REPORT ON DRILLED SHAFT
LOAD TESTING (OSTERBERG METHOD)

Dedicated Test Shaft - I-235 over Des Moines River
Des Moines, IA (LT-8854)

Prepared for: Jensen Construction Company
5550 NE 22nd Street
Des Moines, IA

Attention: Mr. Dan Timmons

PROJECT NUMBER: LT-8854, November 18, 2002

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

November 18, 2002

Jensen Construction Company
5550 NE 22nd Street
Des Moines, IA

Attention: Mr. Dan Timmons

Load Test Report: Dedicated Test Shaft - I-235 over Des Moines River
Location: Des Moines, IA (LT-8854)

Dear Mr. Timmons,

The enclosed report contains the data and analysis summary for the O-cell™ test performed on Dedicated Test Shaft - I-235 over Des Moines River, on November 8, 2002. 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 the information contained herein will suit your current project needs. If you have any questions or require further technical assistance, please do not hesitate to contact us at 800-368-1138.

Best Regards,

_____
Michael D. Ahrens, P.E.
For LOADTEST, Inc.

EXECUTIVE SUMMARY

On November 8, 2002, we tested a 1060-mm (42-inch) dedicated test shaft constructed by Jensen Construction Company. Mr. Robert C. Simpson and Mr. Denton A. Kort of LOADTEST, Inc. carried out the test. Jensen Construction Company completed excavation and concreting of the 22.70-meter (74.5-foot) deep shaft socketed in clay shale under water on October 25, 2002. Sub-surface conditions at the test shaft location consist of overburden soils underlain by clay shale. Representatives of the Iowa Department of Transportation observed construction and testing of the shaft.

The maximum bi-directional load applied to the shaft was 19.01 MN (4,273 kips). At the maximum load, the displacements above and below the O-cell™ were 46.31 mm (1.823 inches) and 38.21 mm (1.504 inches), respectively. Unit shear data calculated from strain gages indicated an average net unit side shear of 671 kPa (14.0 ksf) between the O-cell™ and the tip of the outer isolation casing. Using this average side shear data, we calculate a maximum applied end bearing pressure of 18,083 kPa (378 ksf).

Using the procedures described in the report text and in Appendix C, we constructed an equivalent top load curve for the test shaft. For a top loading of 18.0 MN (4,038 kips), the adjusted test data indicate this shaft would settle approximately 12.7 mm (0.50 inches) of which 10.8 mm (0.42 inches) is estimated elastic compression.

LIMITATIONS OF EXECUTIVE SUMMARY

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

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SITE CONDITIONS AND SHAFT CONSTRUCTION

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

Test Shaft Construction: Jensen Construction Company began excavation of the dedicated test shaft socketed in clay shale on October 21, 2002 and performed the final cleanout and concreting on October 25, 2002. We understand that the 1,060-mm (42-inch) test shaft was excavated to a tip elevation of +222.75 meters (+730.8 feet) under water. The shaft was started with a 1549-mm (61-inch) O.D. temporary casing and a 1245-mm (49-inch) O.D. permanent casing was inserted as the drilling progressed. An auger and core barrel were used for drilling the shaft. The bottom of the shaft was cleaned with a bucket and airlift after drilling. After cleaning the base, approximately 2.7 meters (9 feet) of the concrete was pumped in the base of the excavation and the reinforcing cage with attached O-cell™ assembly was lowered into the fluid concrete. The remainder of the concrete was then delivered by pump until reaching the cutoff elevation of +244.90 meters (+803.5 feet). No unusual problems occurred during construction of the shaft. Representatives of the Iowa Department of Transportation observed construction of the shaft.

OSTERBERG CELL TESTING

Shaft Instrumentation: Test shaft instrumentation and assembly was carried out under the direction of Mr. John Graman of LOADTEST, Inc. on October 21 and 22, 2002. The loading assembly consisted of one 870-mm O-cell™ located 1.39 meters (4.6 feet) above the tip of shaft. The Osterberg cell was calibrated to 13.8 MN (3,090 kips) and then welded closed prior to shipping by American Equipment and Fabricating Corporation. Calibrations of O-cell™ and instrumentation used for this test are included in Appendix B.

Standard O-cell™ testing instrumentation included three Linear Vibrating Wire Displacement Transducers (LVWDTs) – (Geokon Model 4450 series) positioned between the lower and upper plates of the O-cell™ assembly to measure expansion (Appendix A, Page 3). Compression of the rock socket was measured by four pairs of Embedded Compression Telltales (ECTs), consisting of telltale rods in ½-inch steel casings, with an LVWDT attached (Appendix A, Pages 1 and 2). One pair was positioned below the O-cell™ and three pairs above. One telltale casing was also installed extending between the top of the O-cell™ assembly and the top of concrete.

Strain gages were used to assess the side shear load transfer of the shaft above and below the Osterberg cell assembly. One level of two sister bar vibrating wire strain gages (Geokon Model 4911 Series) were installed, 180 degrees apart, in the shaft below the base of the O-cell™ assembly and four levels of two were installed in the shaft above it. Details concerning the strain gage placement appear in Table B and Figure A. The strain gages were positioned as directed by the Iowa Department of Transportation.

One length of steel pipe was also installed, extending from the top of the shaft to the top of the bottom plate, to vent the break in the shaft formed by the expansion of the O-cell™.

Test Arrangement: Throughout the load test, key elements of shaft response were monitored using the equipment and instruments described herein. Shaft compression was measured using telltales (described under Shaft Instrumentation) monitored by LVWDTs. Two LVWDTs attached to a reference system were used to monitor the top of shaft movement (Appendix A, Page 1).

The reference system consisted of steel wide flange section supported on wooden dunnage. The supports were located approximately three shaft diameters from the center of the test shaft. The beam was fully shaded for the duration of the test. An automated digital survey level (Leica NA 3003) was used to monitor the reference beam for movement during testing from a distance of approximately 10.6 meters (34.6 feet) (Appendix F). A maximum movement range of 0.38 mm (0.015 inches) was observed for the reference beam. The top of shaft movements have been corrected for movement of the reference system (Appendix A, Page 1).

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

Data Acquisition: All instrumentation were connected through a data logger (Data Electronics - Model 615 Datataker®), to a laptop computer, allowing data to be recorded and stored automatically at 30 second intervals and displayed in real time. A separate laptop computer synchronized to the data logging system was used to acquire the Leica NA3003 data.

Testing Procedures: As with all of our tests, we begin by pressurizing the O-cell™ in order to break the tack welds that hold it closed (for handling and for placement in the shaft) and to form the fracture plane in the concrete surrounding the base of the O-cell™. After the break occurs, we immediately release the pressure and then begin the loading procedure. Zero readings for all instrumentation are taken prior to

the preliminary weld-breaking load-unload cycle, which in this case involved a maximum applied pressure of 4.14 MPa (600 psi) to the O-cell™.

The Osterberg cell load test was conducted as follows: We pressurized the 870-mm (34-inch) diameter O-cell™, with its base located 1.39 meters (4.6 feet) above the base of shaft to assess the combined end bearing and lower side shear below the O-cell™ and the upper side shear above. We pressurized the O-cell™ in 14 loading increments to 47.78 MPa (6,930 psi) resulting in a bi-directional gross O-cell™ load of 19.01 MN (4,273 kips). The loading was halted after load interval 1L-14 because the upper side shear was approaching ultimate capacity. The O-cell™ was depressurized in four decrements. The O-cell™ was then repressurized in five loading increments to a bi-directional gross O-cell™ load of 18.19 MN (4,089 kips) at 2L-5. At that point, the nominal 150 mm stroke of the O-cell™ was exceeded. The O-cell™ was depressurized in one decrement and the test was concluded.

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

TEST RESULTS AND ANALYSES

General: The loads applied by the O-cell™ act in two opposing directions, resisted by the capacity of the shaft above and below. Theoretically, the O-cell™ does not impose an additional upward load until its expansion force exceeds the buoyant weight of the shaft above the O-cell™. Therefore, *net load*, which is defined as gross O-cell™ load minus the buoyant weight of the shaft above, is used to determine side shear resistance above the O-cell™ and to construct the equivalent top-loaded load-settlement curve. For this test we calculated a buoyant weight of shaft of 0.43 MN (97 kips) above the O-cell.

Side Shear Resistance: The maximum upward applied *net load* to the upper side shear was 18.58 MN (4,177 kips) which occurred at load interval 1L-14 (Appendix A, Page 4, Figure 1). At this loading, the upward movement of the O-cell™ top was 46.31 mm (1.823 inches).

In order to assess the side shear resistance of the test shaft, loads are calculated based on the strain gage data (Appendix A, Pages 5 and 6) and estimates of shaft stiffness (AE), which are presented below and in Appendix H. We used the ACI formula ($E_c=57000\sqrt{f'_c}$) to calculate an elastic modulus for the concrete, where f'_c on

the day of the test was reported to be 23.72 MPa (3,440 psi) above the O-cell™ and 34.41 MPa (4,990 psi) below. This, combined with the area of reinforcing steel and nominal shaft diameter, provided an average shaft stiffness (AE) of 39,300 MN (8,830,000 kips) in the permanently cased section above the O-cell™, 22,700 MN (5,090,000 kips) in the uncased section above the O-cell™ and 26,700 MN (6,010,000 kips) below the O-cell™. The calculated value for the uncased section above the O-cell™ agrees with our tangent stiffness analysis in Appendix H. Net unit shear curves are presented in Appendix G. Net unit shear values for loading increment 1L-14 follow in Table A:

TABLE A: Average Net Unit Side Shear Values for 1L-14

Load Transfer Zone	Load Direction	Net Unit Side Shear *
Average Upper Side Shear	↑	**671 kPa (14.0 ksf)**
Zero Shear to Strain Gage Level 5	↑	448 kPa (9.4 ksf)
Strain Gage Level 5 to Strain Gage Level 4	↑	899 kPa (18.8 ksf)
Strain Gage Level 4 to Strain Gage Level 3	↑	851 kPa (17.8 ksf)
Strain Gage Level 3 to Strain Gage Level 2	↑	178 kPa (3.7 ksf)
Strain Gage Level 2 to O-cell™ **	↑	1297 kPa (27.1 ksf)
O-cell™ to Strain Gage Level 1 **	↓	3940 kPa (82.3 ksf)

* For upward-loaded shear, the buoyant weight of shaft in each zone has been subtracted from the load shed in the respective zone above the O-cell™. An additional correction is made for the weight of the permanently cased, unsupported length of shaft.

** Note that due to the proximity of SG levels 1 and 2 to the O-cell™, the unit side shear values indicated by the analysis of strain gage data in theses zones yielded unusually high unit values. In the analyses that follow, we have assumed a constant unit shear distribution (average shear) in the clay shale socket.

Combined End Bearing And Lower Side Shear Resistance: The maximum O-cell™ load applied to the combined end bearing and lower side shear was 19.01 MN (4,273 kips) which occurred at load interval 1L-14 (Appendix A, Page 4, Figure 1). At this loading, the average downward movement of the O-cell™ base was 38.21 mm (1.504 inches). The load taken in shear by the 1.39 meters (4.6 feet) shaft section below the O-cell™ is calculated to be 3.05 MN (686 kips) assuming an unit side shear value of 659 kPa (13.8 ksf) and a nominal 1,060-mm (42-inch) shaft diameter. Note that the average upper side shear is used in this analysis to estimate the shear below the O-cell™. The applied load to end bearing is then 15.96 MN (3,588 kips) and the unit end bearing at the base of the shaft is calculated to be 18,083 kPa (378 ksf) at the above noted displacement. A unit end bearing curve is presented in Appendix G.

Creep Limit: See Appendix D for our O-cell™ method for determining creep limit. The combined end bearing and lower side shear creep data (Appendix A, Page 4) indicate that a creep limit of 10.5 MN (2,361 kips) was reached at a movement of 5.9 mm (0.23 inches) (Figure 4). The upper side shear creep data (Appendix A, Page 4) indicate that a creep limit of 12.4 MN (2,788 kips) was reached at a movement of 6.1

mm (0.24 inches) (Figure 5). A top-loaded shaft will not begin significant creep until both components begin creep movement. This will occur at the maximum of the movements required to reach the creep limit for each component. We believe that significant creep for this shaft will not begin until a top loading exceeds 22.8 MN (5,119 kips).

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

The test shaft was loaded to a combined side shear and end-bearing load of 37.6 MN (8,450 kips). For a top loading of 18.0 MN (4,038 kips), the adjusted test data indicate this shaft would settle approximately 12.7 mm (0.50 inches) of which 10.8 mm (0.42 inches) is estimated elastic compression. For a top loading of 28.1 MN (6,310 kips) the adjusted test data indicate this shaft would settle approximately 25.4 mm (1.00 inches) of which 16.9 mm (0.67 inches) is estimated elastic compression.

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

Shaft Compression Comparison: The measured shaft compression from ECT levels 2, 3 and 4 (averaged from side A & B) is 3.14 mm (0.124 inches) at 1L-14 (Appendix A, Pages 1 and 2). Using a shaft stiffness of 39,300 MN (8,830,000 kips) and an assumed constant shear distribution, we calculated an elastic compression of 3.15 mm (0.124 inches) over the length of the compression telltales. We believe this excellent agreement provides good evidence that the values of the estimated shaft stiffness are reasonable and that the O-cell™ loaded the shaft in accord with its calibration.

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

_____
Michael D. Ahrens, P.E.
Geotechnical Engineer, LOADTEST, Inc.

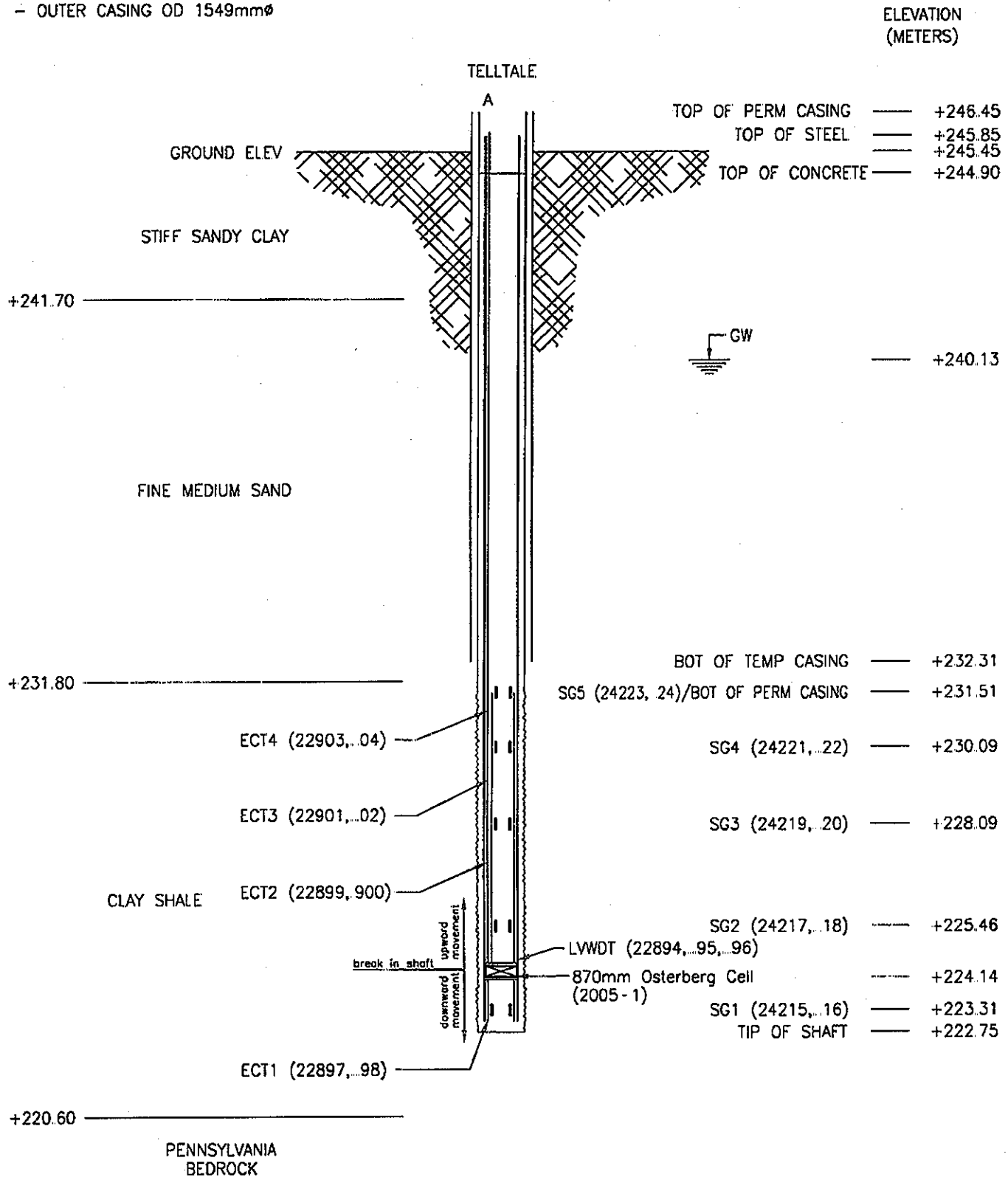
Reviewed by

_____
Denton A. Kort, P.E.
Geotechnical Engineer, LOADTEST, Inc.

TABLE B:
SUMMARY OF DIMENSIONS, ELEVATIONS & SHAFT PROPERTIES

Shaft:			
Nominal shaft diameter (EL +246 45 m to +231 51 m)	=	1245 mm	49 in
Nominal shaft diameter (EL +231 51 m to +222 75 m)	=	1060 mm	42 in
O-cell™: 2005-1	=	870 mm	34 in
Bouyant weight of pile above base of O-cell™	=	0 43 MN	97 kips
Estimated shaft stiffness, AE (EL +244 90 m to +231 51 m)	=	39 300 MN	8,830 000 kips
Estimated shaft stiffness, AE (EL +231 51 m to +224 14 m)	=	22 700 MN	5,090,000 kips
Estimated shaft stiffness, AE (EL +224 14 m to +222 75 m)	=	26 700 MN	6,010 000 kips
Elevation of ground surface	=	+245 45 m	+805 3 ft
Elevation of top of shaft concrete	=	+244 90 m	+803 5 ft
Elevation of water table	=	+240 13 m	+787 8 ft
Elevation of base of O-cell™ (The break between upward and downward movement)	=	+224 14 m	+735 4 ft
Elevation of shaft tip	=	+222 75 m	+730 8 ft
Casings:			
Elevation of top of permanent casing (1245 mm O D., 1220 mm I D)	=	+246 45 m	+808 6 ft
Elevation of bottom of permanent casing (1245 mm O.D., 1220 mm I D)	=	+231 51 m	+759 6 ft
Elevation of top of outer temporary casing (1549 mm O D.)	=	+246 45 m	+808 6 ft
Elevation of bottom of outer temporary casing (1549 mm O D)	=	+232 31 m	+762 2 ft
Compression Sections:			
Elevation of top of telltale used for upper shaft compression	=	+244 90 m	+803 5 ft
Elevation of top of telltale used for upper shaft compression	=	+224 48 m	+736 5 ft
Elevation of top of ECT used for level 4 shaft compression	=	+231 51 m	+759 5 ft
Elevation of bottom of ECT used for level 4 shaft compression	=	+230 09 m	+754 9 ft
Elevation of top of ECT used for level 3 shaft compression	=	+230 09 m	+754 9 ft
Elevation of bottom of ECT used for level 3 shaft compression	=	+228 09 m	+748 3 ft
Elevation of top of ECT used for level 2 shaft compression	=	+228 09 m	+748 3 ft
Elevation of bottom of ECT used for level 2 shaft compression	=	+224 48 m	+736 5 ft
Elevation of top of ECT used for level 1 shaft compression	=	+224 12 m	+735 3 ft
Elevation of bottom of ECT used for level 1 shaft compression	=	+223 31 m	+732 6 ft
Strain Gages:			
Elevation of strain gage Level 5	=	+231 51 m	+759 5 ft
Elevation of strain gage Level 4	=	+230 09 m	+754 9 ft
Elevation of strain gage Level 3	=	+228 09 m	+748 3 ft
Elevation of strain gage Level 2	=	+225 46 m	+739 7 ft
Elevation of strain gage Level 1	=	+223 31 m	+732 6 ft
Miscellaneous:			
Top plate diameter (1 in thickness)	=	870 mm	34 3 in
Bottom plate diameter (1 in thickness)	=	914 mm	36 0 in
ReBar size (16 No)	=	M 32	# 10
Spiral size (305 mm spacing)	=	M 13	# 4
ReBar cage diameter	=	914 mm	36 in
Unconfined compressive concrete strength above O-cell™	=	23 72 MPa	3440 psi
Unconfined compressive concrete strength below O-cell™	=	34 41 MPa	4990 psi
O-cell™ LVWDTs @ 0°, 180° and 270° with radius	=	460 mm	18 1 in

