Model 4900

Vibrating Wire Load Cell

Instruction Manual

GEOKON®

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1. INTRODUCTION

1.1 THEORY OF OPERATION

GEOKON load cells are of an annular design primarily for use on tiebacks and rockbolts. They may also be used during pile load tests and for monitoring loads in cross-lot struts and tunnel supports, etc. In practically all cases, the load cells are used in conjunction with a hydraulic jack, which applies the load, and with bearing plates positioned on either side of the load cell.

GEOKON Model 4900 load cells are frequently used for the following:

- To provide a permanent means of monitoring the load throughout the life of the tieback, rockbolt, strut or support, etc.
- To provide an electronic output for automatic data gathering.
- As a check on the load as determined by the hydraulic pressure applied to the jack during proof testing on tiebacks, rockbolts, etc. **For this purpose the user should be aware that the agreement cannot be guarantee better than ±20% because of the many variables.**

Load cells are positioned so that the tensile load in the tieback or rockbolt produces a compressive load in the load cell. This is done by trapping the load cell between bearing plates positioned between the jack and the structure, either below the anchor plate for permanent installations or above the anchor plate for proof testing. Figure 1 and Figure 2 show the two different installations.

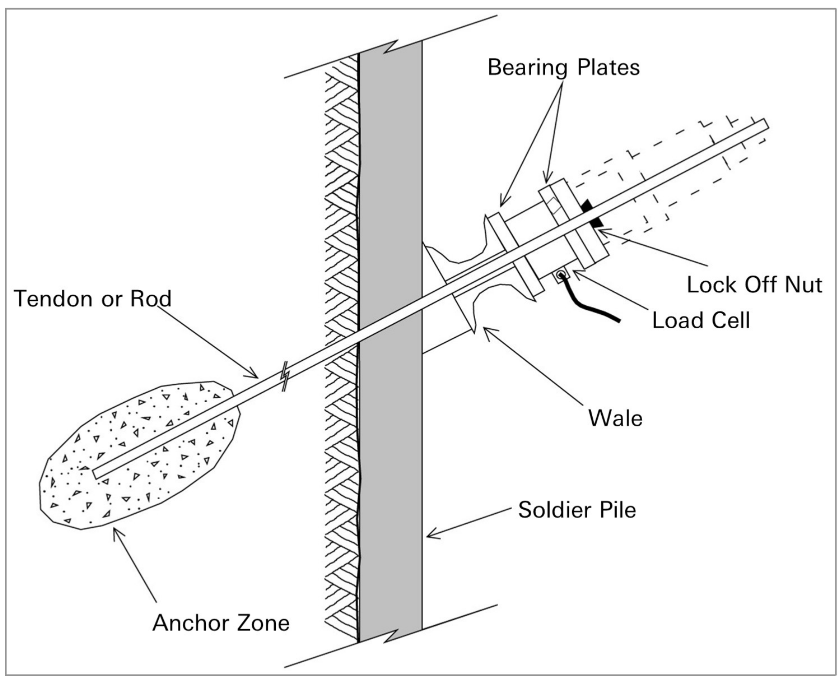

FIGURE 1: *Load Cells on Tiebacks for the Permanent Monitoring*

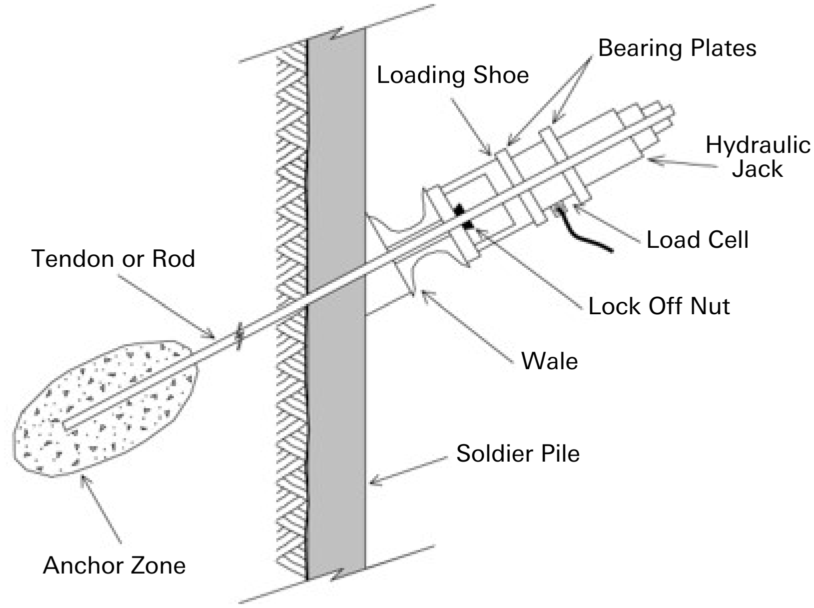

FIGURE 2: *Load Cells on Tieback for Proof Testing Only*

Figure 3 illustrates load cells being used for load monitoring during a pile load test.

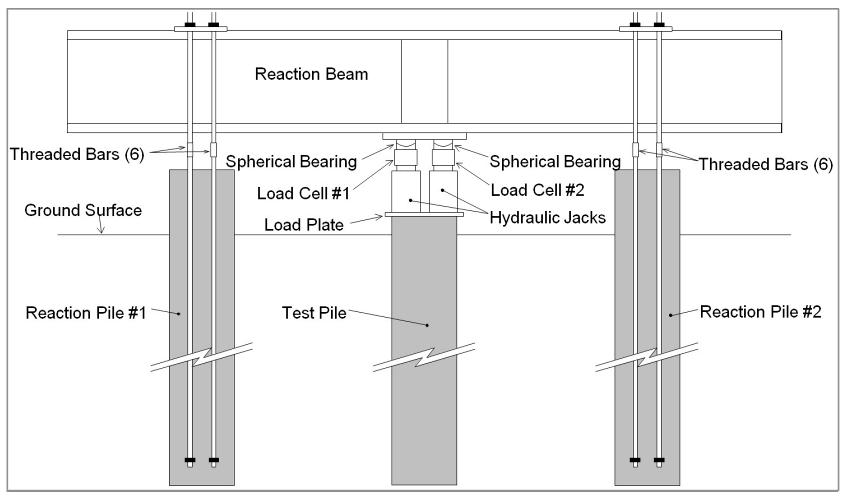

FIGURE 3: *Load Cells for load monitoring during a pile load test*

1.2 LOAD CELL DESIGN AND CONSTRUCTION

The Model 4900 Load Cell body is constructed in the form of a high strength steel cylinder in which three to six vibrating wire strain gauges are embedded to measure the change of strain in the cylinder as it comes under load. Multiple gauges are needed to account for the effects of off-center or eccentric loading. The cable is attached to the cell through a waterproof gland. A Kellem's grip strain relief prevents the cable from being pulled out of the cell. Cables have thick PVC jackets and can be terminated in a connector to mate with terminal boxes or readouts. See Appendix C for cable and connector diagrams. Figure 4 below shows a typical load cell.

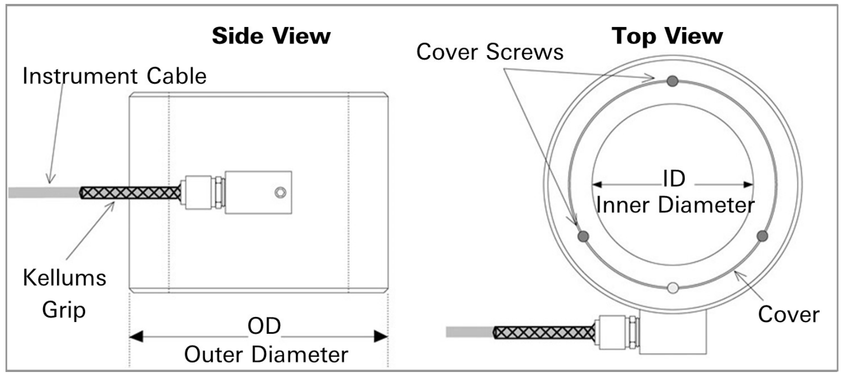

FIGURE 4: *Model 4900 (Three Gauge)*

Additional cable protection can be obtained by either using armored cable or by placing the cable inside flex conduit. Figure 5 shows a typical load cell system.

