dean Heldt	Aaron Smiley

WATER LEVEL OBSERVATIONS				TYPE OF SURFACE	DRILL RIG
WHILE DRILLING	END OF DRILLING	24 HOURS AFTER DRILLING		Grass	B-57
				DRILLING METHOD	**TOTAL DEPTH**
				8.26 cm Hollow stem augers	24.69 meters

DEPTH meters	SAMPLE DATA: SAMPLE No	SPT "N"	REC %	RQD %	SOIL DESCRIPTION: COLOR, MOISTURE, CONSISTENCY, MATERIAL DESCRIPTION & REMARKS, GEOLOGICAL ORIGIN		USCS CLASS	LABORATORY DATA: MC %	DRY DENSITY kg/m3	Qu kPa	DEPTH meters
					Light gray, CLAY SHALE						
15	NQ2-2		75	73		14.9					15
					Light gray, CALCAREOUS SILTSTONE	15.2					
					Light gray, CLAY SHALE			10.6	2090	996	
								12.3	1953	408	
16.5	NQ2-3		58	56							16.5
								14.9	1836	357	
18	NQ2-4		91	78				13.5	1897	278	18
								8.8	2066	693	
19.5	NQ2-5		85	53							19.5
						19.7		5.4	2266	180	
					Light gray, CALCAREOUS SILTSTONE	19.9					
					Black, COAL with vitreous texture						
						20.8					
21	NQ2-6		100	31	Light gray, CLAY SHALE			8.6			21
								10.3	2029	429	
22.5	NQ2-7		100	15							22.5
								16.0	1823	126	
						23.1					
					Black, CARBONIFEROUS CLAY SHALE			8.8	2114	4091	
24	NQ2-8		83	37				8.5	2087	9184	24
					PENNSYLVANIAN BEDROCK	24.7					
					Bottom of Boring at 24.69 meters						
25.5											25.5
27											27

Geotechnical Services Inc.
2853 99th Street, Des Moines, IA 50322-3858
(515) 270-6542 • FAX (515) 270-1911

PROJECT: Drilled shaft demonstration project for Osterberg
LOCATION: Interstate 235 over UP railroad tracks
JOB NO.: 036216
DATE: 1/06/04