NOTE:
- NOMINAL SHAFT 1060mmø
- INNER CASING OD 1245mmø
- OUTER CASING OD 1549mmø



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SCHEMATIC SECTION OF TEST SHAFT

LT-8854
I-235 over Des Moines R
Des Moines, IA

FIGURE A

Osterberg Cell Load-Movement Curves

Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA

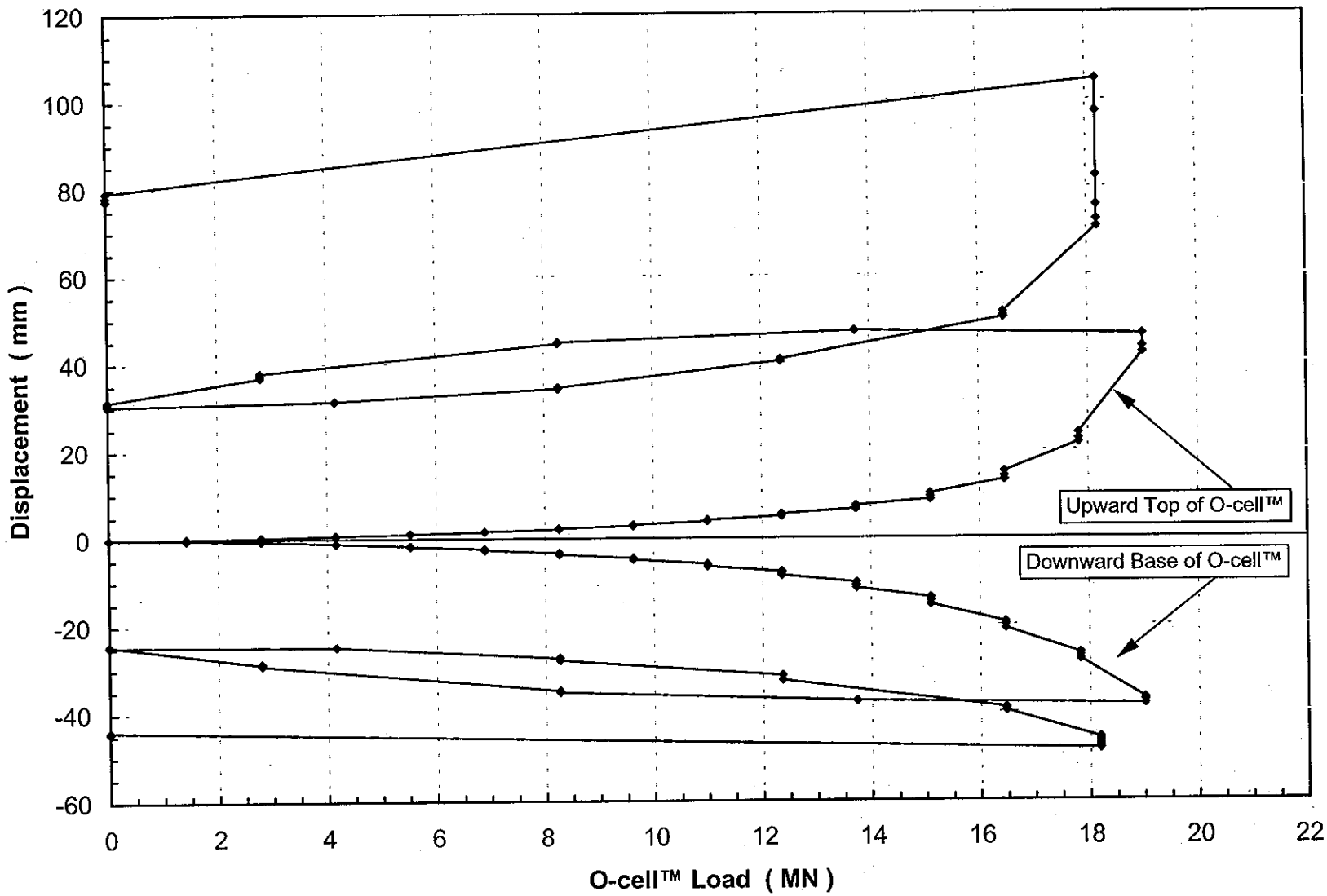

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Figure 1 of 5

Equivalent Top Load Load-Movement Curve

Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA

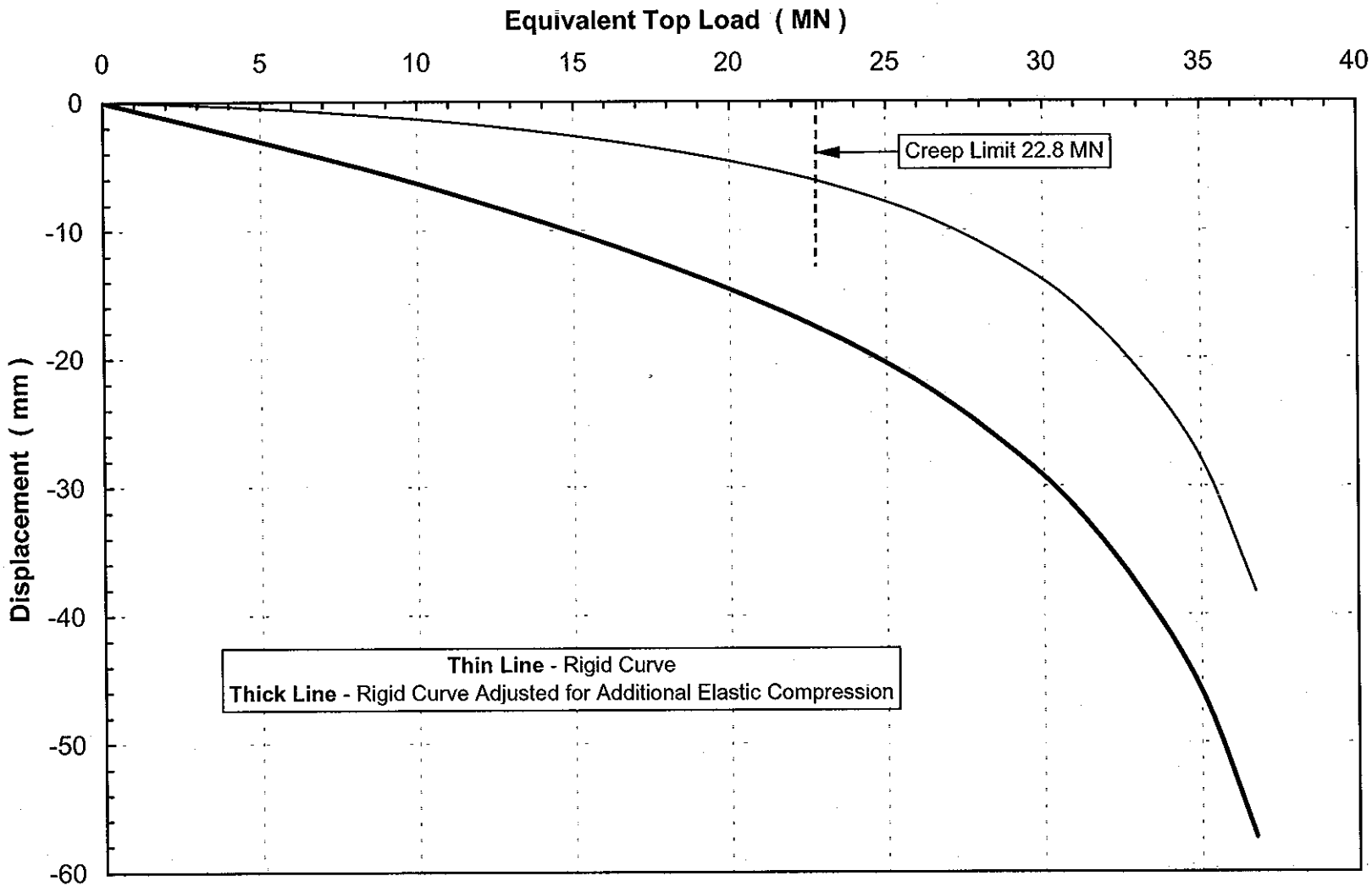

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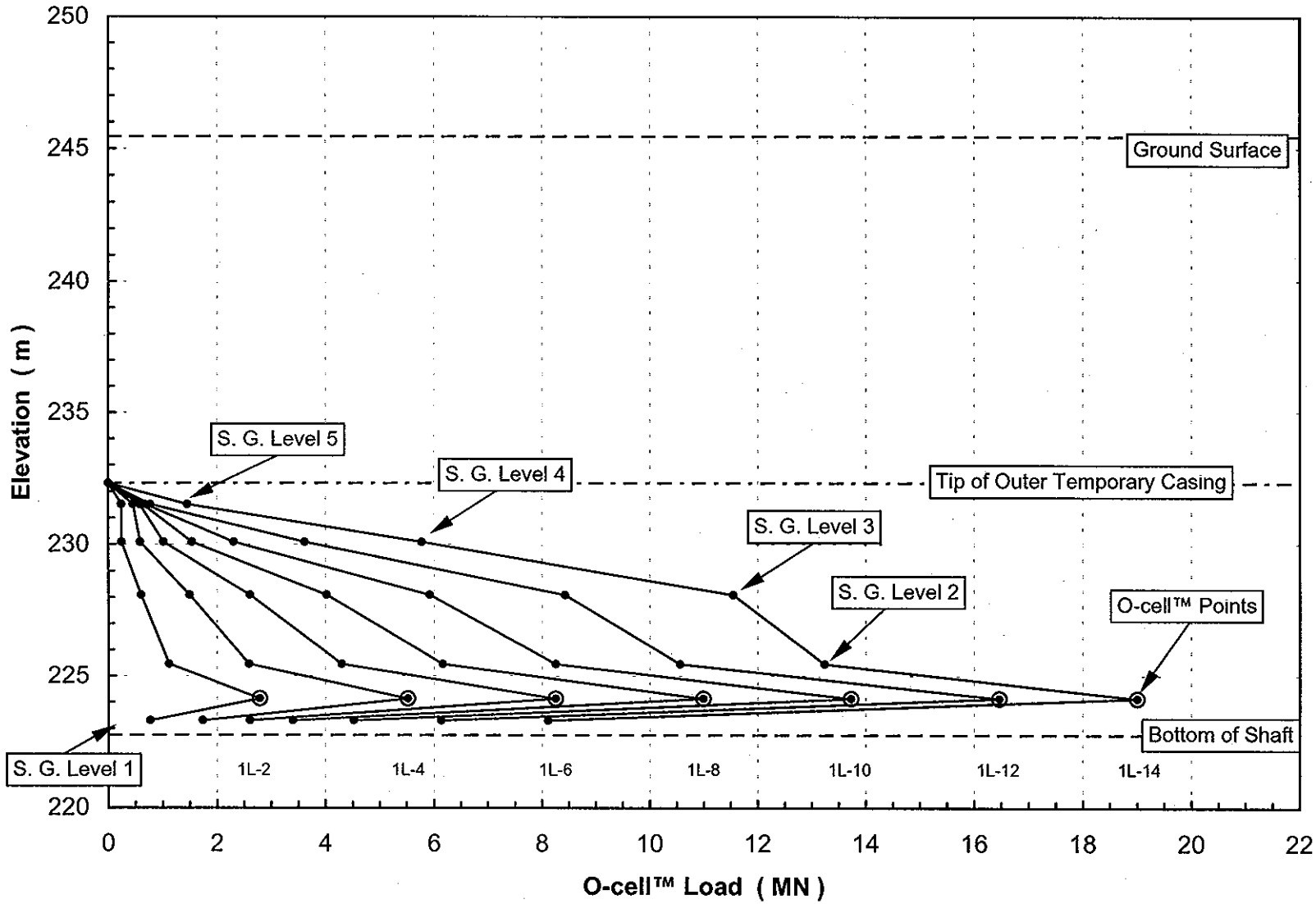
Figure 2 of 5

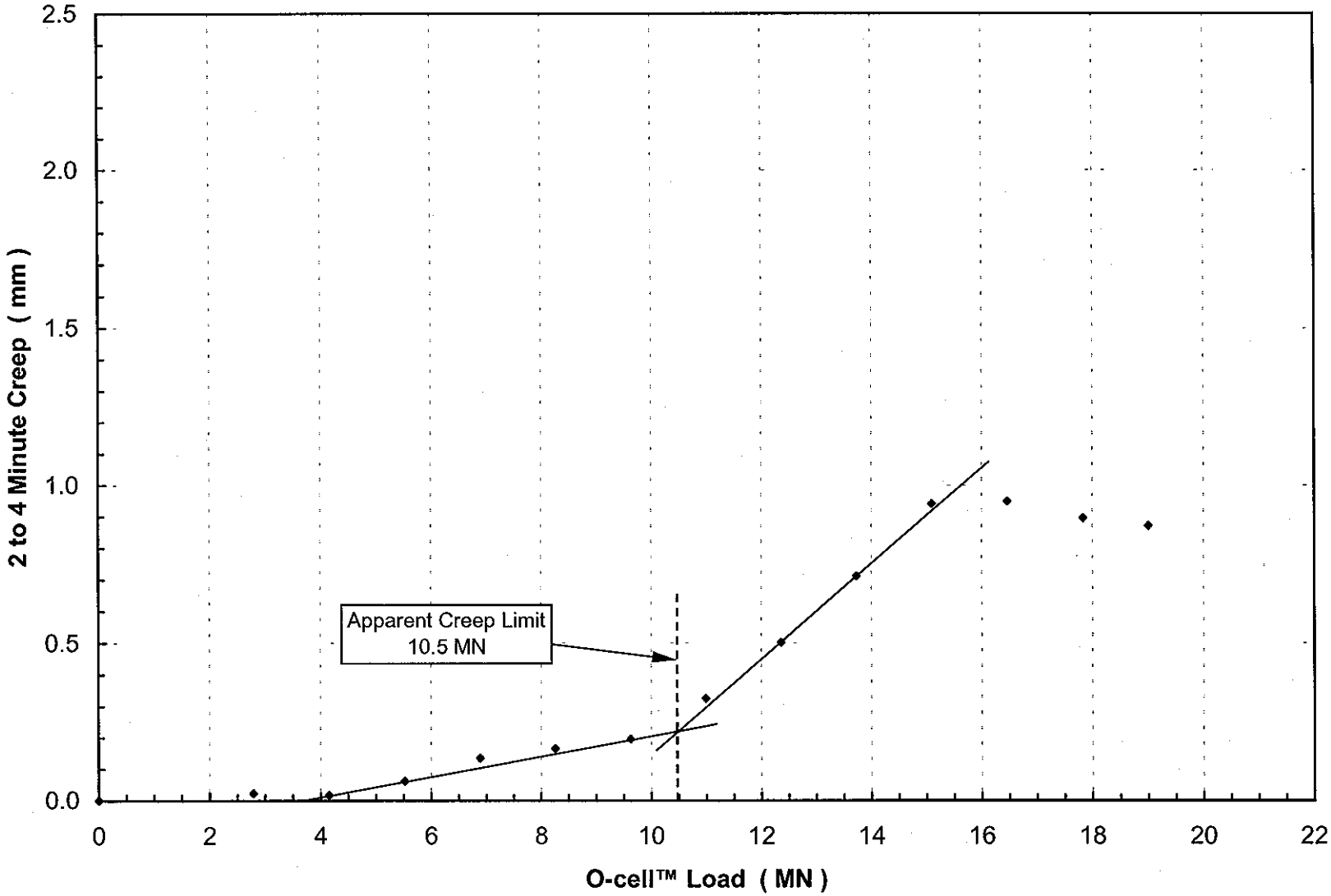
Strain Gage Load Distribution Curves

Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA



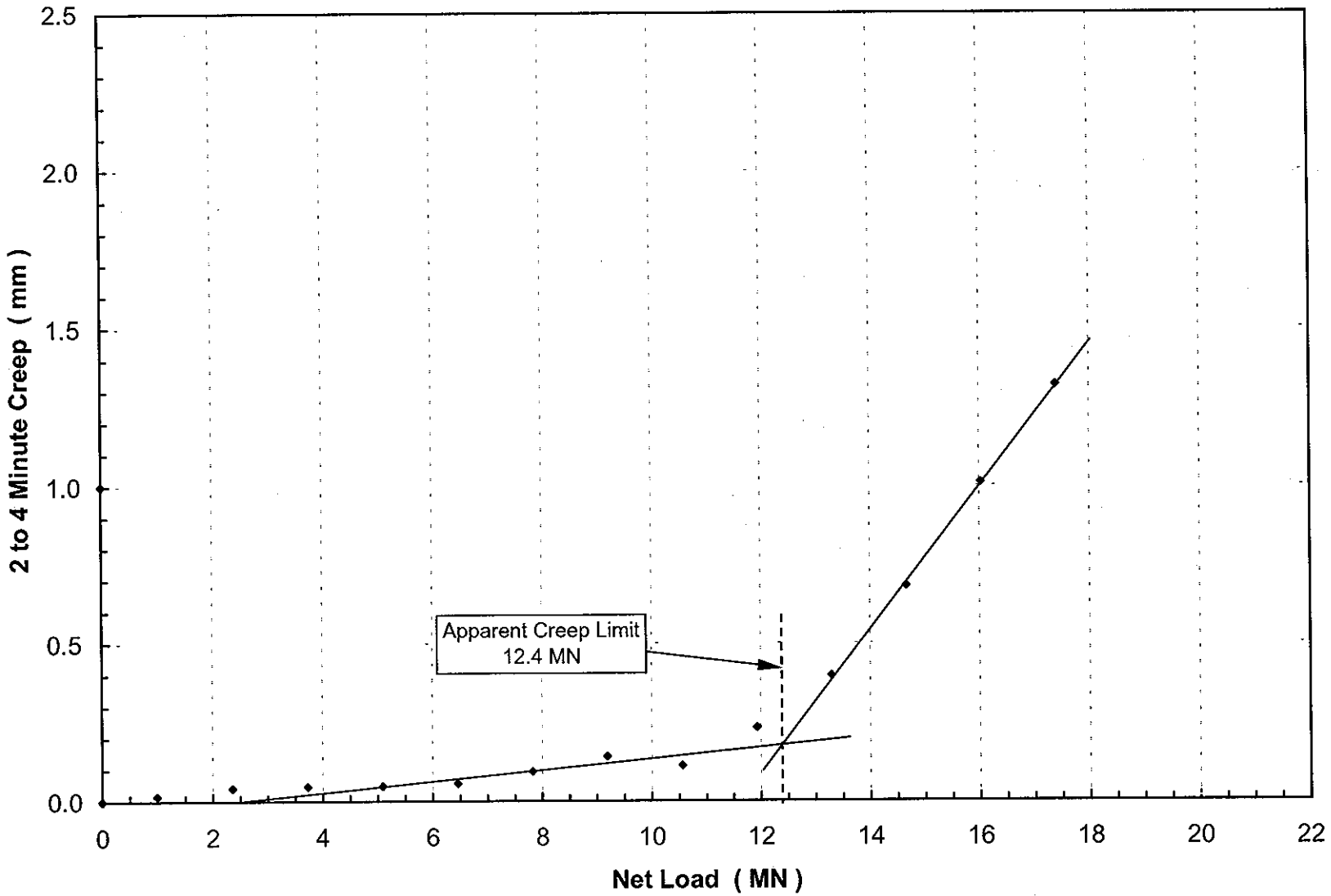
Combined End Bearing and Lower Side Shear Creep Limit

Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA



Upper Side Shear Creep Limit

Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA



LOADTEST, Inc. Project No. LT-8854

Figure 5 of 5

APPENDIX A

FIELD DATA & DATA REDUCTION

Upward Top of Shaft Movement and Shaft Compression
Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell™ Pressure (MPa)	O-cell™ Load (MN)	Ref. Beam (mm)	Top of Shaft ** A (mm)	Top of Shaft ** B (mm)	Top of Shaft ** Average (mm)	TellTale A (mm)	ECT Level 4 22903 (mm)	ECT Level 4 22904 (mm)	ECT Level 4 Average (mm)
1 L - 0	-	11:28:30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 L - 1	1	11:34:00	3.45	1 42	0 01	0 03	0 01	0 03	0 06	0 00	0 00	0 00
1 L - 1	2	11:35:00	3 45	1 42	0 02	0 04	0 01	0 05	0 07	0 00	0 00	0 00
1 L - 1	4	11:37:00	3.45	1 42	0 04	0 04	0 00	0 06	0 07	0 00	0 00	0 00
1 L - 2	1	11:38:00	6.89	2 79	0 04	0 11	0 06	0 13	0 19	0 01	0 01	0 01
1 L - 2	2	11:39:00	6.89	2 79	0 06	0 12	0 07	0 16	0.20	0 01	0 01	0 01
1 L - 2	4	11:41:00	6.89	2 79	0 06	0 15	0 10	0 19	0 21	0 01	0 01	0 01
1 L - 3	1	11:42:00	10 34	4 15	0 08	0 28	0 19	0 31	0 34	0 02	0 02	0 02
1 L - 3	2	11:43:00	10.34	4 15	0 09	0 30	0 21	0 34	0 35	0 02	0 02	0 02
1 L - 3	4	11:45:00	10.34	4 15	0 12	0 31	0 22	0 39	0 35	0 02	0 02	0 02
1 L - 4	1	11:46:00	13.79	5 52	0 13	0 51	0 39	0 58	0.49	0 03	0 03	0 03
1 L - 4	2	11:47:00	13 79	5 52	0 13	0 52	0 40	0 59	0 49	0 03	0 03	0 03
1 L - 4	4	11:49:00	13 79	5 52	0 15	0 55	0 43	0 63	0 49	0 03	0 03	0 03
1 L - 5	1	11:50:00	17 24	6.89	0 15	0.80	0 64	0 87	0 63	0 04	0 04	0 04
1 L - 5	2	11:51:00	17 24	6.89	0 15	0.84	0 70	0 92	0 64	0 04	0 04	0 04
1 L - 5	4	11:53:00	17 24	6.89	0 15	0.88	0 74	0 97	0 65	0 04	0 04	0 04
1 L - 6	1	11:54:00	20 68	8.26	0 16	1 18	1 03	1 26	0 78	0 05	0 05	0 05
1 L - 6	2	11:55:00	20 68	8.26	0 16	1.25	1 10	1 34	0 79	0 06	0 05	0 05
1 L - 6	4	11:57:00	20 68	8 26	0 17	1 32	1 17	1.42	0 81	0 06	0 05	0 05
1 L - 7	1	11:58:30	24 13	9 63	0 18	1 74	1 60	1 85	0 95	0 07	0 06	0 06
1 L - 7	2	11:59:30	24 13	9 63	0 18	1 83	1 68	1 94	0 96	0 07	0 06	0 06
1 L - 7	4	12:01:30	24 13	9 63	0 22	1 91	1 78	2 06	0 98	0 07	0 06	0 07
1 L - 8	1	12:03:00	27 58	10 99	0 24	2 48	2 31	2 63	1 13	0 08	0 07	0 08
1 L - 8	2	12:04:00	27 58	10 99	0 25	2 63	2 43	2 77	1 15	0 08	0 07	0 08
1 L - 8	4	12:06:00	27 58	10 99	0 23	2 76	2 52	2 87	1 16	0 08	0 07	0 08
1 L - 9	1	12:07:30	31 03	12 36	0 21	3 42	3 29	3 56	1 33	0 10	0 08	0 09
1 L - 9	2	12:08:30	31 03	12 36	0 22	3 64	3 50	3.78	1 34	0 10	0 09	0 09
1 L - 9	4	12:10:30	31 03	12 36	0 21	3 85	3 70	3.99	1 36	0 10	0 09	0 09
1 L - 10	1	12:12:30	34 47	13 73	0.20	4 74	4 61	4 88	1 53	0 12	0 10	0 11
1 L - 10	2	12:13:30	34 47	13 73	0 21	5.05	4 91	5.19	1 55	0 12	0 10	0 11
1 L - 10	4	12:15:30	34 47	13 73	0.20	5 43	5.27	5.56	1 58	0 13	0 10	0 11
1 L - 11	1	12:18:30	37 92	15.10	0.19	6 67	6.51	6.78	1 74	0 15	0 12	0 13
1 L - 11	2	12:19:30	37 92	15.10	0 19	7 21	7 05	7 31	1 78	0 15	0 12	0 13
1 L - 11	4	12:21:30	37 92	15 10	0 18	7 87	7 70	7 96	1.80	0 16	0 12	0 14
1 L - 12	1	12:26:00	41 37	16.46	0 18	10 88	10.45	10 85	2.07	0 19	0 14	0 16
1 L - 12	2	12:27:00	41 37	16 46	0 18	11 54	11 37	11 64	2 14	0 19	0 14	0 17
1 L - 12	4	12:29:00	41 37	16.46	0 19	12 54	12 34	12 63	2 15	0 20	0 15	0 17
1 L - 13	1	12:36:00	44 82	17 83	0 19	18 87	18 63	18 94	2 46	0 25	0 18	0 21
1 L - 13	2	12:37:00	44 82	17 83	0 20	19 67	19 44	19 75	2 47	0 25	0 18	0 22
1 L - 13	4	12:39:00	44 82	17 83	0 19	20 97	20 74	21 05	2 49	0 25	0 18	0 22
1 L - 14	1	12:54:00	47 78	19 01	0 27	38 90	38 56	39 00	2 88	0 31	0 25	0 28
1 L - 14	2	12:55:00	47 78	19 01	0 26	40 28	39 95	40 37	2 90	0 30	0 26	0 28
1 L - 14	4	12:57:00	47.78	19.01	0.26	43.08	42.75	43.17	2.94	0.30	0.27	0.28
1 U - 1	1	13:01:00	34 47	13 73	0.26	44 58	44 40	44.75	2 48	0.24	0 22	0 23
1 U - 1	2	13:02:00	34 47	13 73	0 26	44 53	44 36	44 70	2 47	0 24	0 22	0 23
1 U - 1	4	13:04:00	34 47	13 73	0 25	44 52	44 34	44 68	2 47	0 24	0 22	0 23
1 U - 2	1	13:05:00	20 68	8 26	0 24	42 85	42 67	43.00	1 76	0 18	0 14	0 16
1 U - 2	2	13:06:00	20 68	8 26	0 22	42 58	42 43	42 73	1 75	0 18	0 14	0 16
1 U - 2	4	13:08:00	20 68	8 26	0 19	42 53	42 37	42 64	1 75	0 18	0 14	0 16
1 U - 3	1	13:11:00	6.89	2 79	0 14	37 00	36 92	37 10	0.85	0 10	0 03	0 07
1 U - 3	2	13:12:00	6.89	2 79	0 11	36 52	36 46	36 60	0 82	0 10	0 03	0 06
1 U - 3	4	13:14:00	6.89	2 79	0 08	36 05	36 01	36 11	0 79	0 10	0 03	0 06
1 U - 4	1	13:16:30	0 00	0 00	0 06	31 08	31 06	31 13	0 43	0 07	-0 01	0 03
1 U - 4	2	13:17:30	0 00	0 00	0 04	30 71	30 69	30 73	0 42	0 07	-0 01	0 03
1 U - 4	4	13:19:30	0.00	0.00	0.01	30.31	30.31	30.32	0.42	0.06	-0.01	0.03
2 L - 0	-	13:21:00	0.00	0 00	0 00	30.14	30 17	30.16	0 42	0.06	-0 01	0.03
2 L - 1	1	13:24:00	10 34	4 15	0 01	30 70	30 57	30 65	0 77	0 09	0 02	0 05
2 L - 1	2	13:25:00	10 34	4 15	0 02	30 70	30 58	30 66	0 77	0 09	0 02	0 05
2 L - 1	4	13:27:00	10 34	4 15	0 02	30 72	30 60	30 68	0 77	0 09	0 02	0 05
2 L - 2	1	13:30:00	20 68	8 26	0 01	32 94	32 75	32 85	1 30	0 14	0 06	0 10
2 L - 2	2	13:31:00	20 68	8 26	0 00	33 13	32 91	33.02	1 32	0 14	0 06	0 10
2 L - 2	4	13:33:00	20 68	8 26	-0 03	33 21	32 97	33.06	1 31	0 14	0 07	0 10
2 L - 3	1	13:39:00	31 03	12 36	0 08	38 31	38 21	38.34	1 96	0 20	0 14	0 17
2 L - 3	2	13:40:00	31 03	12 36	0 09	38 46	38 23	38 44	1 99	0 20	0 14	0 17
2 L - 3	4	13:42:00	31 03	12 36	0 10	38 71	38 47	38 69	2 00	0 20	0 14	0 17
2 L - 4	1	13:52:00	41 37	16 46	0 14	47 41	47 07	47 38	2 67	0 25	0 25	0 25
2 L - 4	2	13:53:00	41 37	16 46	0 10	47 98	47 61	47 89	2 68	0 25	0 25	0 25
2 L - 4	4	13:55:00	41 37	16 46	0 05	48 78	48 42	48 66	2 69	0 25	0 25	0 25
2 L - 5	1	14:09:00	45 71	18 19	0 15	67 76	67 37	67 71	3 02	0 25	0 33	0 29
2 L - 5	2	14:10:00	45 71	18 19	0 17	69 37	69 07	69 39	3 03	0 24	0 34	0 29
2 L - 5	4	14:12:00	45.71	18 19	0 20	72 69	72 32	72 70	3 03	0 24	0 34	0 29
2 L - 5	8	14:16:00	45.71	18 19	0 23	79.48	79 02	79.48	3 05	0 22	0 36	0 29
2 L - 5	16	14:24:00	45.71	18 19	0 25	94 22	93 70	94 21	3 06	0 20	0 38	0 29
2 L - 5	20	14:28:00	45.71	18.19	0.28	101.61	101.07	101.62	3.07	0.19	0.39	0.29
2 U - 1	1	14:31:00	0 00	0 00	0 13	79 03	78 55	78 93	0.59	-0 02	0 07	0 02
2 U - 1	2	14:32:00	0 00	0 00	0 00	78 16	77 68	77 92	0 57	-0 02	0 07	0 02
2 U - 1	4	14:34:00	0.00	0.00	-0.10	77.42	76.94	77.08	0.56	-0.02	0.07	0.02

* Positive values indicate upward reference beam movement.

** Top of shaft gages went out of range for the 16 and 20-minute holds of 2L-5 Reported values are estimated.

Shaft Compression

Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell™ Pressure (MPa)	O-cell™ Load (MN)	ECT Level 3 22901 (mm)	ECT Level 3 22902 (mm)	ECT Level 3 Average (mm)	ECT Level 2 22899 (mm)	ECT Level 2 22900 (mm)	ECT Level 2 Average (mm)	ECT Level 1 22897 (mm)	ECT Level 1 22898 (mm)	ECT Level 1 Average (mm)
1 L - 0	-	11:28:30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 L - 1	1	11:34:00	3.45	1 42	0 01	0.01	0.01	0 05	0.05	0 05	0 02	0 02	0.02
1 L - 1	2	11:35:00	3.45	1 42	0 01	0.01	0 01	0 05	0 06	0 06	0.02	0 02	0.02
1 L - 1	4	11:37:00	3 45	1 42	0 01	0.01	0 01	0 05	0 06	0 06	0 02	0 02	0.02
1 L - 2	1	11:38:00	6.89	2 79	0 03	0.04	0 03	0 14	0.16	0 15	0 05	0 06	0.06
1 L - 2	2	11:39:00	6.89	2 79	0 03	0.04	0 04	0 15	0 16	0 16	0 05	0 06	0.06
1 L - 2	4	11:41:00	6.89	2 79	0 04	0 04	0 04	0 16	0 17	0 16	0 06	0 07	0.06
1 L - 3	1	11:42:00	10 34	4 15	0 06	0 06	0 06	0 25	0 28	0 26	0 08	0 11	0 09
1 L - 3	2	11:43:00	10 34	4 15	0 06	0 07	0 06	0.25	0 29	0 27	0 08	0 11	0 10
1 L - 3	4	11:45:00	10 34	4 15	0 06	0 07	0 06	0.25	0 29	0 27	0 08	0 11	0 10
1 L - 4	1	11:46:00	13 79	5 52	0 09	0 09	0 09	0 35	0 40	0 37	0 10	0 15	0 13
1 L - 4	2	11:47:00	13 79	5 52	0 09	0 09	0 09	0 35	0.40	0 38	0 10	0 15	0 13
1 L - 4	4	11:49:00	13 79	5.52	0 09	0 09	0 09	0 35	0 41	0 38	0 10	0 16	0 13
1 L - 5	1	11:50:00	17 24	6.89	0 12	0 12	0 12	0 45	0 52	0 49	0 13	0 20	0 16
1 L - 5	2	11:51:00	17 24	6.89	0 12	0 13	0 12	0 46	0 53	0 50	0 12	0 20	0 16
1 L - 5	4	11:53:00	17 24	6.89	0 12	0 13	0 12	0 47	0 54	0 50	0 13	0 20	0 16
1 L - 6	1	11:54:00	20 68	8 26	0 15	0 16	0 15	0 56	0 66	0 61	0 14	0 23	0 19
1 L - 6	2	11:55:00	20 68	8 26	0 15	0 16	0 16	0 57	0 68	0 62	0 15	0 23	0 19
1 L - 6	4	11:57:00	20 68	8 26	0 15	0 17	0 16	0 58	0.69	0 63	0 14	0 24	0 19
1 L - 7	1	11:58:30	24 13	9 63	0 18	0 20	0 19	0 68	0 82	0 75	0 16	0 27	0 22
1 L - 7	2	11:59:30	24 13	9 63	0 19	0 20	0 19	0 68	0 83	0 76	0 16	0 27	0 22
1 L - 7	4	12:01:30	24 13	9 63	0 19	0 21	0 20	0 70	0 85	0 77	0 16	0 27	0 22
1 L - 8	1	12:03:00	27 58	10 99	0 22	0 25	0 23	0 83	0 99	0 91	0 19	0 30	0 24
1 L - 8	2	12:04:00	27 58	10 99	0 22	0 25	0 24	0 83	1 00	0 92	0 19	0 30	0 24
1 L - 8	4	12:06:00	27 58	10 99	0 23	0 25	0 24	0 84	1 01	0 92	0 19	0 30	0 24
1 L - 9	1	12:07:30	31 03	12 36	0 27	0 30	0 28	0 95	1 16	1 06	0 21	0 34	0 27
1 L - 9	2	12:08:30	31 03	12 36	0 27	0 30	0 29	0 96	1 17	1 07	0 21	0 34	0 28
1 L - 9	4	12:10:30	31 03	12 36	0 28	0 31	0 29	0 98	1 20	1 09	0 22	0 34	0 28
1 L - 10	1	12:12:30	34 47	13 73	0 32	0 36	0 34	1 09	1 35	1 22	0 24	0 38	0 31
1 L - 10	2	12:13:30	34 47	13 73	0 32	0 36	0 34	1 10	1 37	1 23	0 25	0 38	0 31
1 L - 10	4	12:15:30	34 47	13 73	0 33	0 37	0 35	1 11	1 39	1 25	0 25	0 38	0 32
1 L - 11	1	12:18:30	37 92	15 10	0 38	0 43	0.40	1 19	1 58	1 38	0 28	0 42	0 35
1 L - 11	2	12:19:30	37 92	15 10	0 39	0 44	0 41	1 28	1 59	1.43	0 28	0 43	0 35
1 L - 11	4	12:21:30	37 92	15 10	0 40	0 45	0 43	1 29	1 61	1 45	0 29	0 43	0 36
1 L - 12	1	12:26:00	41 37	16 46	0 47	0 53	0 50	1 42	1 80	1 61	0 33	0 48	0 40
1 L - 12	2	12:27:00	41 37	16 46	0 48	0 54	0 51	1 44	1 83	1 64	0 33	0 49	0 41
1 L - 12	4	12:29:00	41 37	16 46	0.49	0 55	0 52	1 45	1 84	1 65	0 33	0 49	0 41
1 L - 13	1	12:36:00	44 82	17 83	0 58	0 66	0 62	1 62	2 09	1 86	0 38	0 56	0 47
1 L - 13	2	12:37:00	44 82	17 83	0 58	0 67	0 62	1 63	2 10	1 86	0 38	0 56	0 47
1 L - 13	4	12:39:00	44 82	17 83	0 58	0 68	0 63	1 63	2 11	1 87	0 39	0 56	0 47
1 L - 14	1	12:54:00	47 78	19 01	0 63	0 85	0 74	1 83	2 35	2 09	0 44	0 63	0 53
1 L - 14	2	12:55:00	47 78	19 01	0 63	0 86	0 75	1 84	2 35	2 10	0 44	0 63	0 54
1 L - 14	4	12:57:00	47.78	19.01	0.63	0.88	0.75	1.86	2.35	2.11	0.44	0.63	0.54
1 U - 1	1	13:01:00	34.47	13.73	0 49	0 74	0 62	1 50	1 94	1 72	0 35	0 50	0.43
1 U - 1	2	13:02:00	34 47	13 73	0 49	0 74	0 61	1 49	1 93	1 71	0 35	0 50	0 43
1 U - 1	4	13:04:00	34 47	13 73	0 49	0 74	0 62	1 49	1 93	1 71	0 35	0 50	0 43
1 U - 2	1	13:05:00	20 68	8 26	0 32	0 56	0 44	1 00	1 41	1 21	0 23	0 33	0 28
1 U - 2	2	13:06:00	20 68	8 26	0 33	0 56	0 44	1 01	1 42	1 22	0 24	0 34	0 29
1 U - 2	4	13:08:00	20 68	8 26	0 33	0 57	0 45	1 02	1 44	1 23	0 24	0 34	0 29
1 U - 3	1	13:11:00	6.89	2 79	0 10	0 29	0 20	0 41	0 74	0 57	0 09	0 12	0 11
1 U - 3	2	13:12:00	6.89	2 79	0 10	0 28	0 19	0 39	0 71	0 55	0 09	0 11	0 10
1 U - 3	4	13:14:00	6.89	2 79	0 09	0 28	0 18	0 37	0 69	0 53	0 08	0 11	0 09
1 U - 4	1	13:16:30	0 00	0 00	0 01	0 15	0 08	0 13	0 35	0 24	0 02	0 02	0 02
1 U - 4	2	13:17:30	0 00	0 00	0 01	0 15	0 08	0 13	0 34	0 23	0 02	0 01	0 02
1 U - 4	4	13:19:30	0.00	0.00	0.01	0.15	0.08	0.12	0.34	0.23	0.02	0.01	0.02
2 L - 0	-	13:21:00	0.00	0 00	0 01	0 14	0 08	0 12	0 33	0 23	0 02	0 01	0.02
2 L - 1	1	13:24:00	10 34	4 15	0 09	0 23	0 16	0 43	0 67	0 55	0 11	0 14	0 13
2 L - 1	2	13:25:00	10 34	4 15	0 09	0 23	0 16	0 43	0 68	0 55	0 12	0 14	0 13
2 L - 1	4	13:27:00	10 34	4 15	0 09	0 23	0 16	0 43	0 67	0 55	0 12	0 14	0 13
2 L - 2	1	13:30:00	20 68	8 26	0 22	0 37	0 30	0 83	1 13	0 98	0 21	0 29	0 25
2 L - 2	2	13:31:00	20 68	8 26	0 22	0 38	0 30	0 84	1 13	0 98	0 21	0 29	0 25
2 L - 2	4	13:33:00	20 68	8 26	0 22	0 38	0 30	0 84	1 13	0 99	0 22	0 29	0.25
2 L - 3	1	13:39:00	31 03	12 36	0 38	0 58	0.48	1 28	1 62	1 45	0 31	0 42	0 37
2 L - 3	2	13:40:00	31 03	12 36	0 37	0 57	0 47	1 27	1 61	1.44	0 31	0 42	0 36
2 L - 3	4	13:42:00	31 03	12 36	0 38	0 58	0 48	1 29	1.62	1 46	0 31	0 42	0 36
2 L - 4	1	13:52:00	41 37	16 46	0 53	0 80	0.66	1 69	2 05	1.87	0 41	0 56	0 48
2 L - 4	2	13:53:00	41 37	16 46	0 53	0 80	0 66	1 69	2 05	1.87	0 40	0 56	0 48
2 L - 4	4	13:55:00	41 37	16 46	0 53	0 80	0 67	1 70	2 06	1.88	0 41	0 56	0 48
2 L - 5	1	14:09:00	45 71	18 19	0 59	0 91	0 75	1 96	2 19	2 07	0 45	0 64	0 54
2 L - 5	2	14:10:00	45 71	18 19	0 59	0 91	0 75	1 97	2 18	2 08	0 45	0 64	0 55
2 L - 5	4	14:12:00	45 71	18 19	0 59	0 91	0 75	1 99	2 17	2 08	0 45	0 64	0 55
2 L - 5	8	14:16:00	45 71	18 19	0 60	0 91	0 75	2 02	2 15	2 09	0 45	0 65	0 55
2 L - 5	16	14:24:00	45 71	18 19	0 61	0 90	0 75	2 08	2 11	2 10	0 45	0 65	0 55
2 L - 5	20	14:28:00	45.71	18.19	0.61	0.88	0.75	2.10	2.10	2.10	0.45	0.66	0.55
2 U - 1	1	14:31:00	0 00	0 00	-0.02	0 21	0 10	0 36	0.20	0 28	0 03	0.04	0 03
2 U - 1	2	14:32:00	0 00	0 00	-0.02	0 21	0 09	0 35	0 18	0 27	0 02	0 03	0 02
2 U - 1	4	14:34:00	0.00	0.00	-0.03	0.20	0.09	0.33	0.17	0.25	0.02	0.03	0.02

