WIKA

Certificate No.: 9748

Pressure and Temperature Measurement
WIKA Instrument Corporation
1000 Wiegand Boulevard
Lawrenceville, Georgia 30043

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Fax 770-338-5118
www.wika.com
info@wika.com

Calibration results

Reading DUT psi	Reading WS psi M 1	Reading WS psi M 2	Hysteresis psi	Deviation % M 1	Deviation % M 2	Pass/Fail
0.0	0.0	0.0	0.0	0.0	0.0	PASS
3000.0	3069.1	2916.6	152.5	-0.5	0.6	PASS
9000.0	9075.7	8922.1	153.6	-0.5	0.5	PASS
12000.0	12074.4	11929.3	145.1	-0.5	0.5	PASS
15000.0	14972.4	14958.8	13.6	0.2	0.3	PASS

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

Declaration of conformity:

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

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

Calibration is carried out according to the following procedures:

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

ISO 9001 Certified

Certificate of Calibration

Instrument: Geokon VW Pressure Transducer

Calibration Date: June 22, 2006

Model: 4500HH-10000

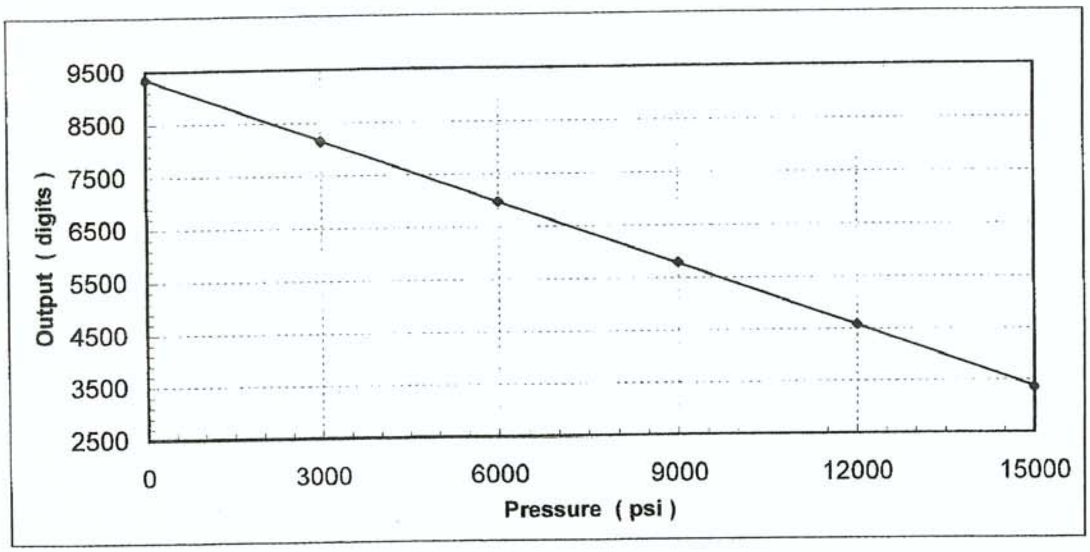
Temperature: 23.8 °C

Serial Number: 59688

Barometric Pressure: 1020 mbar

Pressure (psi)	1st Cycle (digits)	2nd Cycle (digits)	Average (digits)	Linearity * (% FS)	Poly Fit (% FS)
0	9343	9345	9344	-0.15	0.04
3000	8149	8154	8152	-0.11	-0.20
6000	6974	6975	6975	0.20	-0.03
9000	5783	5783	5783	0.26	0.03
12000	4578	4578	4578	0.10	0.02
15000	3357	3361	3359	-0.30	-0.08

* Linearity based on regression zero.



Linear Gage Factor: 2.510 **psi / digit** 17.31 **kPa / digit** **Regression Zero:** 9353 **digits**

Polynomial Gage Factors: -7.656E-06 **psi / digit ² +** -2.412 **psi / digit +** 23200 **psi**

Polynomial Gage Factors: -5.279E-05 **kPa / digit ² +** -16.63 **kPa / digit +** 160000 **kPa**

LOADTEST certifies that the above named instrument has been calibrated by comparison to laboratory standards traceable to the NIST, and was found to be in tolerance in all operating ranges.

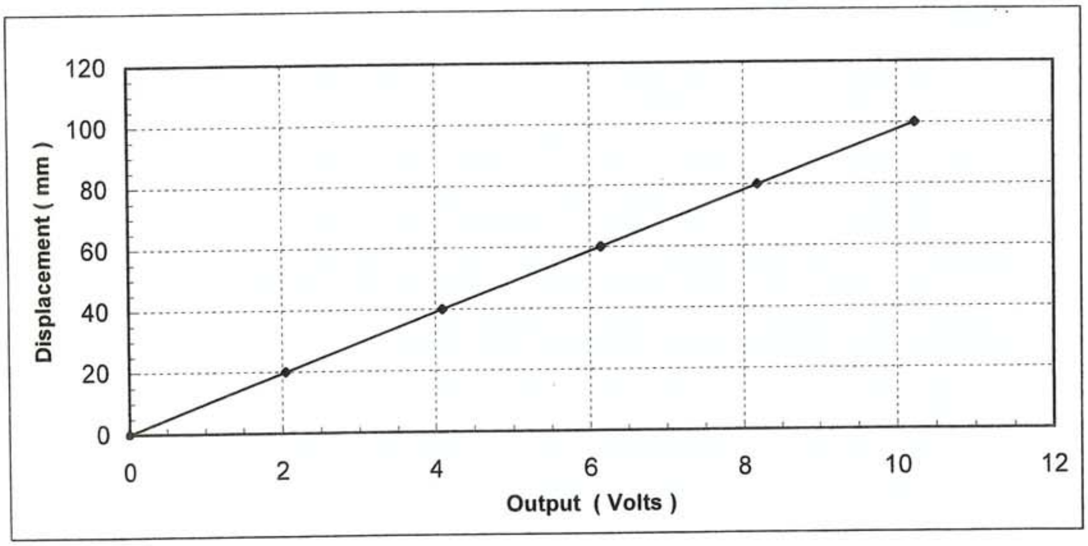
Tested by: Steve Evans Signed: [signature]