O-cell™ Expansion
Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell™ Pressure (MPa)	O-cell™ Load (MN)	O-cell™ Expansion LVWDT 22894 (mm)	LVWDT 22895 (mm)	LVWDT 22896 * (mm)	Average (mm)
1 L - 0	-	11:28:30	0.00	0.00	0.00	0.00	0.00	0.00
1 L - 1	1	11:34:00	3 45	1.42	0.21	0.23	0 30	0.22
1 L - 1	2	11:35:00	3 45	1 42	0 24	0 27	0 34	0 25
1 L - 1	4	11:37:00	3 45	1 42	0.25	0 27	0 35	0 26
1 L - 2	1	11:38:00	6 89	2 79	0 84	0 75	0 94	0 80
1 L - 2	2	11:39:00	6 89	2 79	0 92	0 81	1 02	0 87
1 L - 2	4	11:41:00	6 89	2 79	0 98	0 88	1 08	0 93
1 L - 3	1	11:42:00	10 34	4 15	1 69	1 69	1 86	1 69
1 L - 3	2	11:43:00	10 34	4 15	1 79	1 79	1 96	1 79
1 L - 3	4	11:45:00	10 34	4 15	1.85	1 85	2 03	1 85
1 L - 4	1	11:46:00	13.79	5 52	2 71	2 68	2 94	2 70
1 L - 4	2	11:47:00	13.79	5 52	2.80	2 77	3 03	2 78
1 L - 4	4	11:49:00	13.79	5 52	2 91	2 88	3.15	2 89
1 L - 5	1	11:50:00	17.24	6 89	3.90	3 85	4 20	3.87
1 L - 5	2	11:51:00	17.24	6 89	4.10	4 05	4 42	4 07
1 L - 5	4	11:53:00	17.24	6 89	4 29	4 24	4 61	4 27
1 L - 6	1	11:54:00	20.68	8.26	5.43	5 37	5.83	5.40
1 L - 6	2	11:55:00	20.68	8.26	5.69	5 64	6.13	5.67
1 L - 6	4	11:57:00	20.68	8 26	5.97	5 88	6.40	5.93
1 L - 7	1	11:58:30	24 13	9 63	7 42	7 35	7 97	7 39
1 L - 7	2	11:59:30	24 13	9.63	7 71	7 64	8.27	7 67
1 L - 7	4	12:01:30	24 13	9 63	8.05	7 97	8.62	8 01
1 L - 8	1	12:03:00	27 58	10 99	9 79	9 73	10.46	9.76
1 L - 8	2	12:04:00	27 58	10 99	10 18	10 13	10 87	10 16
1 L - 8	4	12:06:00	27 58	10 99	10 62	10 56	11 32	10 59
1 L - 9	1	12:07:30	31 03	12 36	12 71	12 65	13.54	12 68
1 L - 9	2	12:08:30	31 03	12 36	13 36	13 29	14 20	13 33
1 L - 9	4	12:10:30	31 03	12 36	14 09	14 03	14 96	14 06
1 L - 10	1	12:12:30	34 47	13.73	16 81	16 78	17 84	16 79
1 L - 10	2	12:13:30	34 47	13.73	17 71	17 69	18 77	17 70
1 L - 10	4	12:15:30	34 47	13.73	18 82	18 79	19.92	18 81
1 L - 11	1	12:18:30	37 92	15.10	22 37	22 49	23.66	22 43
1 L - 11	2	12:19:30	37 92	15.10	23 76	23.62	25.07	23 69
1 L - 11	4	12:21:30	37 92	15.10	25 34	25.29	26.72	25 31
1 L - 12	1	12:26:00	41 37	16.46	32 42	32 56	34 10	32 49
1 L - 12	2	12:27:00	41 37	16.46	33 82	33 92	35.53	33 87
1 L - 12	4	12:29:00	41 37	16.46	35 79	35 87	37 55	35 83
1 L - 13	1	12:36:00	44 82	17 83	48 08	48 19	50 37	48 13
1 L - 13	2	12:37:00	44 82	17 83	49 50	49 57	51 84	49 53
1 L - 13	4	12:39:00	44 82	17 83	51 70	51 80	54 15	51 75
1 L - 14	1	12:54:00	47 78	19.01	78 96	78.98	82 33	78 97
1 L - 14	2	12:55:00	47 78	19 01	80 84	80 84	84 26	80 84
1 L - 14	4	12:57:00	47.78	19.01	84.64	84.41	88.04	84.52
1 U - 1	1	13:01:00	34 47	13.73	84 80	84 41	87 97	84 61
1 U - 1	2	13:02:00	34 47	13 73	84 69	84 36	87 86	84 53
1 U - 1	4	13:04:00	34 47	13.73	84 65	84 36	87 84	84 51
1 U - 2	1	13:05:00	20 68	8.26	80 10	79 78	82 93	79 94
1 U - 2	2	13:06:00	20 68	8 26	79 47	79 23	82 41	79 35
1 U - 2	4	13:08:00	20 68	8 26	79 37	79.19	82 38	79 28
1 U - 3	1	13:11:00	6.89	2 79	66 46	67 34	69 93	66 90
1 U - 3	2	13:12:00	6.89	2 79	65 18	66.50	69 07	65 84
1 U - 3	4	13:14:00	6.89	2 79	65 55	65.69	68 22	65 62
1 U - 4	1	13:16:30	0 00	0 00	55 57	56 06	58 10	55 81
1 U - 4	2	13:17:30	0 00	0 00	55 50	55.44	57 47	55 47
1 U - 4	4	13:19:30	0.00	0.00	55.50	54.80	56.81	55.15
2 L - 0	-	13:21:00	0 00	0 00	55.50	54.57	56.56	55 03
2 L - 1	1	13:24:00	10 34	4 15	55 50	56.88	59 01	56 19
2 L - 1	2	13:25:00	10 34	4 15	55 50	56.91	59 06	56 20
2 L - 1	4	13:27:00	10 34	4 15	55 50	56.93	59 07	56 21
2 L - 2	1	13:30:00	20 68	8 26	60 98	62 25	64.70	61 61
2 L - 2	2	13:31:00	20 68	8 26	60 72	62 62	65 08	61 67
2 L - 2	4	13:33:00	20 68	8 26	61 87	62 76	65 23	62 31
2 L - 3	1	13:39:00	31 03	12 36	72 58	71 14	75 69	71 86
2 L - 3	2	13:40:00	31 03	12 36	72 83	73 00	75.92	72 91
2 L - 3	4	13:42:00	31 03	12 36	73 24	73.44	76.37	73 34
2 L - 4	1	13:52:00	41 37	16.46	89 14	89.02	92 72	89 08
2 L - 4	2	13:53:00	41 37	16.46	89 94	89 88	93 57	89 91
2 L - 4	4	13:55:00	41 37	16.46	91 26	91 10	94 91	91 18
2 L - 5	1	14:09:00	45 71	18 19	116 88	116.61	119 13	116 74
2 L - 5	2	14:10:00	45 71	18 19	118 70	118 50	122 64	118 60
2 L - 5	4	14:12:00	45 71	18 19	122 43	122.28	126 22	122 36
2 L - 5	8	14:16:00	45 71	18 19	129 98	129.80	134 55	129 89
2 L - 5	16	14:24:00	45 71	18 19	145 39	144 92	149.61	145 15
2 L - 5	20	14:28:00	45.71	18.19	153.76	152.51	157.53	153.13
2 U - 1	1	14:31:00	0 00	0 00	122 58	123.98	126.23	123 28
2 U - 1	2	14:32:00	0 00	0 00	122 79	122 55	125 94	122 67
2 U - 1	4	14:34:00	0.00	0.00	121.86	121.43	124.75	121.65

* LVWDT 22896 is not included in the average due to its orientation.
LVWDTs 22894 and 22895 are oriented 180° opposed

Upward and Downward O-cell™ Plate Movement and Creep (calculated)
Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell™ Pressure (MPa)	O-cell™ Load (MN)	Top of Shaft (mm)	Total Comp. * (mm)	Top Plate Movement (mm)	O-cell™ Expansion (mm)	Bot. Plate Movement (mm)	Creep Up Per Hold (mm)	Creep Dn Per Hold (mm)
1 L - 0	-	11:28:30	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
1 L - 1	1	11:34:00	3.45	1.42	0.03	0 07	0 10	0 22	-0 12		
1 L - 1	2	11:35:00	3.45	1 42	0 05	0 07	0 12	0 25	-0 14	0.02	0.02
1 L - 1	4	11:37:00	3.45	1.42	0 06	0 07	0 13	0 26	-0 13	0.02	-0 01
1 L - 2	1	11:38:00	6.89	2 79	0 13	0 19	0.32	0 80	-0 47		
1 L - 2	2	11:39:00	6.89	2 79	0 16	0 20	0 36	0.87	-0 51	0 04	0 03
1 L - 2	4	11:41:00	6.89	2 79	0 19	0 21	0 40	0 93	-0 53	0 04	0 02
1 L - 3	1	11:42:00	10 34	4 15	0 31	0 35	0 66	1 69	-1 03		
1 L - 3	2	11:43:00	10.34	4 15	0 34	0 36	0 70	1 79	-1 08	0 04	0 05
1 L - 3	4	11:45:00	10 34	4 15	0 39	0 36	0 75	1 85	-1 10	0 05	0 02
1 L - 4	1	11:46:00	13 79	5.52	0 58	0 50	1 07	2 70	-1 63		
1 L - 4	2	11:47:00	13 79	5 52	0 59	0 50	1 09	2 78	-1 69	0 02	0 07
1 L - 4	4	11:49:00	13.79	5 52	0.63	0 50	1 14	2 89	-1 76	0 05	0 06
1 L - 5	1	11:50:00	17 24	6 89	0 87	0 65	1 52	3.87	-2 36		
1 L - 5	2	11:51:00	17 24	6 89	0 92	0 66	1 58	4 07	-2 49	0 06	0 14
1 L - 5	4	11:53:00	17 24	6 89	0 97	0.67	1 64	4 27	-2 63	0 06	0 13
1 L - 6	1	11:54:00	20 68	8 26	1 26	0 82	2 08	5 40	-3 32		
1 L - 6	2	11:55:00	20 68	8.26	1 34	0.83	2 17	5 67	-3 50	0 09	0 17
1 L - 6	4	11:57:00	20 68	8 26	1 42	0 85	2 27	5 93	-3 66	0 09	0 17
1 L - 7	1	11:58:30	24.13	9 63	1.85	1 01	2 86	7 39	-4 53		
1 L - 7	2	11:59:30	24.13	9 63	1 94	1 02	2 96	7 67	-4 71	0 10	0 19
1 L - 7	4	12:01:30	24 13	9 63	2 06	1 04	3 10	8 01	-4 91	0 14	0 20
1 L - 8	1	12:03:00	27 58	10 99	2 63	1 22	3.85	9 76	-5 91		
1 L - 8	2	12:04:00	27 58	10 99	2 77	1 23	4.00	10 16	-6 15	0 15	0 24
1 L - 8	4	12:06:00	27 58	10 99	2 87	1 24	4 12	10 59	-6 48	0 11	0 32
1 L - 9	1	12:07:30	31 03	12 36	3 56	1 43	4 99	12 68	-7 69		
1 L - 9	2	12:08:30	31 03	12 36	3 78	1 45	5 23	13.33	-8 10	0 23	0 41
1 L - 9	4	12:10:30	31 03	12 36	3 99	1 47	5 46	14 06	-8 60	0 23	0 50
1 L - 10	1	12:12:30	34.47	13 73	4 88	1 66	6.54	16.79	-10.25		
1 L - 10	2	12:13:30	34 47	13.73	5 19	1 69	6.87	17 70	-10 83	0 34	0 57
1 L - 10	4	12:15:30	34 47	13 73	5.56	1 71	7 27	18 81	-11 54	0 40	0 71
1 L - 11	1	12:18:30	37 92	15 10	6.78	1 92	8 70	22 43	-13 74		
1 L - 11	2	12:19:30	37 92	15 10	7 31	1 98	9 29	23 69	-14 40	0 60	0 66
1 L - 11	4	12:21:30	37 92	15 10	7 96	2 02	9 98	25.31	-15 34	0 68	0 94
1 L - 12	1	12:26:00	41 37	16 46	10 85	2 28	13 13	32 49	-19 37		
1 L - 12	2	12:27:00	41 37	16.46	11 64	2 32	13 96	33 87	-19 91	0 83	0 55
1 L - 12	4	12:29:00	41 37	16.46	12 63	2 34	14 97	35 83	-20 86	1 01	0 95
1 L - 13	1	12:36:00	44 82	17 83	18 94	2 69	21 63	48 13	-26 50		
1 L - 13	2	12:37:00	44 82	17 83	19 75	2 70	22 45	49 53	-27 08	0 82	0 58
1 L - 13	4	12:39:00	44 82	17 83	21 05	2 72	23 77	51 75	-27 98	1 32	0 90
1 L - 14	1	12:54:00	47 78	19 01	39 00	3 11	42 11	78 97	-36.86		
1 L - 14	2	12:55:00	47 78	19.01	40 37	3.12	43 50	80 84	-37 34	1 39	0 48
1 L - 14	4	12:57:00	47.78	19.01	43.17	3.14	46.31	84.52	-38.21	2.82	0.87
1 U - 1	1	13:01:00	34 47	13 73	44 75	2 56	47 31	84 61	-37 29		
1 U - 1	2	13:02:00	34 47	13 73	44 70	2 55	47 26	84 53	-37 27		
1 U - 1	4	13:04:00	34 47	13 73	44 68	2 56	47 24	84 51	-37 27		
1 U - 2	1	13:05:00	20 68	8 26	43 00	1 80	44 80	79 94	-35 14		
1 U - 2	2	13:06:00	20 68	8 26	42 73	1 82	44 55	79 35	-34 80		
1 U - 2	4	13:08:00	20 68	8 26	42 64	1 84	44 48	79 28	-34 81		
1 U - 3	1	13:11:00	6 89	2 79	37 10	0 84	37 94	66 90	-28 96		
1 U - 3	2	13:12:00	6.89	2 79	36 60	0 81	37 40	65 84	-28 44		
1 U - 3	4	13:14:00	6 89	2 79	36.11	0 77	36 89	65 62	-28 74		
1 U - 4	1	13:16:30	0 00	0 00	31 13	0 35	31 48	55 81	-24 34		
1 U - 4	2	13:17:30	0 00	0 00	30 73	0 34	31 08	55 47	-24 39		
1 U - 4	4	13:19:30	0.00	0.00	30.32	0.33	30.66	55.15	-24.49		
2 L - 0	-	13:21:00	0 00	0 00	30 16	0 33	30 49	55.03	-24.54		
2 L - 1	1	13:24:00	10 34	4 15	30 65	0 76	31 41	56 19	-24 77		
2 L - 1	2	13:25:00	10 34	4 15	30 66	0 77	31 43	56 20	-24 78		
2 L - 1	4	13:27:00	10 34	4 15	30 68	0 77	31 45	56.21	-24 77		
2 L - 2	1	13:30:00	20 68	8 26	32 85	1 37	34 23	61 61	-27 39		
2 L - 2	2	13:31:00	20 68	8 26	33 02	1 38	34 40	61 67	-27 27		
2 L - 2	4	13:33:00	20 68	8.26	33 06	1 39	34 45	62 31	-27 87		
2 L - 3	1	13:39:00	31 03	12 36	38 34	2 10	40 44	71 86	-31 42		
2 L - 3	2	13:40:00	31 03	12 36	38.44	2 09	40 52	72 91	-32 39		
2 L - 3	4	13:42:00	31 03	12 36	38 69	2 10	40 80	73 34	-32 54		
2 L - 4	1	13:52:00	41 37	16 46	47 38	2 78	50 16	89 08	-38 91		
2 L - 4	2	13:53:00	41 37	16.46	47 89	2 79	50 68	89 91	-39 23		
2 L - 4	4	13:55:00	41 37	16 46	48 66	2 80	51 46	91 18	-39 73		
2 L - 5	1	14:09:00	45.71	18 19	67 71	3 12	70 83	116 74	-45 91		
2 L - 5	2	14:10:00	45 71	18 19	69 39	3 12	72 51	118 60	-46 09		
2 L - 5	4	14:12:00	45 71	18 19	72 70	3 12	75 83	122 36	-46 53		
2 L - 5	8	14:16:00	45 71	18 19	79 48	3 13	82 61	129 89	-47 28		
2 L - 5	16	14:24:00	45.71	18 19	94 21	3 14	97 35	145 15	-47 80		
2 L - 5	20	14:28:00	45.71	18.19	101.62	3.14	104.75	153.13	-48.38		
2 U - 1	1	14:31:00	0 00	0 00	78.93	0.40	79 33	123 28	-43 96		
2 U - 1	2	14:32:00	0 00	0 00	77 92	0 38	78 30	122 67	-44 37		
2 U - 1	4	14:34:00	0.00	0.00	77.08	0.36	77.44	121.65	-44.21		

* Sum of ECT levels 2, 3 and 4

Strain Gage Readings and Loads at Levels 1, 2 and 3
Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA

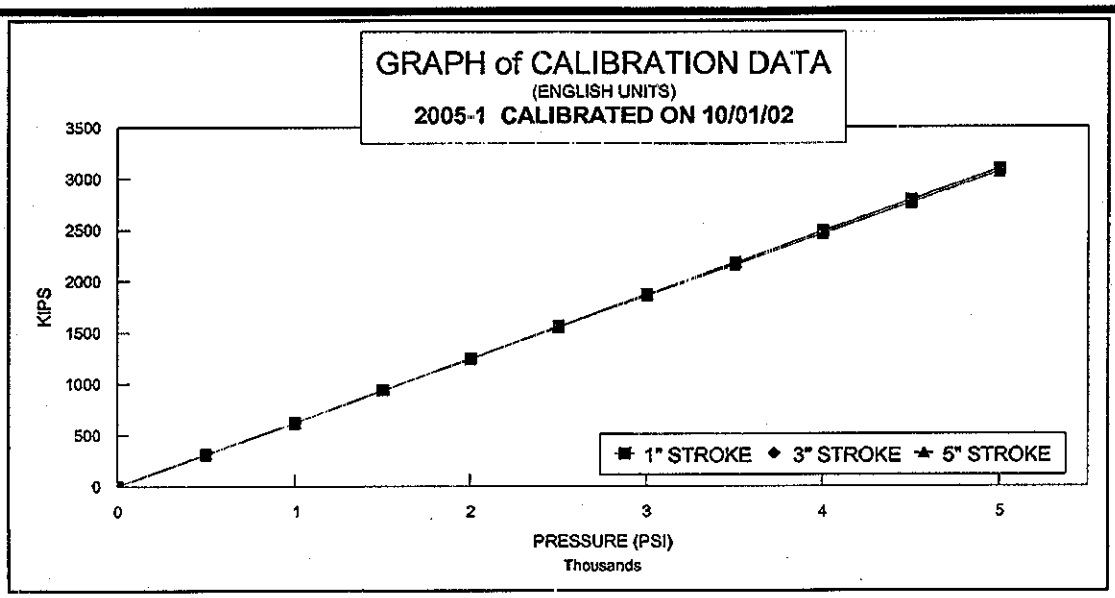
Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell™ Pressure (MPa)	O-cell™ Load (MN)	Level 1 24215 (με)	Level 1 24216 (με)	Level 1 Av. Load (MN)	Level 3 24219 (με)	Level 3 24220 (με)	Level 3 Av. Load (MN)	Level 2 24217 (με)	Level 2 24218 (με)	Level 2 Av. Load (MN)
1 L - 0	-	11:28:30	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
1 L - 1	1	11:34:00	3.45	1 42	9 0	11 4	0 27	9 0	8 2	0 20	16.5	17 0	0 38
1 L - 1	2	11:35:00	3.45	1 42	8 8	11 3	0 27	8 9	8 1	0 19	16.4	17 0	0 38
1 L - 1	4	11:37:00	3.45	1 42	8 5	11 3	0 26	9 0	8 2	0 20	16 4	17 0	0 38
1 L - 2	1	11:38:00	6 89	2 79	19 2	34 8	0 72	25 4	23 2	0 55	43 8	47 3	1 03
1 L - 2	2	11:39:00	6 89	2 79	19 2	36 4	0 74	26 5	24 2	0 58	45 4	49 1	1 07
1 L - 2	4	11:41:00	6.89	2 79	19 2	38 5	0 77	27 7	25 3	0 60	47.0	51 1	1 11
1 L - 3	1	11:42:00	10.34	4 15	27 5	69 1	1 29	47 1	42.4	1 02	75 0	85.1	1 82
1 L - 3	2	11:43:00	10.34	4 15	26 2	69.9	1 28	47 8	42 8	1 03	76 0	85 6	1 83
1 L - 3	4	11:45:00	10.34	4 15	25 7	71 5	1 30	48 7	43 5	1.05	77 2	86 7	1 86
1 L - 4	1	11:46:00	13 79	5 52	32 0	96 4	1 71	68.4	60 0	1 46	105 1	117 1	2 52
1 L - 4	2	11:47:00	13 79	5 52	31 7	98 8	1 74	69 7	61 1	1 48	107 3	119 3	2 57
1 L - 4	4	11:49:00	13.79	5 52	30 4	99 8	1 74	70 5	61 4	1 50	108 1	119.7	2 59
1 L - 5	1	11:50:00	17 24	6.89	37 8	125 5	2 18	92 6	79 8	1 96	139 0	153 8	3 32
1 L - 5	2	11:51:00	17 24	6.89	36 6	127 3	2 19	94 5	81 1	1 99	141 5	156 0	3 38
1 L - 5	4	11:53:00	17 24	6.89	34 9	128 8	2 19	96.1	82 0	2.02	143 5	157 5	3 42
1 L - 6	1	11:54:00	20 68	8 26	41 5	152 8	2 59	120 5	101 5	2 52	175 0	192 5	4 17
1 L - 6	2	11:55:00	20 68	8 26	40.2	154 5	2 60	122 8	103 1	2 56	177.4	195.4	4 23
1 L - 6	4	11:57:00	20 68	8 26	38 9	156 3	2 61	125 1	104 7	2 61	180 3	198.3	4 30
1 L - 7	1	11:58:30	24 13	9 63	45 8	181 3	3 03	154 1	127 0	3 19	214 9	238.6	5 15
1 L - 7	2	11:59:30	24 13	9.63	44 1	180 9	3.00	155.8	127 6	3.22	216 0	239 6	5 17
1 L - 7	4	12:01:30	24 13	9.63	43 2	182 7	3 02	159 3	130 0	3 28	219 6	243 5	5 26
1 L - 8	1	12:03:00	27 58	10 99	50 5	206 4	3 43	192 0	153 6	3 92	253.8	283 8	6 10
1 L - 8	2	12:04:00	27 58	10 99	48.8	206 0	3 40	194 4	154 6	3 96	254 3	284.6	6 12
1 L - 8	4	12:06:00	27 58	10 99	47 4	206.8	3 39	197 8	156.4	4 02	256.6	286 7	6 17
1 L - 9	1	12:07:30	31 03	12 36	57 1	232 8	3.87	235 9	182 8	4 75	293 9	329 4	7 08
1 L - 9	2	12:08:30	31 03	12 36	55 6	234 2	3 87	241.2	185 2	4 84	296 2	331 8	7 13
1 L - 9	4	12:10:30	31 03	12 36	55.8	239 1	3 94	248 1	189 5	4 97	301 5	337 3	7 25
1 L - 10	1	12:12:30	34 47	13 73	63 4	267 6	4 42	286 5	215 5	5 70	335.0	378 2	8 09
1 L - 10	2	12:13:30	34 47	13 73	63 0	272 1	4 47	294 2	219 1	5 83	338 7	383.5	8 20
1 L - 10	4	12:15:30	34.47	13 73	62 0	276.7	4 52	300 5	221 8	5 93	340 8	387 0	8 26
1 L - 11	1	12:18:30	37 92	15 10	73 2	312 7	5 15	342 9	250 1	6 73	376 3	431 2	9 16
1 L - 11	2	12:19:30	37 92	15 10	72 5	317 3	5 20	351 9	253 9	6 88	379 2	436.5	9 26
1 L - 11	4	12:21:30	37 92	15 10	73 0	322 8	5 28	362 0	259.0	7 05	383.2	442 2	9 37
1 L - 12	1	12:26:00	41 37	16.46	86 0	366 9	6 05	424 2	295 9	8 17	420 8	496.1	10 41
1 L - 12	2	12:27:00	41 37	16.46	87 2	372 6	6 14	433 4	301 0	8 34	425 1	503 2	10 54
1 L - 12	4	12:29:00	41 37	16.46	84 9	374 8	6 14	440 1	302 9	8 43	425 5	505 2	10 56
1 L - 13	1	12:36:00	44 82	17 83	100 4	427 8	7 05	517 7	351 5	9 87	472 1	572 4	11 86
1 L - 13	2	12:37:00	44 82	17 83	98 4	428 5	7 03	520 9	352 3	9 91	472 1	573.6	11 87
1 L - 13	4	12:39:00	44 82	17 83	97 3	431 9	7 07	527 3	355 3	10 02	474 0	577 3	11 93
1 L - 14	1	12:54:00	47 78	19 01	110 3	491 8	8 04	611 7	394 1	11 42	520 3	640 1	13 17
1 L - 14	2	12:55:00	47 78	19 01	110 0	494 1	8 07	615 6	393 9	11 46	521 4	641 2	13 20
1 L - 14	4	12:57:00	47.78	19.01	109.6	498.4	8.12	624.2	393.0	11.55	523.7	642.6	13.24
1 U - 1	1	13:01:00	34 47	13 73	49 4	394 9	5 93	542 5	313 4	9 71	414 2	530.4	10.72
1 U - 1	2	13:02:00	34 47	13 73	49 0	393 6	5 91	540 6	312 2	9 68	412 5	528 3	10 68
1 U - 1	4	13:04:00	34 47	13 73	49 6	395.2	5 94	540 7	312 7	9 69	413 5	529 4	10 70
1 U - 2	1	13:05:00	20 68	8 26	11 8	262 2	3 66	426 6	214 6	7 28	282 5	383 8	7 56
1 U - 2	2	13:06:00	20 68	8 26	13 0	263 4	3 69	426 8	215 3	7 29	283 4	384 8	7 58
1 U - 2	4	13:08:00	20 68	8 26	15 0	267 4	3 77	429 0	217 8	7 34	286 9	388 9	7 67
1 U - 3	1	13:11:00	6 89	2 79	-3 5	93.2	1 20	248 1	78 5	3 71	115 2	191 6	3 48
1 U - 3	2	13:12:00	6 89	2 79	-3 2	88 1	1 13	241 5	74 3	3 58	109 6	185 5	3 35
1 U - 3	4	13:14:00	6 89	2 79	-3 3	83 2	1 07	235 7	70 5	3 48	104 3	179 6	3 22
1 U - 4	1	13:16:30	0 00	0 00	-0 2	24 4	0 32	146 5	16.0	1 84	35 7	91 7	1 45
1 U - 4	2	13:17:30	0 00	0 00	0 2	23 5	0 32	144 6	15 6	1 82	34 2	90 0	1 41
1 U - 4	4	13:19:30	0.00	0.00	0.2	22.4	0.30	142.9	15.4	1.80	32.7	88.6	1.38
2 L - 0	-	13:21:00	0 00	0.00	0 2	22 4	0 30	142 8	15 5	1.80	32.5	88.9	1 38
2 L - 1	1	13:24:00	10 34	4 15	12 8	98 5	1 49	209 9	70 6	3 18	123 1	184 4	3 49
2 L - 1	2	13:25:00	10 34	4 15	13 0	99 6	1 50	210 8	71 3	3 20	124 2	185 5	3 51
2 L - 1	4	13:27:00	10 34	4 15	12 8	99 5	1 50	211 1	71 3	3 21	123 9	185.3	3 51
2 L - 2	1	13:30:00	20 68	8 26	22 3	207 1	3 06	315 2	153 6	5 32	235 4	312 3	6 22
2 L - 2	2	13:31:00	20 68	8 26	22 0	207 7	3 07	317 1	154 7	5 36	236 6	313 1	6 24
2 L - 2	4	13:33:00	20 68	8 26	21 5	208 5	3 07	317 8	155 0	5 37	237 3	313 6	6 25
2 L - 3	1	13:39:00	31 03	12 36	40 7	336 2	5 03	443 0	241 2	7 76	351 1	443 1	9 01
2 L - 3	2	13:40:00	31 03	12 36	40 0	323 3	4 85	442 9	248 1	7 84	350 7	442 3	9 00
2 L - 3	4	13:42:00	31 03	12 36	39 4	324 5	4 86	445 7	249 8	7 89	352 1	443 5	9 03
2 L - 4	1	13:52:00	41 37	16 46	80 6	448 0	7 06	575 7	337 2	10 36	466 3	566 8	11 73
2 L - 4	2	13:53:00	41 37	16 46	79 1	447 8	7 03	576 9	336 5	10 37	466 2	566.2	11 72
2 L - 4	4	13:55:00	41 37	16 46	77 9	450 7	7 06	580 7	337 0	10 42	468 3	567 5	11 76
2 L - 5	1	14:09:00	45.71	18 19	99 9	516 0	8 22	673 5	355 4	11 68	517 6	615 5	12 86
2 L - 5	2	14:10:00	45.71	18 19	100 0	517 8	8 25	676.6	354 1	11 70	518 4	615 4	12 87
2 L - 5	4	14:12:00	45 71	18 19	99 6	520 7	8 28	681 6	350 8	11 72	518 9	614 6	12 87
2 L - 5	8	14:16:00	45 71	18 19	99 2	526 6	8 36	690 3	344 4	11 74	520 3	613.6	12 87
2 L - 5	16	14:24:00	45.71	18 19	98.8	535 7	8 47	699 3	335.6	11 75	525 0	610 1	12.88
2 L - 5	20	14:28:00	45.71	18.19	98.2	539.2	8.51	701.8	332.4	11.74	526.0	608.9	12.88
2 U - 1	1	14:31:00	0 00	0 00	-1 4	38 2	0.49	223 1	-33.2	2 15	45 5	83 5	1 46
2 U - 1	2	14:32:00	0 00	0 00	-0 9	35 0	0 45	217 3	-36.2	2 06	41 3	79 5	1 37
2 U - 1	4	14:34:00	0.00	0.00	-0.5	32.4	0.43	212.6	-38.7	1.97	37.9	76.5	1.30

Strain Gage Readings and Loads at Levels 4 and 5
Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell™ Pressure (MPa)	O-cell™ Load (MN)	Level 4 24221 (με)	Level 4 24222 (με)	Level 4 Av. Load (MN)	Level 5 24223 (με)	Level 5 24224 (με)	Level 5 Av. Load (MN)
1 L - 0	-	11:28:30	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.00
1 L - 1	1	11:34:00	3.45	1.42	3 2	4.0	0.08	2 1	2 0	0 08
1 L - 1	2	11:35:00	3.45	1 42	3 2	4 0	0.08	2 1	2 0	0 08
1 L - 1	4	11:37:00	3.45	1 42	3 2	4 0	0.08	2 1	2 1	0 08
1 L - 2	1	11:38:00	6.89	2 79	8 7	11 4	0.23	5 4	5 7	0 22
1 L - 2	2	11:39:00	6.89	2 79	8 9	11 7	0.23	5 6	5.9	0 23
1 L - 2	4	11:41:00	6.89	2 79	9 2	12 2	0 24	6 0	6 3	0 24
1 L - 3	1	11:42:00	10 34	4 15	15 2	20 3	0 40	9 3	9 5	0 37
1 L - 3	2	11:43:00	10 34	4 15	15 3	20 5	0 41	9 4	9 4	0 37
1 L - 3	4	11:45:00	10 34	4 15	15 5	20 8	0 41	9 6	9 5	0 38
1 L - 4	1	11:46:00	13.79	5 52	21 4	28 6	0 57	12 5	10 9	0 46
1 L - 4	2	11:47:00	13.79	5 52	21 7	29 2	0 58	12 4	10 7	0 46
1 L - 4	4	11:49:00	13 79	5 52	21 9	29 4	0 58	12 4	10 7	0 45
1 L - 5	1	11:50:00	17 24	6 89	29 0	38 4	0 76	15 0	12 0	0 53
1 L - 5	2	11:51:00	17 24	6 89	29 5	39 0	0 78	15 0	12 0	0 53
1 L - 5	4	11:53:00	17 24	6 89	30.0	39 5	0 79	15.2	12 0	0 53
1 L - 6	1	11:54:00	20 68	8 26	37 5	49 1	0 98	17 0	12 7	0 58
1 L - 6	2	11:55:00	20 68	8 26	38 2	49 7	1 00	16.8	12 5	0 58
1 L - 6	4	11:57:00	20 68	8 26	38 9	50 4	1 01	16 7	12 6	0 58
1 L - 7	1	11:58:30	24 13	9 63	47 8	60 9	1.23	18 1	12 9	0 61
1 L - 7	2	11:59:30	24 13	9 63	48 2	61 1	1.24	17 9	12 8	0 60
1 L - 7	4	12:01:30	24 13	9 63	49 5	62 2	1.27	18.0	13.0	0 61
1 L - 8	1	12:03:00	27 58	10 99	59 4	73.1	1 50	18 9	13.2	0 63
1 L - 8	2	12:04:00	27 58	10 99	60 1	73.4	1 52	18.8	13.3	0 63
1 L - 8	4	12:06:00	27 58	10 99	61 3	74 2	1 54	18 8	13.4	0 63
1 L - 9	1	12:07:30	31 03	12 36	73 2	86.3	1.81	19 8	13.4	0 65
1 L - 9	2	12:08:30	31 03	12 36	74 8	87 1	1 84	19 5	13.7	0 65
1 L - 9	4	12:10:30	31 03	12 36	77 8	88 9	1.89	19 5	14.0	0 66
1 L - 10	1	12:12:30	34 47	13 73	92 1	101 2	2 19	19 7	14 4	0 67
1 L - 10	2	12:13:30	34.47	13 73	95 4	102 8	2 25	19 6	14 7	0 67
1 L - 10	4	12:15:30	34 47	13 73	98 9	104 4	2 31	19 5	14 7	0 67
1 L - 11	1	12:18:30	37 92	15 10	117 9	120 1	2 70	20 4	14 5	0 69
1 L - 11	2	12:19:30	37 92	15 10	122 6	121 3	2 77	19 3	15.1	0 68
1 L - 11	4	12:21:30	37 92	15 10	129 2	123 8	2 87	19 2	15.7	0 69
1 L - 12	1	12:26:00	41 37	16 46	161 8	142 1	3 45	18 7	20 3	0 77
1 L - 12	2	12:27:00	41 37	16 46	167 5	145 0	3 55	19 0	20 2	0 77
1 L - 12	4	12:29:00	41 37	16 46	172 4	146 2	3 62	19 6	19 7	0 77
1 L - 13	1	12:36:00	44 82	17 83	219 9	172 0	4 45	24 3	17 1	0 81
1 L - 13	2	12:37:00	44 82	17 83	222 3	172 6	4 48	24 8	16 9	0 82
1 L - 13	4	12:39:00	44 82	17 83	227 1	173 7	4 55	25 5	17 0	0 83
1 L - 14	1	12:54:00	47 78	19 01	290 3	206 3	5 64	45 6	24 0	1 37
1 L - 14	2	12:55:00	47 78	19 01	293 4	207 7	5 69	45 7	25 5	1 40
1 L - 14	4	12:57:00	47.78	19.01	297.8	211.1	5.78	46.2	27.7	1.45
1 U - 1	1	13:01:00	34 47	13 73	250 4	160 4	4 66	32 7	20 3	1 04
1 U - 1	2	13:02:00	34 47	13 73	249 4	159 4	4 64	33 2	20 6	1 06
1 U - 1	4	13:04:00	34 47	13 73	249 5	159 7	4 64	34 5	21 5	1 10
1 U - 2	1	13:05:00	20 68	8 26	187 9	95 1	3 21	20 2	10 4	0 60
1 U - 2	2	13:06:00	20 68	8 26	190 1	97 4	3 26	21 9	10 6	0 64
1 U - 2	4	13:08:00	20 68	8 26	192 0	99 4	3 31	23 2	11 1	0 67
1 U - 3	1	13:11:00	6 89	2 79	100 9	14 2	1 31	9 3	1 2	0 21
1 U - 3	2	13:12:00	6 89	2 79	98 3	12 7	1 26	9 1	1 0	0 20
1 U - 3	4	13:14:00	6 89	2 79	95 7	11 2	1 21	9 2	0 7	0 19
1 U - 4	1	13:16:30	0 00	0 00	55 7	-12 6	0 49	5 7	-2 7	0 06
1 U - 4	2	13:17:30	0 00	0 00	55 0	-11 9	0.49	5 8	-2 6	0 06
1 U - 4	4	13:19:30	0.00	0.00	54.1	-11.7	0.48	5.7	-2.6	0.06
2 L - 0	-	13:21:00	0 00	0 00	54 0	-11 4	0 48	5 6	-2 7	0 06
2 L - 1	1	13:24:00	10 34	4 15	77 4	13 1	1 03	14 6	4 6	0 38
2 L - 1	2	13:25:00	10 34	4 15	77 6	13 5	1 03	14 8	4 7	0 38
2 L - 1	4	13:27:00	10 34	4 15	77 7	13 5	1 03	14 7	4 5	0 38
2 L - 2	1	13:30:00	20 68	8 26	121 1	52 9	1 97	21 9	11 5	0 66
2 L - 2	2	13:31:00	20 68	8 26	121 8	53.1	1 98	22 1	11 7	0 66
2 L - 2	4	13:33:00	20 68	8 26	122 1	53.2	1 99	22 3	11 9	0 67
2 L - 3	1	13:39:00	31 03	12 36	189 5	109.8	3 40	30 2	19 5	0 98
2 L - 3	2	13:40:00	31 03	12 36	189 1	110 2	3 40	30 3	19 8	0 98
2 L - 3	4	13:42:00	31 03	12 36	190 7	112 2	3 44	30 8	20 6	1 01
2 L - 4	1	13:52:00	41 37	16 46	265 5	183 2	5.09	40 9	30 0	1 39
2 L - 4	2	13:53:00	41 37	16 46	265 6	183 4	5 10	41 5	30 3	1 41
2 L - 4	4	13:55:00	41 37	16 46	267 0	185 4	5 13	42 2	31 6	1 45
2 L - 5	1	14:09:00	45.71	18 19	299 4	230 5	6.01	52 3	47 3	1 96
2 L - 5	2	14:10:00	45.71	18 19	299 2	232 4	6.03	53 5	48 1	2 00
2 L - 5	4	14:12:00	45.71	18 19	296 1	236 0	6.04	55 0	49 0	2 04
2 L - 5	8	14:16:00	45.71	18 19	293 2	242 4	6 08	56 5	51 1	2 11
2 L - 5	16	14:24:00	45.71	18 19	285 7	253 3	6.12	60 7	45 2	2 08
2 L - 5	20	14:28:00	45.71	18.19	282.7	256.9	6.12	61.3	42.9	2.05
2 U - 1	1	14:31:00	0.00	0 00	54.3	12 7	0 76	-5 7	1 7	-0 08
2 U - 1	2	14:32:00	0 00	0 00	53.6	12 2	0 75	-6.2	1 9	-0 08
2 U - 1	4	14:34:00	0.00	0.00	53.1	12.0	0.74	-6.7	2.1	-0.09