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

Certificate of Calibration

Instrument:	RDP Electronics LVDT	Calibration Date:	April 12, 2007
Model:	DCW2000A/85B	Temperature:	25.8 °C
Serial Number:	2262	Linear Range:	100 mm

Displacement (mm)	1st Cycle (Volts)	2nd Cycle (Volts)	Average (Volts)	Linearity (% FS)
0	0.000	0.000	0.000	0.00
20	2.047	2.044	2.045	-0.02
40	4.091	4.091	4.091	-0.03
60	6.148	6.148	6.148	0.07
80	8.184	8.184	8.184	-0.04
100	10.236	10.236	10.236	0.01



Linear Gage Factor: __9.770__ **mm/V** __0.3846__ **in/V**

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

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

Approved by: Jon Sinnreich, M.Eng. Signed: Jon Sinnreich

Certificate of Calibration

Instrument: RDP Electronics LVDT

Model: DCW2000A/85B

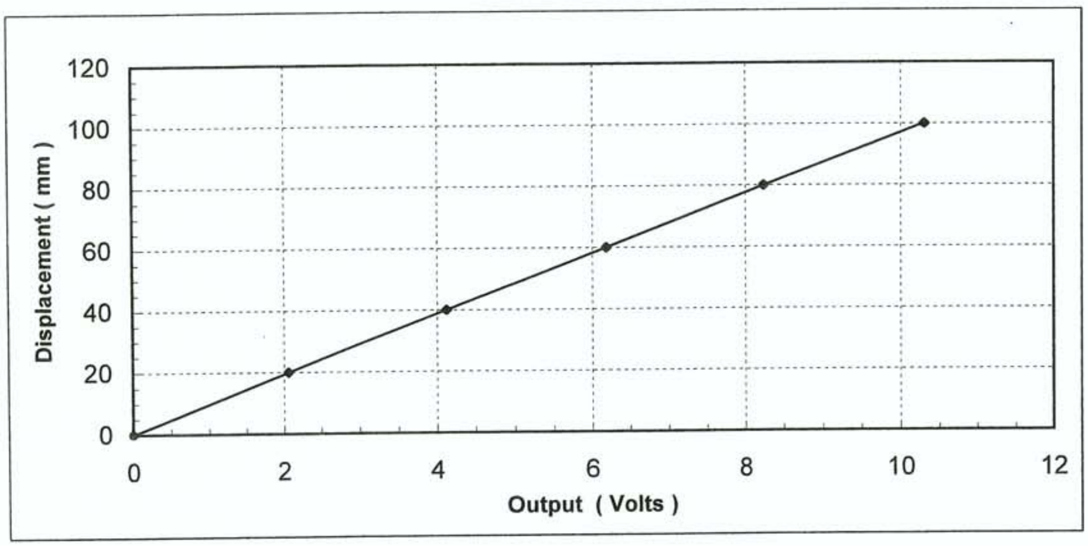
Serial Number: 2263

Calibration Date: April 12, 2007

Temperature: 25.7 °C

Linear Range: 100 mm

Displacement (mm)	1st Cycle (Volts)	2nd Cycle (Volts)	Average (Volts)	Linearity (% FS)
0	0.000	0.000	0.000	0.00
20	2.055	2.057	2.056	-0.05
40	4.117	4.120	4.119	-0.03
60	6.185	6.185	6.185	0.03
80	8.240	8.240	8.240	-0.04
100	10.308	10.308	10.308	0.03



Linear Gage Factor: 9.705 mm/V 0.3821 in/V

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

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

Approved by: Jon Sinnreich, M.Eng. Signed:

Certificate of Calibration

Instrument: RDP Electronics LVDT

Model: DCW500A/85B

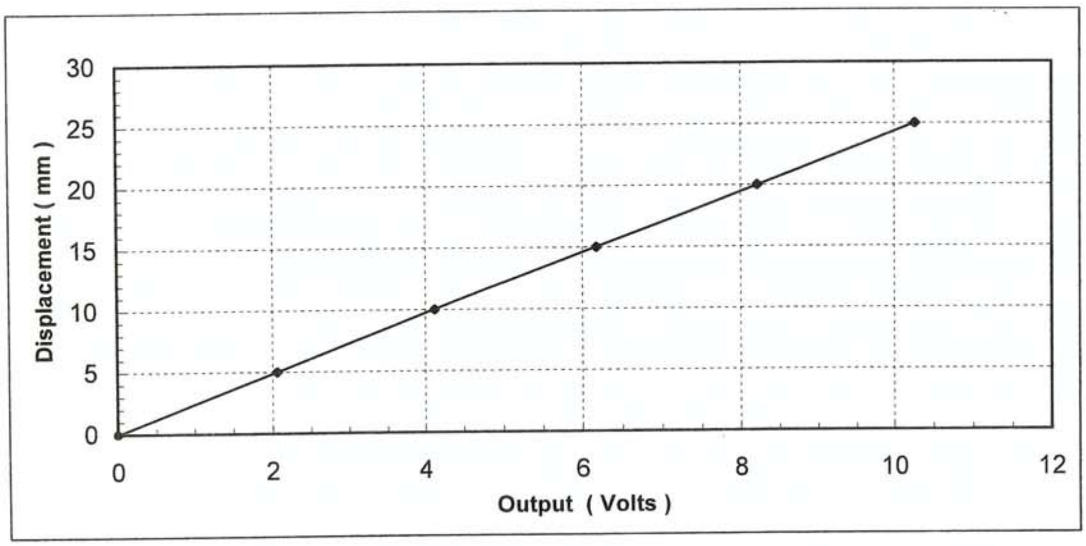
Serial Number: 3354

Calibration Date: April 12, 2007

Temperature: 23.8 °C

Linear Range: 25 mm

Displacement (mm)	1st Cycle (Volts)	2nd Cycle (Volts)	Average (Volts)	Linearity (% FS)
0	0.000	0.000	0.000	0.00
5	2.052	2.068	2.060	0.05
10	4.107	4.133	4.120	0.10
15	6.167	6.185	6.176	0.10
20	8.213	8.213	8.213	-0.07
25	10.271	10.268	10.269	-0.06



Linear Gage Factor: 2.433 mm/V 0.09579 in/V

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

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

Approved by: Jon Sinnreich, M.Eng. Signed: Jon Sinnreich

Certificate of Calibration

Instrument: RDP Electronics LVDT

Model: DCW500A/85B

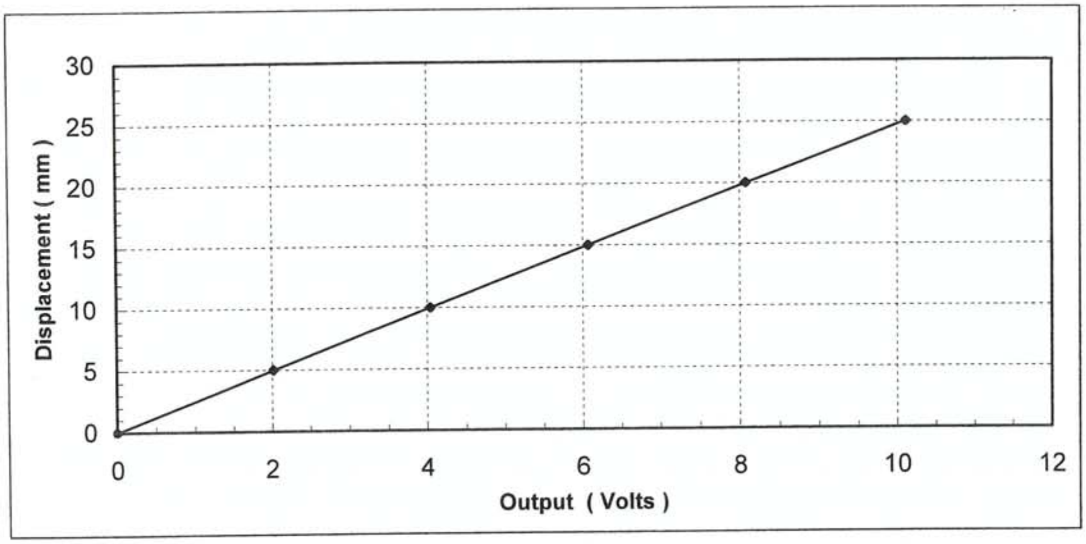
Serial Number: 3355

Calibration Date: April 12, 2007

Temperature: 23.9 °C

Linear Range: 25 mm

Displacement (mm)	1st Cycle (Volts)	2nd Cycle (Volts)	Average (Volts)	Linearity (% FS)
0	0.000	0.000	0.000	0.00
5	2.015	2.018	2.016	-0.05
10	4.038	4.040	4.039	-0.04
15	6.063	6.077	6.070	0.05
20	8.078	8.081	8.080	-0.06
25	10.122	10.101	10.112	0.04



Linear Gage Factor: 2.473 mm/V 0.09738 in/V

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

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

Approved by: Jon Sinnreich, M.Eng. Signed: [signature]