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	314	313	311
1000	621	621	621
1500	942	937	935
2000	1248	1245	1239
2500	1561	1557	1548
3000	1871	1864	1852
3500	2180	2168	2154
4000	2483	2477	2455
4500	2787	2783	2758
5000	3092	3087	3061

34" O-CELL, SERIAL # 2005-1

LOAD CONVERSION FORMULA

LOAD = PRESSURE * 0.615 + (11.6)
{KIPS} {PSI}

Regression Output:

Constant	11.582
X Coefficient	0.615
R Squared	1.000
No. of Observations	30
Degrees of Freedom	28
Std Err of Y Est	10 088
Std Err of X Coef	0 001

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.: 3641 *CUSTOMER P.O NO.: LT-8854	*CONTRACTOR: JENSEN CONSTRUCTION *JOB LOCATION: DES MOINES, IA *DATED: 10/04/02

SERVICE ENGINEER: _____ DATE: 7 oct 2002

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

Vibrating Wire Displacement Transducer Calibration Report

Model Number: 4450-3-6

Serial Number: 22894

Customer: Loadtest Inc.

Cust I.D. #: n/a

Job Number: 19578

Range: 6"

Mfg. Number: 02-2847

Temperature: 23 °C

Cal. Std. Control Numbers: 124, 213, 506, 524, 529

Calibration Date: October 04, 2002

Technician:

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2273	2278	2276		-0.28
1.200	3488	3494	3491	1216	0.16
2.400	4679	4680	4680	1189	0.14
3.600	5871	5869	5870	1191	0.16
4.800	7053	7051	7052	1182	0.03
6.000	8226	8227	8227	1175	-0.22

Calibration Factor (C): 0.0010089 (Inches/ Digit)

Regression Zero: 2292

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5303

or

Position "F":

Date: October 10, 2002

Temperature: 24.2 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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

Model Number: 4450-3-6
Range: 6"
Serial Number: 22895
Mfg. Number: 02-2848
Customer: Loadtest Inc.
Temperature: 23 °C
Cust. I D #: n/a
Cal. Std. Control Numbers: 124, 213, 506, 524, 529
Job Number: 19578
Calibration Date: October 04, 2002
Technician:

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2315	2315	2315		-0.26
1.200	3527	3526	3527	1212	0 10
2.400	4720	4723	4722	1195	0 18
3 600	5908	5911	5910	1188	0 15
4 800	7091	7092	7092	1182	0 01
6 000	8268	8270	8269	1178	-0 20

Calibration Factor (C): 0.0010083 (Inches/ Digit)

Regression Zero: 2330

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5329
or
Position "F":
Date: October 10, 2002
Temperature: 24.4 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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

Model Number: 4450-3-6
Range: 6"
Serial Number: 22896
Mfg Number: 02-2850
Customer: Loadtest Inc.
Temperature: 23 °C
Cust. I D #: n/a
Cal. Std Control Numbers: 124, 213, 506, 524, 529
Job Number: 19578
Calibration Date: October 04, 2002
Technician:

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2292	2291	2292		-0.25
1.200	3508	3505	3507	1215	0.10
2.400	4705	4705	4705	1199	0.17
3.600	5898	5898	5898	1193	0.15
4.800	7085	7084	7085	1187	0.01
6.000	8267	8266	8267	1182	-0.19

Calibration Factor (C): 0.0010047 (Inches/ Digit)

Regression Zero: 2306

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5349
Date: October 10, 2002
or
Position "F":
Temperature: 24.8 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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

Model Number: 4450-3-1
Range: 1"
Serial Number: 22897
Mfg. Number: 02-2815
Customer: Loadtest Inc.
Temperature: 22.2 °C
Cust I.D. #: n/a
Cal. Std. Control Numbers: 338, 249, 406, 524, 529
Job Number: 19578
Calibration Date: October 03, 2002
Technician:

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2250	2245	2248		-0.26
0.200	3441	3437	3439	1192	0.08
0.400	4620	4616	4618	1179	0.21
0.600	5789	5784	5787	1169	0.16
0.800	6953	6949	6951	1165	0.04
1.000	8107	8107	8107	1156	-0.23

Calibration Factor (C): 0.0001707 (Inches/ Digit)

Regression Zero: 2263

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 4906
or
Position "F":
Date: October 10, 2002
Temperature: 26.3 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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

Model Number: 4450-3-1
Range: 1"

Serial Number: 22898
Mfg. Number: 02-2816

Customer: Loadtest Inc.
Temperature: 22.2 °C

Cust I.D. #: n/a
Cal. Std. Control Numbers: 338, 249, 406, 524, 529

Job Number: 19578
Calibration Date: October 03, 2002

Technician:

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2282	2278	2280		-0.27
0.200	3481	3477	3479	1199	0.09
0.400	4665	4662	4664	1185	0.22
0.600	5839	5836	5838	1174	0.16
0.800	7007	7004	7006	1168	0.00
1.000	8170	8170	8170	1165	-0.21

Calibration Factor (C): 0.0001699 (Inches/ Digit)

Regression Zero: 2296

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5087
Date: October 10, 2002

or

Position "F":
Temperature: 26.0 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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

Model Number: 4450-3-1

Serial Number: 22899

Customer: Loadtest Inc.

Cust I.D. #: n/a

Job Number: 19578

Range: 1"

Mfg. Number: 02-2817

Temperature: 22.2 °C

Cal Std Control Numbers: 338, 249, 406, 524, 529

Calibration Date: October 03, 2002

Technician:

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2221	2219	2220		-0.26
0.200	3414	3412	3413	1193	0.07
0.400	4595	4593	4594	1181	0.20
0.600	5768	5766	5767	1173	0.18
0.800	6932	6931	6932	1165	0.03
1.000	8090	8090	8090	1159	-0.23

Calibration Factor (C): 0.0001704 (Inches/ Digit)

Regression Zero: 2235

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 4908

or

Position "F":

Date: October 10, 2002

Temperature: 27.0 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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

Model Number: 4450-3-1
Range: 1"
Serial Number: 22900
Mfg. Number: 02-2818
Customer: Loadtest Inc.
Temperature: 22.2 °C
Cust I.D. #: n/a
Cal Std Control Numbers: 338, 249, 406, 524, 529
Job Number: 19578
Calibration Date: October 03, 2002
Technician:

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2231	2226	2229		-0.29
0.200	3441	3433	3437	1209	0.11
0.400	4632	4626	4629	1192	0.23
0.600	5814	5806	5810	1181	0.17
0.800	6990	6980	6985	1175	0.00
1.000	8160	8153	8157	1172	-0.22

Calibration Factor (C): 0.0001688 (Inches/ Digit)

Regression Zero: 2246

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 4895
or
Position "F":
Date: October 10, 2002
Temperature: 26.4 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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

Model Number: 4450-3-1
Range: 1"
Serial Number: 22901
Mfg. Number: 02-2819
Customer: Loadtest Inc.
Temperature: 22.6 °C
Cust. I.D. #: n/a
Cal. Std. Control Numbers: 338, 249, 406, 524, 529
Job Number: 19578
Calibration Date: October 04, 2002
Technician:

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2219	2218	2219		-0.32
0.200	3430	3429	3430	1211	0.11
0.400	4623	4622	4623	1193	0.23
0.600	5805	5805	5805	1183	0.18
0.800	6983	6983	6983	1178	0.05
1.000	8150	8149	8150	1167	-0.27

Calibration Factor (C): 0.0001687 (Inches/ Digit)

Regression Zero: 2237

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 4985
or
Position "F":
Date: October 10, 2002
Temperature: 24.2 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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

Model Number: 4450-3-1
Range: 1"
Serial Number: 22902
Mfg. Number: 02-2820
Customer: Loadtest Inc.
Temperature: 22.6 °C
Cust ID #: n/a
Cal. Std. Control Numbers: 338, 249, 406, 524, 529
Job Number: 19578
Calibration Date: October 04, 2002
Technician: DJL

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2311	2307	2309		-0.25
0.200	3563	3560	3562	1253	0.08
0.400	4802	4798	4800	1239	0.19
0.600	6031	6029	6030	1230	0.15
0.800	7256	7255	7256	1226	0.04
1.000	8473	8470	8472	1216	-0.22

Calibration Factor (C): 0.0001623 (Inches/ Digit)

Regression Zero: 2324

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5205
or
Position "F":
Date: October 10, 2002
Temperature: 27.2 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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

Model Number: 4450-3-1

Serial Number: 22903

Customer: Loadtest Inc.

Cust I.D. #: n/a

Job Number: 19578

Range: 1"

Mfg. Number: 02-2821

Temperature: 22.6 °C

Cal. Std. Control Numbers: 338, 249, 406, 524, 529

Calibration Date: October 04, 2002

Technician:

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2404	2400	2402		-0.25
0.200	3608	3605	3607	1205	0.10
0.400	4797	4794	4796	1189	0.19
0.600	5976	5975	5976	1180	0.12
0.800	7155	7153	7154	1179	0.03
1.000	8324	8324	8324	1170	-0.20

Calibration Factor (C): 0.0001689 (Inches/ Digit)

Regression Zero: 2417

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5258

or

Position "F":

Date: October 10, 2002

Temperature: 24.4 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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

Model Number: 4450-3-1

Serial Number: 22904

Customer: Loadtest Inc.

Cust. I.D. #: n/a

Job Number: 19578

Range: 1"

Mfg. Number: 02-2822

Temperature: 22.6 °C

Cal. Std. Control Numbers: 338, 249, 406, 524, 529

Calibration Date: October 04, 2002

Technician: DJK

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2293	2292	2293		-0.27
0.200	3501	3499	3500	1208	0.10
0.400	4691	4690	4691	1191	0.19
0.600	5875	5873	5874	1184	0.16
0.800	7052	7051	7052	1178	0.03
1.000	8223	8221	8222	1171	-0.22

Calibration Factor (C): 0.0001687 (Inches/ Digit)

Regression Zero: 2309

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 4921

or

Position "F":

Date: October 10, 2002

Temperature: 27.0 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

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.

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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 24215

Customer: Loadtest Inc.

Job Number: 19578

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 24.8 °C

Calibration Date: October 09, 2002

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

Cable Length: 100 ft.

Factory Zero Reading: 7263

Regression Zero: 7284

Technician: KDB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7333	7342	7338		
1,500	8004	8015	8010	672	-0.13
3,000	8737	8742	8740	730	-0.11
4,500	9467	9479	9473	734	0.03
6,000	10200	10208	10204	731	0.08
100	7342				

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

Gage Factor: 0.347 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: 24216

Customer: Loadtest Inc.

Job Number: 19578

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.2 °C

Calibration Date: October 09, 2002

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

Cable Length: 100 ft.

Factory Zero Reading: 6999

Regression Zero: 7042

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7090	7089	7090		
1,500	7776	7777	7777	687	-0.03
3,000	8519	8515	8517	741	0.14
4,500	9249	9252	9251	734	0.07
6,000	9981	9981	9981	731	-0.10
100	7090				

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: 24217

Customer: Loadtest Inc.

Job Number: 19578

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 24.8 °C

Calibration Date: October 09, 2002

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

Cable Length: 85 ft.

Factory Zero Reading: 6892

Regression Zero: 6905

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6956	6961	6959		
1,500	7628	7634	7631	673	-0.14
3,000	8362	8364	8363	732	-0.07
4,500	9095	9099	9097	734	0.07
6,000	9822	9831	9827	730	0.06
100	6961				

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

Gage Factor: 0.347 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: 24218

Customer: Loadtest Inc.

Job Number: 19578

Cust I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.1 °C

Calibration Date: October 09, 2002

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

Cable Length: 85 ft.

Factory Zero Reading: 6801

Regression Zero: 6841

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6897	6893	6895		
1,500	7577	7579	7578	683	-0.14
3,000	8321	8322	8322	744	-0.07
4,500	9070	9068	9069	748	0.15
6,000	9805	9807	9806	737	0.00
100	6893				

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

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 24219

Customer: Loadtest Inc.

Job Number: 19578

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 22.7 °C

Calibration Date: October 09, 2002

Cal. Std Control Numbers: 85888-1, 398

Cable Length: 80 ft.

Factory Zero Reading: 7145

Regression Zero: 7185

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7245	7242	7244		
1,500	7916	7919	7918	674	-0.22
3,000	8654	8659	8657	739	-0.21
4,500	9405	9403	9404	748	0.08
6,000	10145	10145	10145	741	0.15
100	7243				

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

Gage Factor: 0.344 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: 24220

Customer: Loadtest Inc.

Job Number: 19578

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.0 °C

Calibration Date: October 09, 2002

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

Cable Length: 80 ft.

Factory Zero Reading: 6997

Regression Zero: 7048

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7104	7102	7103		
1,500	7793	7803	7798	695	-0.15
3,000	8555	8551	8553	755	-0.13
4,500	9315	9319	9317	764	0.19
6,000	10065	10065	10065	748	-0.02
100	7102				

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

Gage Factor: 0.339 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: 24221

Customer: Loadtest Inc.

Job Number: 19578

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.3 °C

Calibration Date: October 09, 2002

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

Cable Length: 75 ft.

Factory Zero Reading: 6808

Regression Zero: 6851

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6900	6898	6899		
1,500	7587	7578	7583	684	-0.01
3,000	8315	8318	8317	734	0.07
4,500	9051	9050	9051	734	0.14
6,000	9766	9784	9775	725	-0.10
100	6898				

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: 24222

Customer: Loadtest Inc.

Job Number: 19578

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.2 °C

Calibration Date: October 09, 2002

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

Cable Length: 75 ft.

Factory Zero Reading: 6950

Regression Zero: 6986

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7036	7040	7038		
1,500	7713	7721	7717	679	-0.12
3,000	8452	8456	8454	737	-0.03
4,500	9193	9190	9192	738	0.07
6,000	9925	9923	9924	733	0.00
100	7040				

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: 24223

Customer: Loadtest Inc.

Job Number: 19578

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.1 °C

Calibration Date: October 09, 2002

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

Cable Length: 70 ft.

Factory Zero Reading: 6928

Regression Zero: 6976

Technician: KDB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7029	7026	7028		
1,500	7717	7714	7716	688	-0.13
3,000	8465	8463	8464	749	0.05
4,500	9210	9210	9210	746	0.14
6,000	9946	9948	9947	737	-0.07
100	7027				

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

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 24224

Customer: Loadtest Inc.

Job Number: 19578

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.1 °C

Calibration Date: October 09, 2002

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

Cable Length: 70 ft.

Factory Zero Reading: 6981

Regression Zero: 7032

Technician: KDB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7088	7086	7087		
1,500	7759	7756	7758	671	-0.26
3,000	8498	8495	8497	739	-0.06
4,500	9236	9232	9234	738	0.09
6,000	9964	9966	9965	731	0.02
100	7087				

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

APPENDIX C

CONSTRUCTION OF THE EQUIVALENT TOP-LOADED LOAD-SETTLEMENT CURVE

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

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

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

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

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

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

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

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

Note: This report shows the O-cell movement data in a Figure similar to Fig. A, but uses the gross loads as obtained in the field. Fig. A uses net loads to make it easier for the reader to convert Fig. A into Fig. B without the complication of 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 $L_3 = 0$. Subtracting the OLT from the TLT compression gives the desired additional elastic compression at the top of the TLT. We then add the additional elastic compression to the 'rigid' equivalent curve obtained from Part I to obtain the final, corrected equivalent load-settlement curve for the TLT on the same pile as the actual OLT.

Note that the above pp. 6 and 7 give equations for each of three assumed patterns of developed side shear stress along the pile. The pattern shown in the center of the three applies to any approximately determined side shear distribution. Experience has

shown the initial solution for the additional elastic compression, as described above, gives an adequate and slightly conservative (high) estimate of the additional compression versus more sophisticated load-transfer analyses as described in the first paragraph of this Part II.

The analysis p. 8 provides an example of calculated results in English units on a hypothetical 1-stage, single level OLT using the simplified method in Part II with the 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

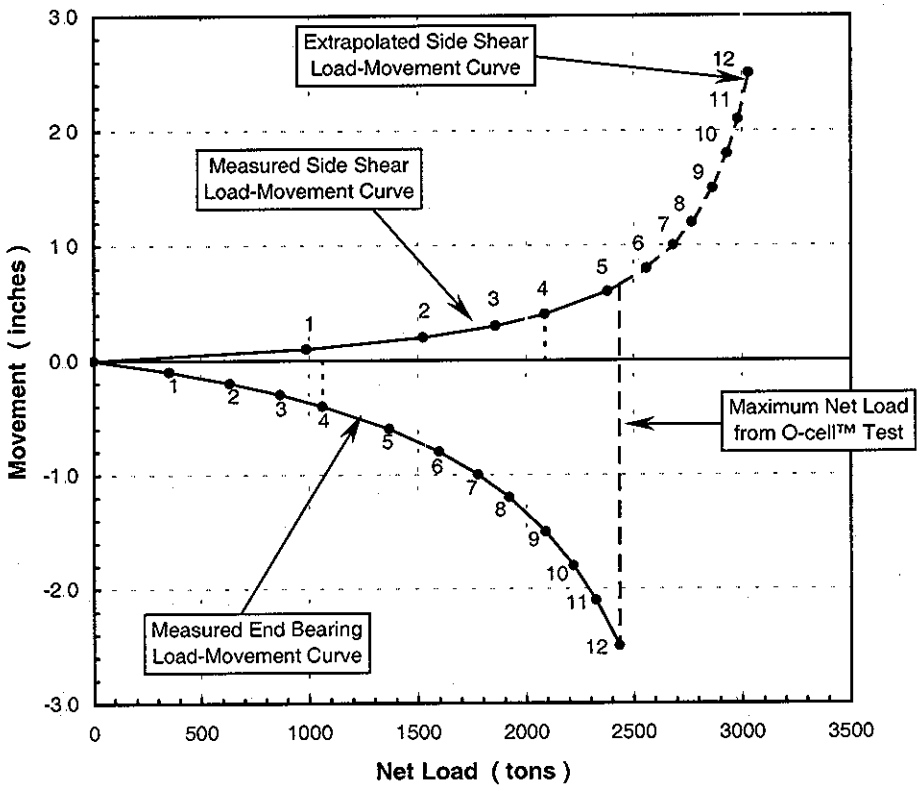
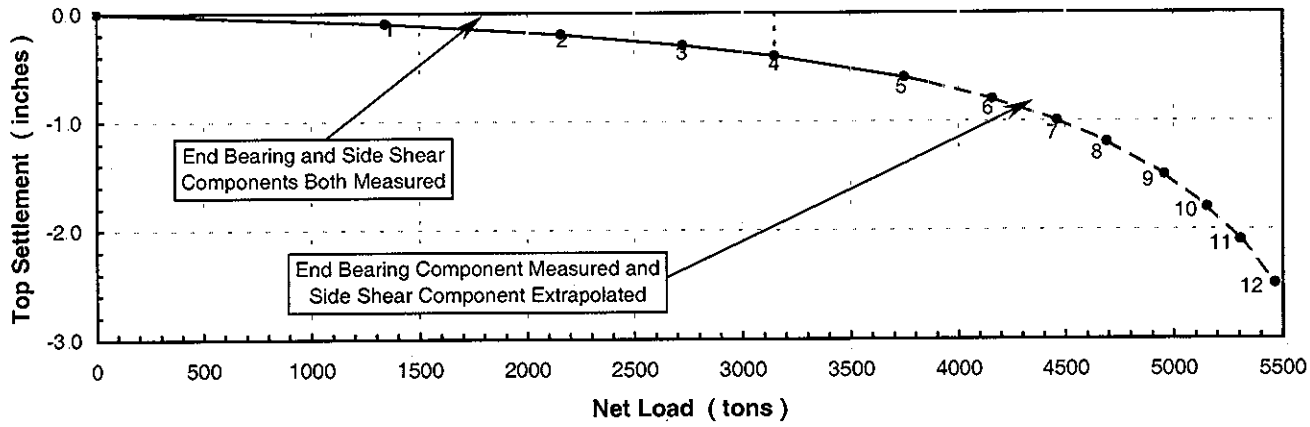
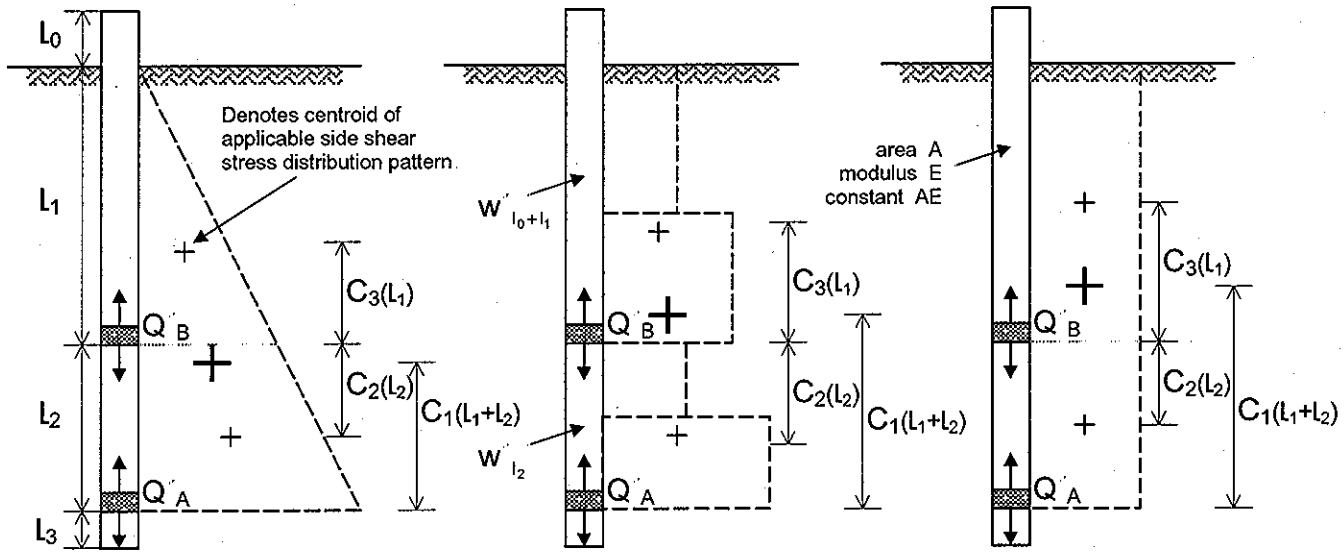


Figure B



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



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

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

3-Stage Multi Level Test (Q'_A and Q'_B): $\delta_{OLT} = \delta_{\uparrow l_1} + \delta_{\downarrow l_2}$

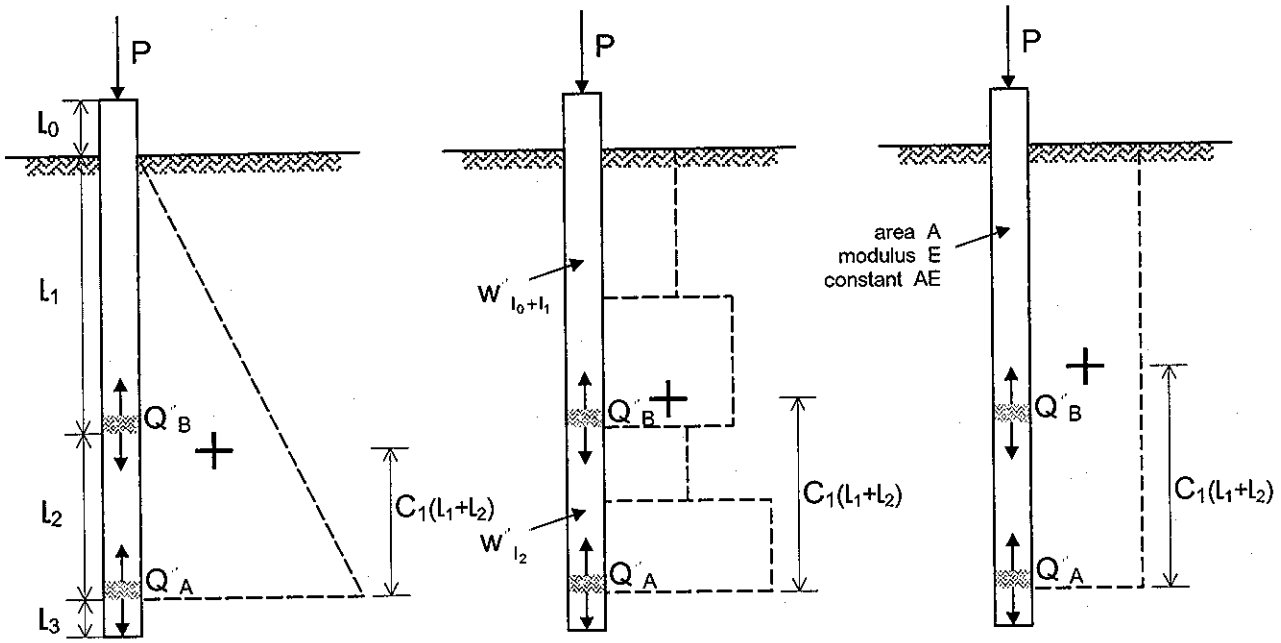
$C_3 = \frac{1}{3}$	Centroid Factor = C_3	$C_3 = \frac{1}{2}$
$\delta_{\uparrow l_1} = \frac{1}{3}\frac{Q'_{\uparrow B} l_1}{AE}$	$\delta_{\uparrow l_1} = C_3\frac{Q'_{\uparrow B} l_1}{AE}$	$\delta_{\uparrow l_1} = \frac{1}{3}\frac{Q'_{\uparrow B} l_1}{AE}$
$C_2 = \frac{1}{3}\left(\frac{3l_1+2l_2}{2l_1+l_2}\right)$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

Net Loads:

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

w' = pile weight, bouyant where below water table

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



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

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

Net and Equivalent Loads:

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

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™)

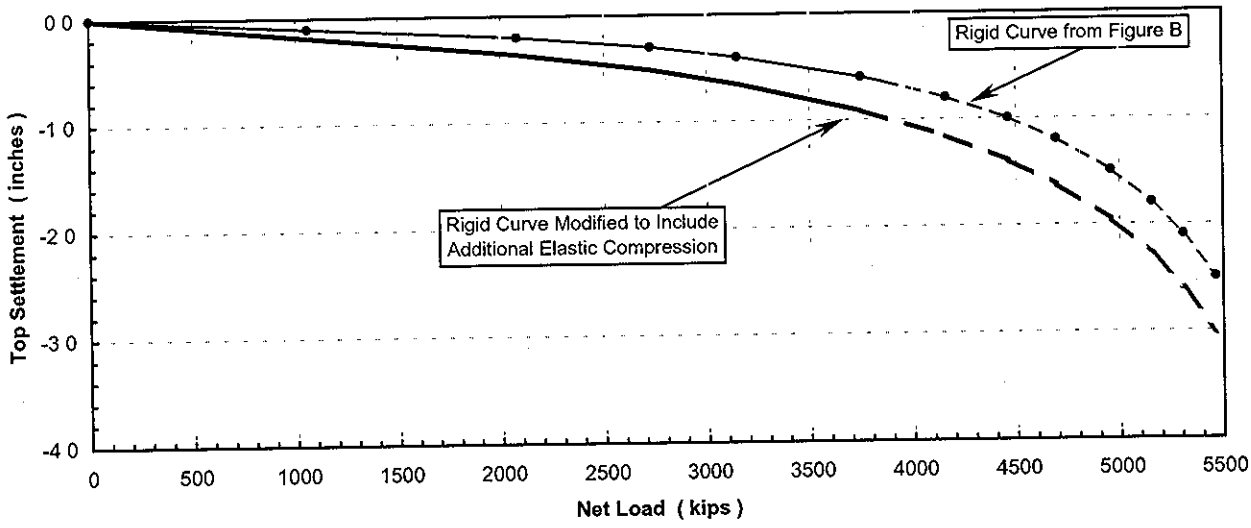
l_2 = 0.0 **ft**

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



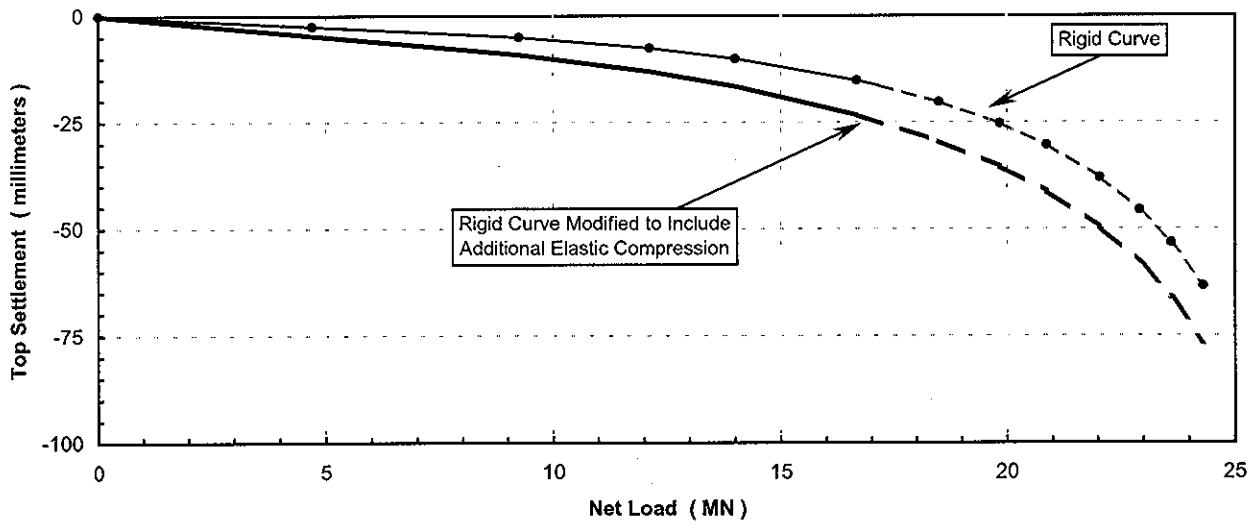
Example Calcuation for the Additional Elastic Compression Correction for Single Level Test (SI Units)

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



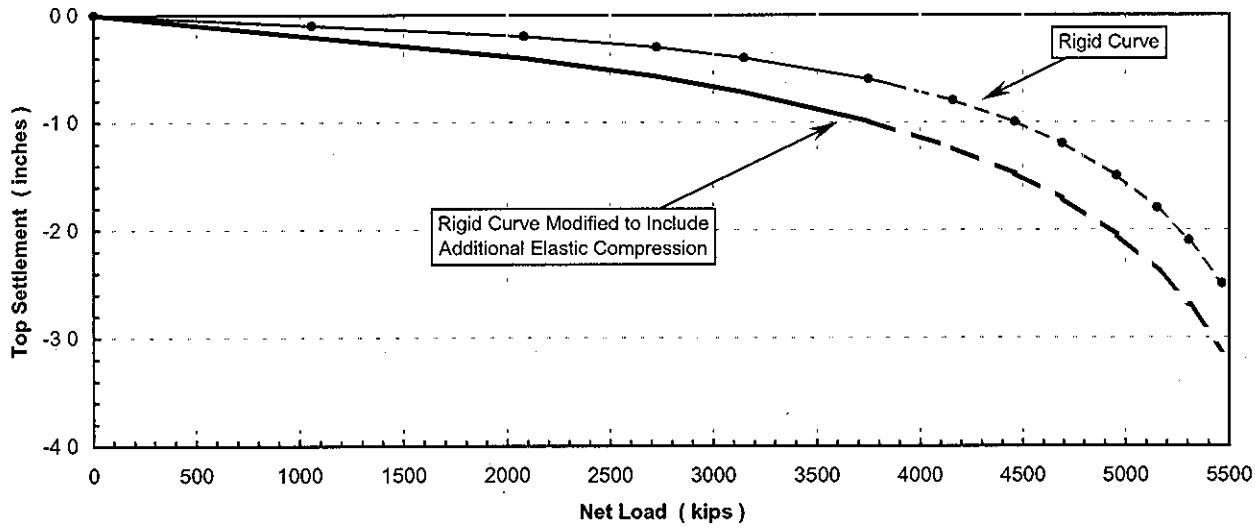
Example Calcuation for the Additional Elastic Compression Correction for Multi Level Test (English Units)

Given:

C_1 = 0.441
C_2 = 0.579
C_3 = 0.396
AE = 3820000 **kips** (assumed constant throughout test)
l_0 = 5.9 **ft**
l_1 = 30.0 **ft** (embedded length of shaft above mid-cell)
l_2 = 18.2 **ft** (embedded length of shaft between O-cells™)
l_3 = 0.0 **ft**
Shear reduction factor = 1.00 (cohesive soil)

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

Figure E



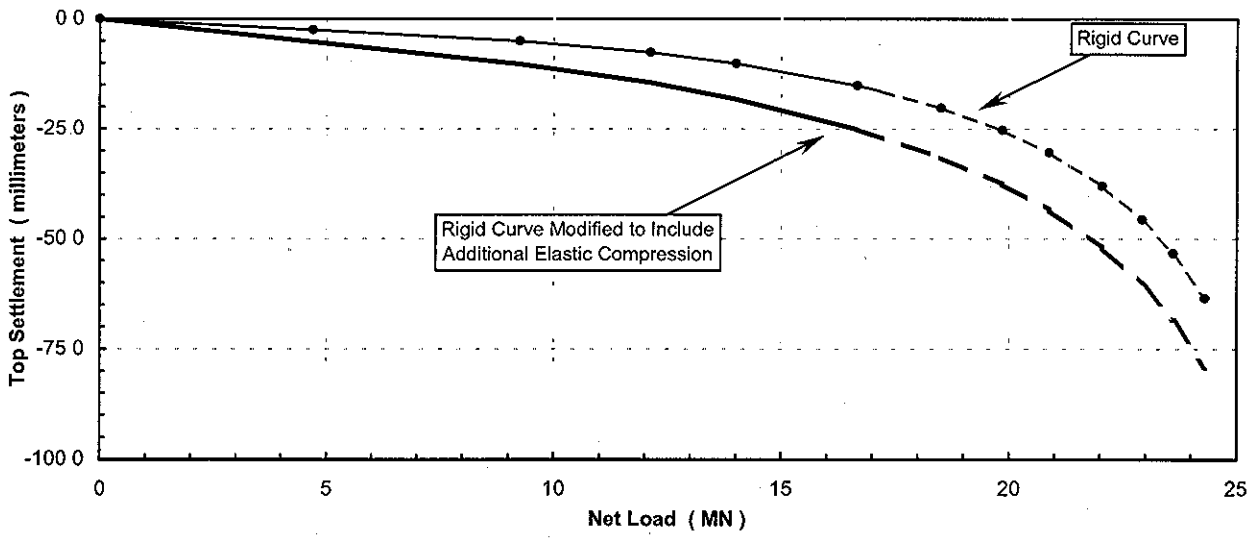
Example Calcuation for the Additional Elastic Compression Correction for Multi Level Test (SI Units)

Given:

C_1 = 0.441
C_2 = 0.579
C_3 = 0.396
AE = 17000 **MN** (assumed constant throughout test)
l_0 = 1.80 **m**
l_1 = 9.14 **m** (embedded length of shaft above mid-cell)
l_2 = 5.55 **m** (embedded length of shaft between O-cells™)
l_3 = 0.00 **m**
Shear reduction factor = 1.00 (cohesive soil)

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

Figure F



APPENDIX D

O-CELL™ METHOD FOR DETERMINING CREEP LIMIT LOADING

O-CELL METHOD FOR DETERMINING A CREEP LIMIT LOADING ON THE EQUIVALENT TOP-LOADED SHAFT

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, 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 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.

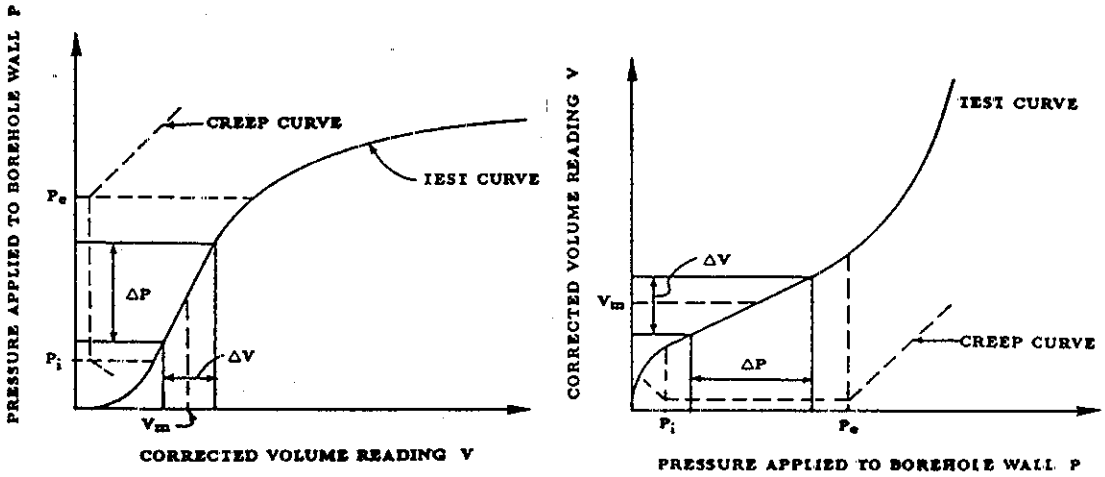


FIG. 8 Pressuremeter Test Curves for Procedure A

References

Housel, W S. (1959), "Dynamic & Static Resistance of Coshesive Soils" 1846-1959, ASTM STP 254, pp. 22-23

Stoll, M.U W. (1961, Discussion, Proc. 3rd 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. (1966), Basics of Foundation Design, BiTech Publishers Ltd., p.79.