Certificate of Calibration

Instrument: Leica Digital Level

Model: NA 3003

Serial Number: 282185

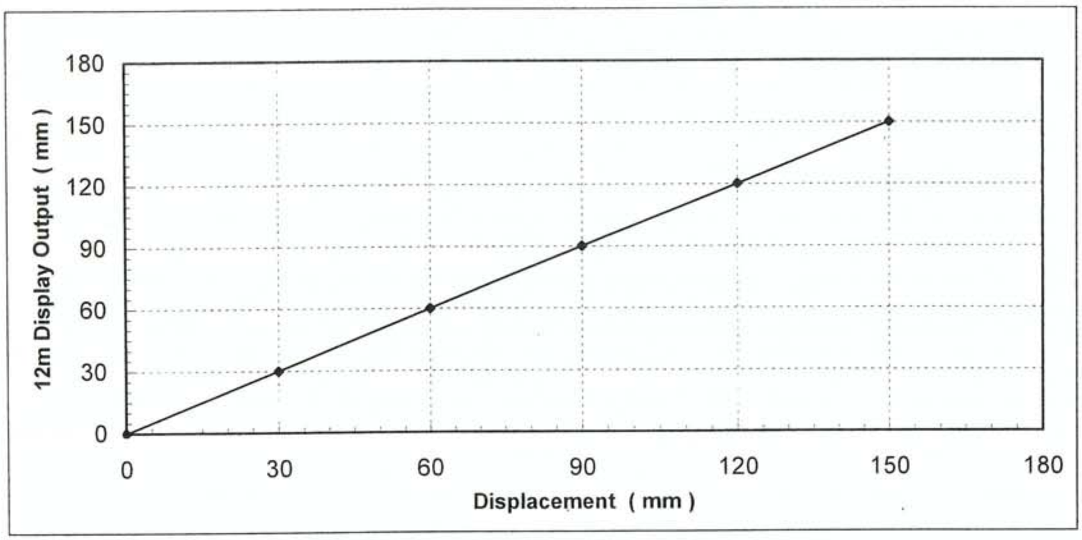
Calibration Date: June 15, 2006

Temperature: 24.9 °C

Staff: 60 cm Invar

Displacement (mm)	1st Cycle @ 6m (mm)	Linearity (% FS *)	2nd Cycle @ 12m (mm)	Linearity (% FS *)
0	0.00	0.00	0.00	0.00
30	29.99	0.01	30.00	0.00
60	59.99	0.01	60.03	-0.02
90	90.02	-0.01	90.10	-0.07
120	120.02	-0.01	120.11	-0.07
150	150.02	-0.01	150.02	-0.01

* Full scale taken as maximum calibration displacement of 150 mm.



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

Tested by: Steve Evans

Signed:

Approved by: Michael D. Ahrens, P.E.

Signed:

Certificate of Calibration

Instrument: Leica Digital Level

Model: NA 3003

Serial Number: 281740

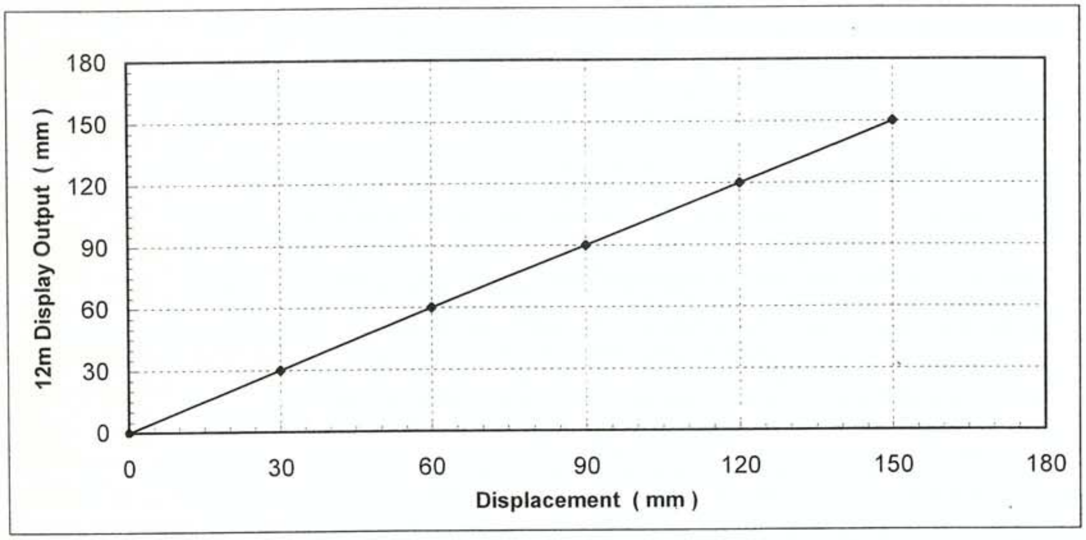
Calibration Date: June 15, 2006

Temperature: 24.9 °C

Staff: 60 cm Invar

Displacement (mm)	1st Cycle @ 6m (mm)	Linearity (% FS *)	2nd Cycle @ 12m (mm)	Linearity (% FS *)
0	0.00	0.00	0.00	0.00
30	30.01	-0.01	29.98	0.01
60	60.03	-0.02	60.03	-0.02
90	90.06	-0.04	89.90	0.07
120	120.04	-0.03	119.93	0.05
150	150.06	-0.04	150.08	-0.05

* Full scale taken as maximum calibration displacement of 150 mm.



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

Tested by: Steve Evans Signed: [signature]

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

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

Vibrating Wire Displacement Transducer Calibration Report

Range: 150 mm

Calibration Date: June 1, 2007

Serial Number: 07-10498

Temperature: 24.6 °C

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

Calibration Instruction: CI-4400

Technician: J. Ouellette

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2765	2765	2765	0.04	0.03	-0.02	-0.01
30.0	3732	3731	3732	30.02	0.01	30.03	0.02
60.0	4696	4697	4697	59.95	-0.03	60.00	0.00
90.0	5663	5663	5663	89.93	-0.04	89.98	-0.01
120.0	6632	6632	6632	119.99	-0.01	120.00	0.00
150.0	7601	7602	7602	150.06	0.04	150.01	0.00

(mm) Linear Gage Factor (G): 0.03102 (mm/ digit) **Regression Zero: 2764**

Polynomial Gage Factors: A: -1.8353E-08 B: 0.03121 C: -86.169

(inches) Linear Gage Factor (G): 0.001221 (inches/ digit)

Polynomial Gage Factors: A: -7.2258E-10 B: 0.001229 C: -3.3925

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

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5175 Temp(T_0): 23.9 °C Date: June 13, 2007

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

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

Vibrating Wire Displacement Transducer Calibration Report

Range: 150 mm

Calibration Date: June 1, 2007

Serial Number: 07-10503

Temperature: 24.6 °C

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

Calibration Instruction: CI-4400

Technician: J. Ouellette

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2660	2657	2659	-0.06	-0.04	0.00	0.00
30.0	3643	3642	3643	30.03	0.02	30.02	0.01
60.0	4624	4622	4623	60.02	0.01	59.97	-0.02
90.0	5604	5603	5604	90.00	0.00	89.95	-0.03
120.0	6589	6588	6589	120.12	0.08	120.11	0.07
150.0	7562	7562	7562	149.89	-0.07	149.95	-0.03

(mm) Linear Gage Factor (G): 0.03058 (mm/ digit)

Regression Zero: 2660

Polynomial Gage Factors: A: 1.95319E-08 B: 0.03038 C: -80.901

(inches) Linear Gage Factor (G): 0.001204 (inches/ digit)

Polynomial Gage Factors: A: 7.68974E-10 B: 0.001196 C: -3.1851

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

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5094

Temp(T_0): 23.9 °C

Date: June 13, 2007

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

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

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

Vibrating Wire Displacement Transducer Calibration Report

Range: 150 mm

Calibration Date: June 1, 2007

Serial Number: 07-10504

Temperature: 24.6 °C

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

Calibration Instruction: CI-4400

Technician: J. Ouellette

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2746	2745	2746	0.22	0.15	0.03	0.02
30.0	3703	3702	3703	29.95	-0.04	29.98	-0.01
60.0	4664	4662	4663	59.78	-0.15	59.94	-0.04
90.0	5632	5631	5632	89.87	-0.09	90.02	0.01
120.0	6604	6602	6603	120.04	0.03	120.08	0.06
150.0	7572	7572	7572	150.14	0.09	149.95	-0.03

(mm) Linear Gage Factor (G): 0.03106 (mm/ digit) **Regression Zero: 2738**

Polynomial Gage Factors: A: -6.187E-08 B: 0.03170 C: -86.541

(inches) Linear Gage Factor (G): 0.001223 (inches/ digit)

Polynomial Gage Factors: A: -2.4358E-09 B: 0.001248 C: -3.4071

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

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5182 Temp(T_0): 23.9 °C Date: June 13, 2007

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

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

Vibrating Wire Displacement Transducer Calibration Report

Range: 150 mm

Serial Number: 07-10505

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

Calibration Date: June 1, 2007

Temperature: 24.6 °C

Calibration Instruction: CI-4400

Technician: J. Ouellette

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2774	2773	2774	0.18	0.12	0.00	0.00
30.0	3740	3739	3740	29.97	-0.02	30.00	0.00
60.0	4708	4708	4708	59.84	-0.11	59.98	-0.02
90.0	5682	5682	5682	89.87	-0.08	90.01	0.01
120.0	6658	6658	6658	119.97	-0.02	120.01	0.01
150.0	7637	7637	7637	150.17	0.11	149.99	-0.01

(mm) Linear Gage Factor (G): 0.03084 (mm/ digit) **Regression Zero: 2768**

Polynomial Gage Factors: A: -5.5287E-08 B: 0.03142 C: -86.701

(inches) Linear Gage Factor (G): 0.001214 (inches/ digit)

Polynomial Gage Factors: A: -2.1766E-09 B: 0.001237 C: -3.4134

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

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5185 Temp(T_0): 23.9 °C Date: June 13, 2007

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

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

Vibrating Wire Displacement Transducer Calibration Report

Range: 25 mm

Calibration Date: June 8, 2007

Serial Number: 05-9939

Temperature: 22.7 °C

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

Calibration Instruction: CI-4400

Technician: J. Ouellette

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2375	2373	2374	-0.06	-0.23	-0.01	-0.03
5.0	3515	3514	3515	5.02	0.09	5.01	0.05
10.0	4641	4640	4641	10.04	0.16	10.00	0.00
15.0	5763	5761	5762	15.04	0.15	15.00	-0.01
20.0	6877	6876	6877	20.00	0.01	19.99	-0.03
25.0	7988	7987	7988	24.95	-0.19	25.00	0.02

(mm) Linear Gage Factor (G): 0.004456 (mm/ digit) **Regression Zero: 2387**

Polynomial Gage Factors: A: 1.22284E-08 B: 0.004329 C: -10.353

(inches) Linear Gage Factor (G): 0.0001754 (inches/ digit)

Polynomial Gage Factors: A: 4.81434E-10 B: 0.0001704 C: -0.40759

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

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 4931 Temp(T_0): 24.7 °C Date: June 13, 2007