APPENDIX E

SOIL BORING LOG

BORING LOG No. Test Shaft

BORING NO.	LOCATION OF BORING	ELEVATION	DATUM	DRILLER	LOGGER
Test Shaft	Sta. 25439 + 08.023, 10.753R	245.769	IDOT I-235	DAH	MTL

WATER LEVEL OBSERVATIONS			TYPE OF SURFACE	DRILL RIG
WHILE DRILLING	END OF DRILLING	24 HOURS AFTER DRILLING	Grass	B-57
5.64m	NA		DRILLING METHOD	TOTAL DEPTH
			0m to 14.63m 83mm HSA, 14.63m to 25.15m NQ2 Core	25.15m

DEP. M	SAMPLE DATA: SAMPLE NO & TYPE	N BLOWS 30 CM	% REC	SOIL DESCRIPTION: COLOR, MOISTURE, CONSISTENCY, GEOLOGIC DESCRIPTION & OTHER REMARKS	USCS CLASS.	LABORATORY DATA: % MC	DRY DENS. kg/m3	Qu kPa	DEP. M
				Dark brown, Dry, STIFF SANDY GLACIAL CLAY					
	S-1	22							
2.2					CL				2.2
	S-2	21							
				FILL 4.1					
4.4	S-3	26		Light gray, Dry, FINE-MEDIUM SAND					4.4
	S-4	4							
6.6									6.6
	S-5	12		Dark gray with silt in S-5					
8.8	S-6	8			SP-SM				8.8
	S-7	7							
11									11
	S-8	16							
13.2									13.2
	S-9	26							
	S-10	50/ 06		ALLUVIUM 14.0					
	NQ			Light gray, Moist CLAY SHALE					
15.4	NQ			NQ Core Run 1 REC=100 RQD=100			2284	10314	15.4
				NQ Core Run 2 REC=100 RQD=100			2320	1791	
	NQ			NQ Core Run 3 REC=100 RQD=100			2257	448	
17.6				NQ Core Run 4 REC=100 RQD=82			2349	10087	17.6
	NQ			Black Coal between 18 4m to 18 8m			2288	4037	
				NQ Core Run 5 REC=100 RQD=83			1582	4037	
19.8	NQ						2240	1791	19.8
				NQ Core Run 6 REC=100 RQD=92			2288	3362	
	NQ						2288	3362	
22				NQ Core Run 7 REC=100 RQD=88					22

Geotechnical Services Inc.
2853 99th Street, Des Moines, IA 50322-3858
(515) 270-8542 * FAX (515) 270-1911

PROJECT: Des Moines River and I-235 Bridge Test Shaft
LOCATION: I-235 and West River Drive, Des Moines, IA
JOB NO.: 026162
DATE: 10/14-15/02

BORING LOG No. Test Shaft

BORING NO.	LOCATION OF BORING	ELEVATION	DATUM	DRILLER	LOGGER
Test Shaft	Sta. 25439 + 08.023, 10.753R	245.769	IDOT I-235	DAH	MTL

WATER LEVEL OBSERVATIONS			TYPE OF SURFACE	DRILL RIG
WHILE DRILLING	END OF DRILLING	24 HOURS AFTER DRILLING	Grass	B-57
			DRILLING METHOD	TOTAL DEPTH
5.64m	NA		0m to 14.63m 83mm HSA, 14.63m to 25.15m NQ2 Core	25.15m

DEPTH	SAMPLE DATA: SAMPLE NO. & TYPE	"N" BLOWS 30 CM.	% REC	SOIL DESCRIPTION: COLOR, MOISTURE, CONSISTENCY, GEOLOGIC DESCRIPTION & OTHER REMARKS	USCS CLASS	LABORATORY DATA: % MC	DRY DENS. kg/m³	QU KPa	DEPTH
	NQ						2270	4485	
24.2	NQ			NQ Core Run 8 REC=95 RQD=100			2362	4485	24.2
	NQ			NQ Core Run 9 REC=100 RQD=100			2390	4485	
				PENNSYLVANIAN BEDROCK 25.2					
				Bottom of Boring @ 25.15m					
26.4									26.4
28.6									28.6
30.8									30.8
33									33
35.2									35.2
37.4									37.4
39.6									39.6
41.8									41.8
44									44

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(515) 270-8542 * FAX (515) 270-1911

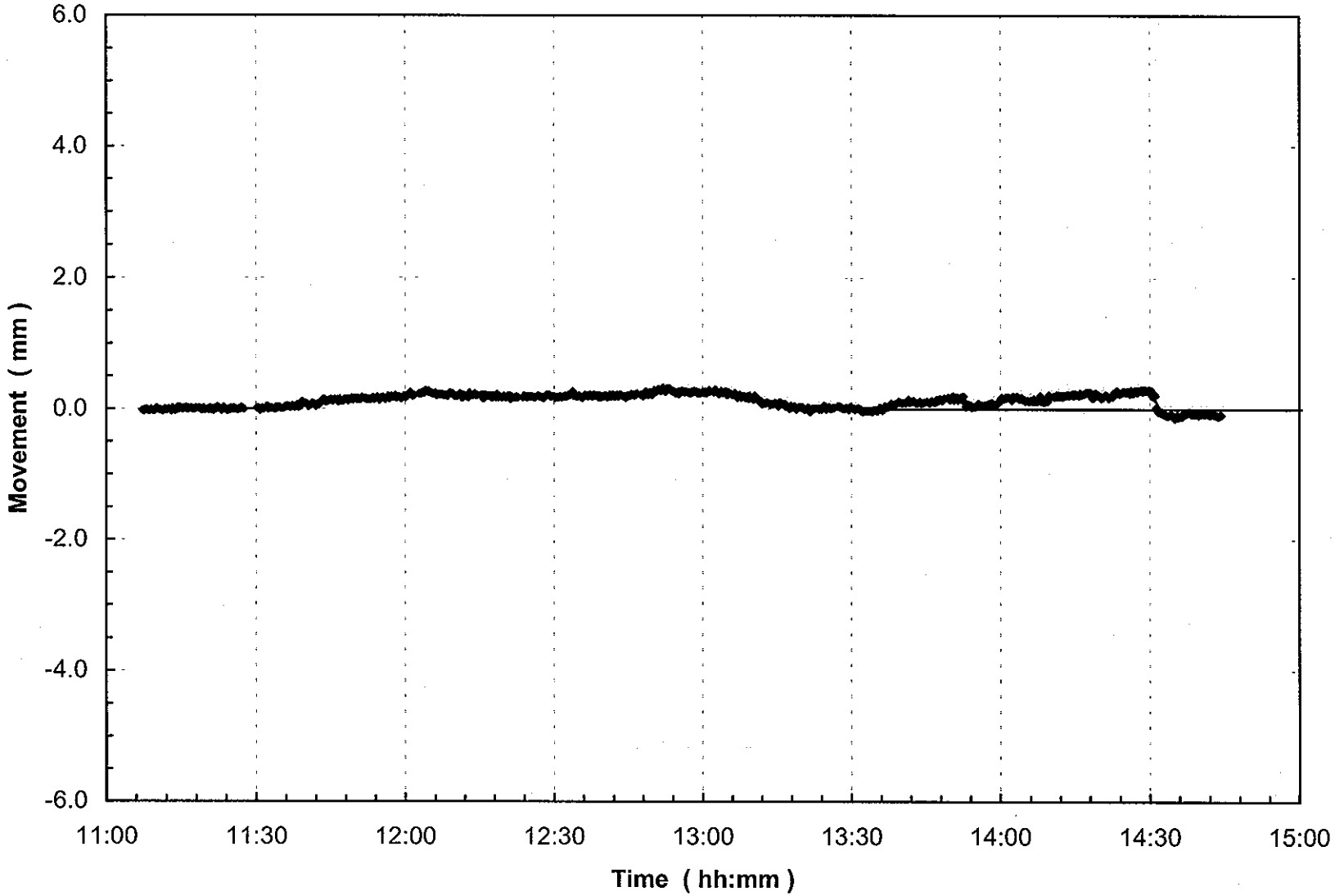
PROJECT: Des Moines River and I-235 Bridge Test Shaft
LOCATION: I-235 and West River Drive, Des Moines, IA
JOB NO.: 026162
DATE: 10/14-15/02

APPENDIX F

REFERENCE BEAM MONITORING

Reference Beam Monitoring

Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA

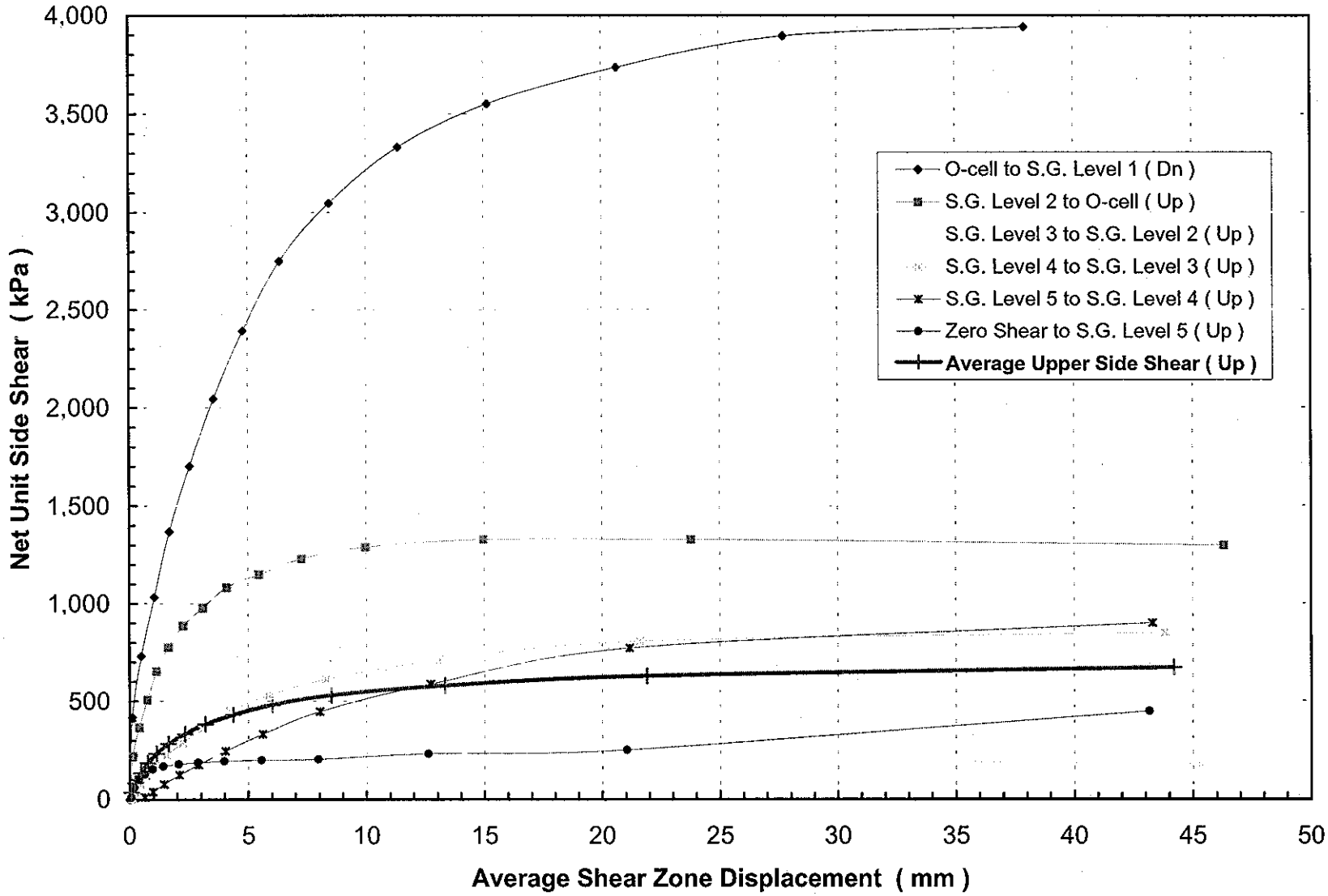


APPENDIX G

NET UNIT SHEAR CURVES AND UNIT END BEARING CURVE

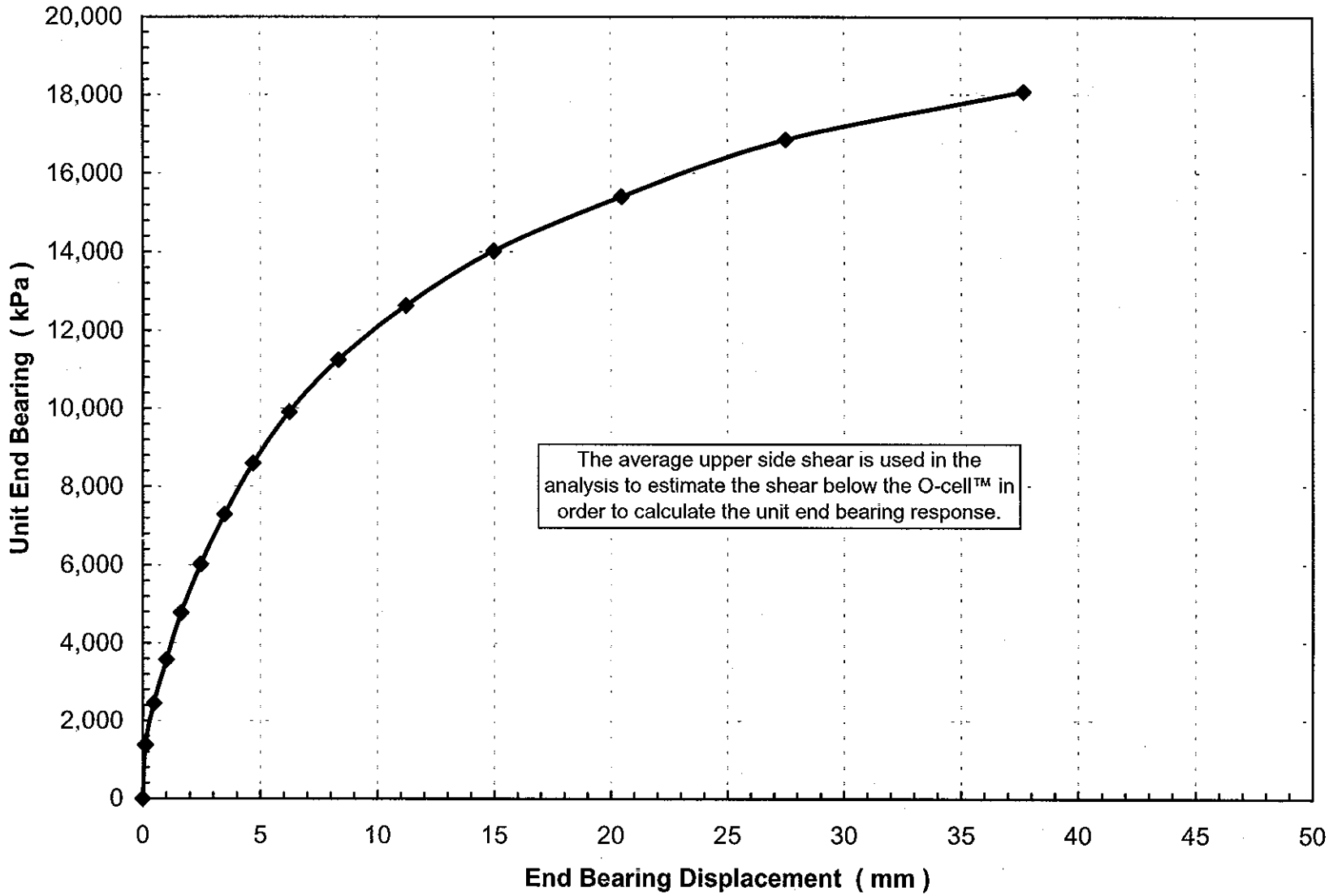
Net Unit Side Shear Curves

Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA



Unit End Bearing

Dedicated Test Shaft - I-235 over Des Moines River - Des Moines, IA



APPENDIX H

SHAFT STIFFNESS ESTIMATION

Table H-1: Tangent Stiffness Analysis for Strain Gage Levels 1, 2 and 3

O-cell™		Strain Gage Level 1			Strain Gage Level 2			Strain Gage Level 3		
Load (MN)	Δ Load (MN)	μ Strain (με)	Δ μ Strain (με)	AE * (MN)	μ Strain (με)	Δ μ Strain (με)	AE * (MN)	μ Strain (με)	Δ μ Strain (με)	AE * (MN)
0.00	-	0.0	-	-	0.0	-	-	0.0	-	-
1.42	-	9.9	-	-	16.7	-	-	8.6	-	-
2.79	-	28.8	-	-	49.1	-	-	26.5	-	-
4.15	4.15	48.6	48.6	85,492	81.9	81.9	50,715	46.1	46.1	90,120
5.52	4.10	65.1	55.2	74,294	113.9	97.2	42,227	65.9	57.3	71,549
6.89	4.10	81.8	53.0	77,389	150.5	101.4	40,452	89.1	62.6	65,597
8.26	4.10	97.6	49.0	83,690	189.3	107.4	38,215	114.9	68.8	59,628
9.63	4.10	113.0	47.9	85,712	231.5	117.6	34,879	144.7	78.7	52,114
10.99	4.10	127.1	45.3	90,646	271.6	121.1	33,874	177.1	88.1	46,592
12.36	4.10	147.5	49.8	82,311	319.4	130.1	31,535	218.8	103.9	39,505
13.73	4.10	169.4	56.4	72,783	363.9	132.4	31,000	261.2	116.5	35,218
15.10	4.10	197.9	70.8	57,955	412.7	141.0	29,097	310.5	133.4	30,758
16.46	4.10	229.9	82.4	49,795	465.3	145.9	28,119	371.5	152.7	26,872
17.83	4.10	264.6	95.3	43,069	525.7	161.8	25,367	441.3	180.1	22,779
19.01	3.91	304.0	106.1	36,872	583.1	170.5	22,946	508.6	198.1	19,748

* Tangent Pile Stiffness Calculation: AE = Δ Load / Δ μ Strain

Table H-1: Tangent Stiffness Analysis for Strain Gage Levels 4 and 5

O-cell™		Strain Gage Level 4			Strain Gage Level 5					
Load (MN)	Δ Load (MN)	μ Strain (με)	Δ μ Strain (με)	AE * (MN)	μ Strain (με)	Δ μ Strain (με)	AE * (MN)			
0.00	-	0.0	-	-	0.0	-	-			
1.42	-	3.6	-	-	2.1	-	-			
2.79	-	10.7	-	-	6.1	-	-			
4.15	4.15	18.2	18.2	228,886	9.6	9.6	434,480			
5.52	4.10	25.6	22.1	186,041	11.6	9.5	431,635			
6.89	4.10	34.8	24.0	170,666	13.6	7.5	546,658			
8.26	4.10	44.7	26.5	154,762	14.7	5.1	805,094			
9.63	4.10	55.9	30.2	135,743	15.5	3.9	1,048,865			
10.99	4.10	67.7	33.0	124,431	16.1	2.5	1,660,930			
12.36	4.10	83.4	38.7	105,988	16.8	2.1	1,943,245			
13.73	4.10	101.7	45.8	89,586	17.1	1.7	2,484,054			
15.10	4.10	126.5	58.8	69,782	17.5	1.4	2,933,553			
16.46	4.10	159.3	75.9	54,049	19.6	2.9	1,429,075			
17.83	4.10	200.4	98.8	41,550	21.2	4.1	1,005,036			
19.01	3.91	254.5	127.9	30,573	36.9	19.5	201,007			

* Tangent Pile Stiffness Calculation: AE = Δ Load / Δ μ Strain

Figure H-1: Tangent Shaft Stiffness Analysis for Strain Gage Levels 1 through 5