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

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

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

Vibrating Wire Displacement Transducer Calibration Report

Range: 25 mm

Serial Number: 05-9940

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

Calibration Date: June 8, 2007

Temperature: 22.7 °C

Calibration Instruction: CI-4400

Technician: J. Ouellette

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2427	2424	2426	-0.06	-0.22	-0.01	-0.03
5.0	3563	3560	3562	5.02	0.10	5.01	0.06
10.0	4683	4682	4683	10.04	0.15	10.00	0.00
15.0	5800	5799	5800	15.03	0.13	14.99	-0.02
20.0	6911	6911	6911	20.00	0.01	19.99	-0.02
25.0	8019	8019	8019	24.96	-0.17	25.01	0.02

(mm) Linear Gage Factor (G): 0.004472 (mm/ digit) **Regression Zero: 2438**

Polynomial Gage Factors: A: 1.1373E-08 B: 0.004353 C: -10.633

(inches) Linear Gage Factor (G): 0.0001761 (inches/ digit)

Polynomial Gage Factors: A: 4.47755E-10 B: 0.0001714 C: -0.41863

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

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

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 4956 Temp(T_0): 24.8 °C Date: June 13, 2007

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.
 092605

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

Sister Bar Calibration Report

Model Number : 4911-4

Date of Calibration: June 08, 2007

Serial Number: 07-12904

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

Prestress: 35,000 psi

Cable Length: 120 ft.

Temperature: 23.2 °C

Factory Zero Reading: 6839

Calibration Instruction: CI-VW Rebar

Regression Zero: 6843

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6896	6894	6895		
1,500	7572	7571	7572	677	-0.06
3,000	8299	8303	8301	730	-0.08
4,500	9039	9033	9036	735	0.08
6,000	9761	9769	9765	729	0.04
100	6895				

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

Date of Calibration: June 08, 2007

Serial Number: 07-12905

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

Prestress: 35,000 psi

Cable Length: 120 ft.

Temperature: 22.8 °C

Factory Zero Reading: 6730

Calibration Instruction: CI-VW Rebar

Regression Zero: 6736

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6785	6784	6785		
1,500	7432	7434	7433	649	-0.07
3,000	8138	8133	8136	703	0.05
4,500	8838	8838	8838	703	0.18
6,000	9531	9530	9531	693	-0.06
100	6785				

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

Gage Factor: 0.358 microstrain/ digit (GK-401 Pos."B")

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Date of Calibration: June 08, 2007

Serial Number: 07-12906

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

Prestress: 35,000 psi

Cable Length: 120 ft.

Temperature: 23.0 °C

Factory Zero Reading: 6775

Calibration Instruction: CI-VW Rebar

Regression Zero: 6778

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6828	6828	6828		
1,500	7517	7513	7515	687	-0.07
3,000	8252	8262	8257	742	0.03
4,500	8999	8998	8999	742	0.12
6,000	9730	9734	9732	734	-0.07
100	6829				

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

Date of Calibration: June 08, 2007

Serial Number: 07-12907

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

Prestress: 35,000 psi

Cable Length: 120 ft.

Temperature: 23.4 °C

Factory Zero Reading: 6838

Calibration Instruction: CI-VW Rebar

Regression Zero: 6838

Technician: G. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6895	6892	6894		
1,500	7566	7561	7564	670	-0.21
3,000	8297	8299	8298	735	-0.11
4,500	9034	9036	9035	737	0.08
6,000	9764	9769	9767	732	0.08
100	6893				

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: 07-12908

Prestress: 35,000 psi

Temperature: 22.9 °C

Calibration Instruction: CI-VW Rebar

Date of Calibration: June 08, 2007

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

Cable Length: 78 ft.

Factory Zero Reading: 6909

Regression Zero: 6906

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6964	6963	6964		
1,500	7639	7633	7636	673	-0.24
3,000	8378	8376	8377	741	-0.10
4,500	9119	9121	9120	743	0.10
6,000	9855	9859	9857	737	0.10
100	6964				

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

Date of Calibration: June 08, 2007

Serial Number: 07-12909

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

Prestress: 35,000 psi

Cable Length: 78 ft.

Temperature: 23.2 °C

Factory Zero Reading: 6914

Calibration Instruction: CI-VW Rebar

Regression Zero: 6914

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity
	Cycle #1	Cycle #2	Average	Change	% Max.Load
100	6968	6965	6967		
1,500	7621	7623	7622	656	-0.13
3,000	8332	8335	8334	712	-0.14
4,500	9049	9048	9049	715	-0.02
6,000	9763	9765	9764	716	0.11
100	6967				

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

Gage Factor: 0.353 microstrain/ digit (GK-401 Pos."B")

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Date of Calibration: June 08, 2007

Serial Number: 07-12910

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

Prestress: 35,000 psi

Cable Length: 58 ft.

Temperature: 22.9 °C

Factory Zero Reading: 7047

Calibration Instruction: CI-VW Rebar

Regression Zero: 7051

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7105	7104	7105		
1,500	7770	7770	7770	666	-0.32
3,000	8512	8513	8513	743	0.17
4,500	9238	9236	9237	725	0.04
6,000	9963	9964	9964	727	-0.02
100	7105				

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: 07-12911

Prestress: 35,000 psi

Temperature: 23.1 °C

Calibration Instruction: CI-VW Rebar

Date of Calibration: June 08, 2007

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

Cable Length: 58 ft.

Factory Zero Reading: 6775

Regression Zero: 6783

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6831	6830	6831		
1,500	7506	7510	7508	678	-0.03
3,000	8234	8238	8236	728	0.05
4,500	8965	8964	8965	729	0.14
6,000	9681	9685	9683	719	-0.11
100	6831				

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

Gage Factor: 0.348 microstrain/ digit (GK-401 Pos."B")

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

APPENDIX C

CONSTRUCTION OF THE EQUIVALENT TOP-LOADED LOAD-SETTLEMENT CURVE

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

> Kishida H. et al., 1992, "Pile Loading Tests at Osaka Amenity Park Project," Paper by Mitsubishi Co., also briefly described in Schmertmann (1993, see bibliography). Compares one drilled shaft in tension and another in compression.
>
> Ogura, H. et al., 1995, "Application of Pile Toe Load Test to Cast-in-place

Concrete Pile and Precast Pile," special volume 'Tsuchi-to-Kiso' on Pile Loading Test, Japanese Geotechnical Society, Vol. 3, No. 5, Ser. No. 448. Original in Japanese. Translated by M. B. Karkee, GEOTOP Corporation. Compares one drilled shaft and one driven pile, both in compression.

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

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

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

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

August, 2000

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

Figure A

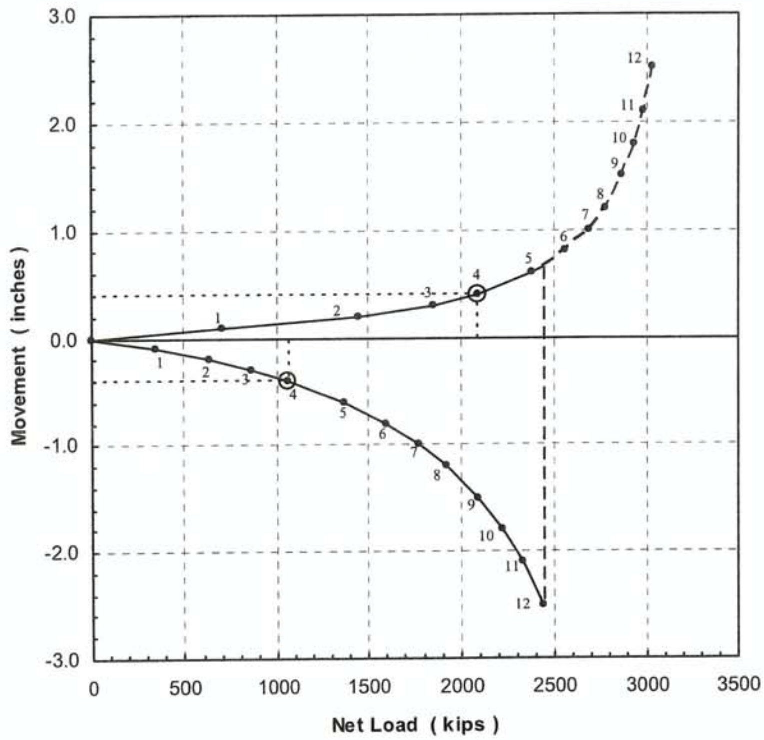
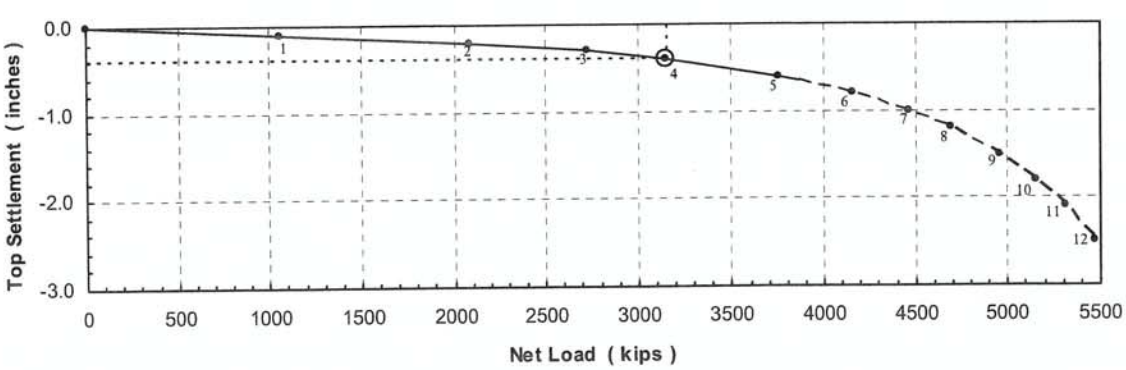
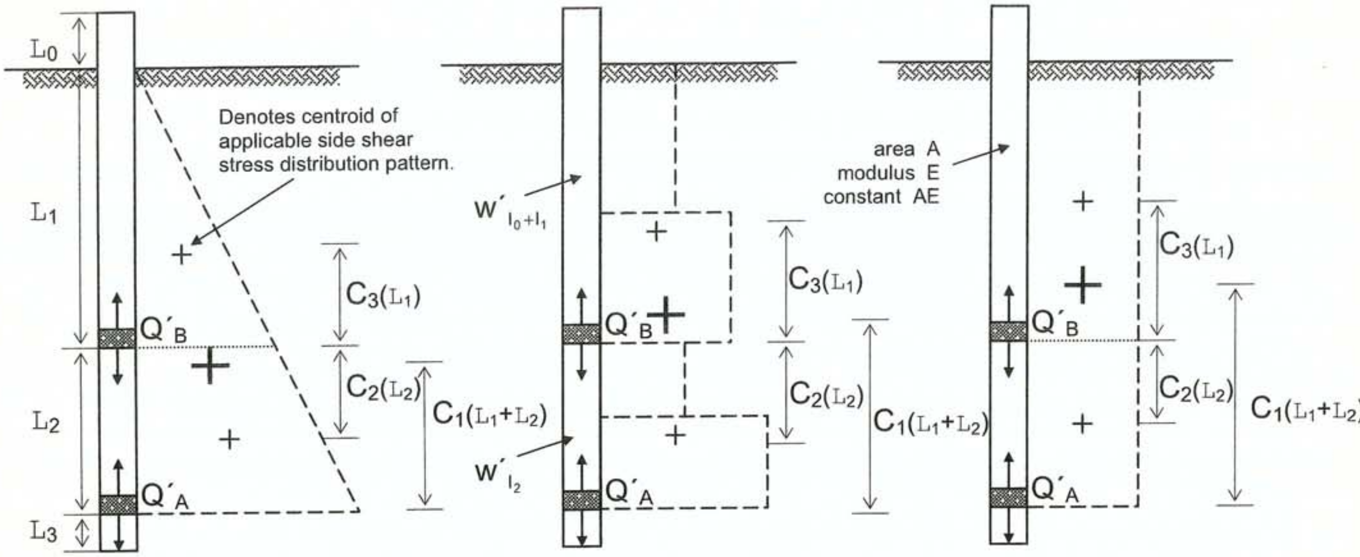


Figure B



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



1-Stage Single Level Test (Q'_A only):

$$\delta_{OLT} = \delta_{\uparrow(l_1+l_2)}$$

$C_1 = \frac{1}{3}$	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): $\delta_{OLT} = \delta_{\uparrow l_1} + \delta_{\downarrow l_2}$

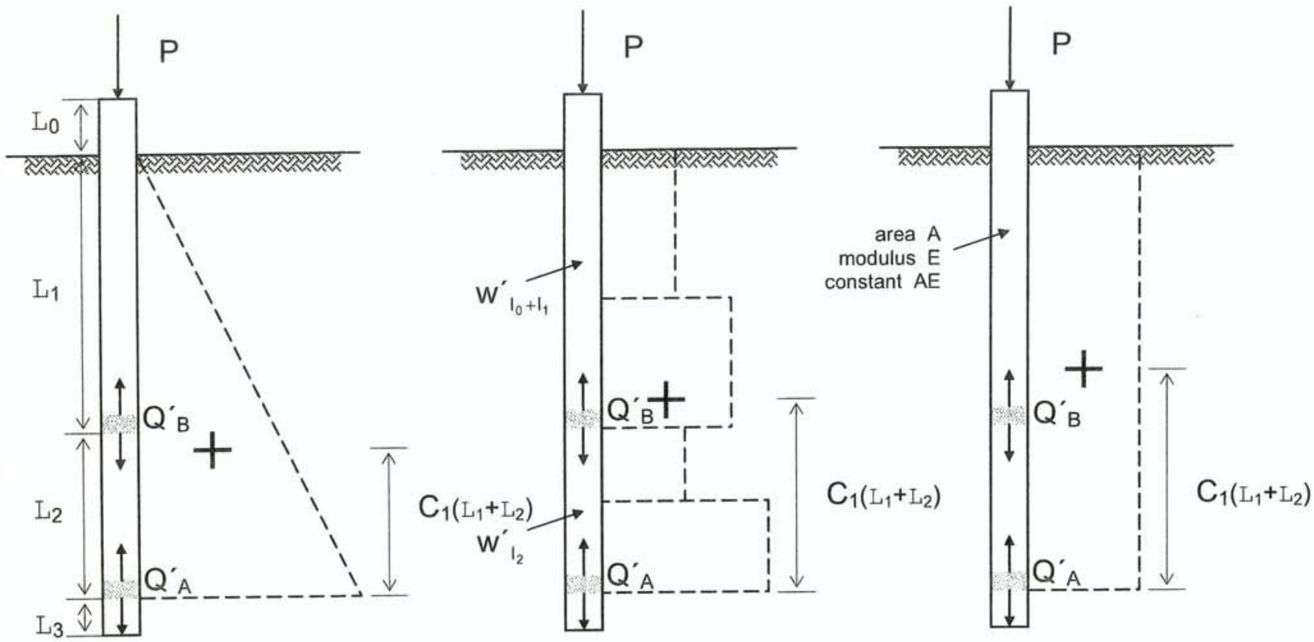
$C_3 = \frac{1}{3}$	Centroid Factor $= C_3$	$C_3 = \frac{1}{2}$
$\delta_{\uparrow l_1} = \frac{1}{3}\frac{Q'_{\uparrow B}l_1}{AE}$	$\delta_{\uparrow l_1} = C_3\frac{Q'_{\uparrow B}l_1}{AE}$	$\delta_{\uparrow l_1} = \frac{1}{3}\frac{Q'_{\uparrow B}l_1}{AE}$
$C_2 = \frac{1}{3}\left(\frac{3l_1+2l_2}{2l_1+l_2}\right)$	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, buoyant where below water table

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



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

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

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}.