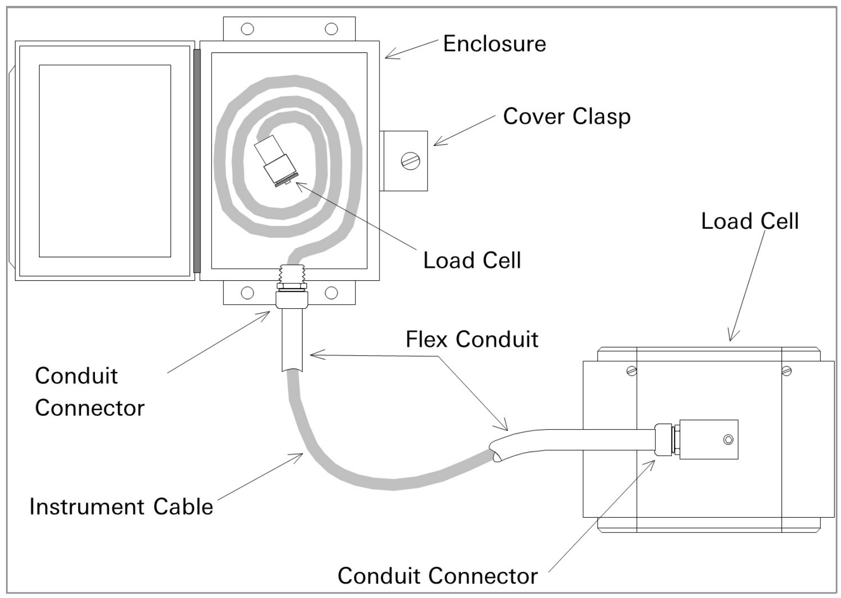

FIGURE 5: *Typical Load Cell System*

Annular load cells, because of their design, are inherently susceptible to varying conditions of end loading, unlike solid load cells, which can be designed with button shaped ends so that the load always falls in a uniform, predictable fashion. Thus, the output and calibration of an annular load cell can be affected by the factors discussed in the subsections below. Note that all of these effects can be accumulative, and can cause the calibration to vary by as much as 20%, unless special precautions are taken.

1.2.1 FRICTION BETWEEN THE BEARING PLATE AND LOAD CELL

Friction between the bearing plate and the load cell can radically affect the performance of a load cell. Interposing deformable plates or lubricant between the bearing plates and the load cell in the field will cause the load cell to overregister, perhaps by as much as 10%. Again, **for best results, it is important to calibrate the load cell in the laboratory under the same loading conditions as will be used in the field.**

End effects of this nature can be reduced somewhat by using tall load cells. A rough rule of thumb for good load cell design calls for a load cell height at least four times the wall thickness of the loaded annulus. On some jobs where there are space restrictions calling for a pancake style load cell, friction between bearing plates and load cell can give rise to large hysteresis effects between loading and unloading cycles.

1.2.2 WARPING OF THE BEARING PLATES AND BEARING PLATE DESIGN

Warping of the bearing plates is caused primarily by a size mismatch between the hydraulic jack and the load cell. A jack larger than the load cell tends to wrap the intervening bearing plate around the load cell, causing the center of the load cell to hourglass or pinch inwards causing the load cell to under-register.

Conversely, a hydraulic jack smaller than the load cell will try to punch the intervening bearing plate through the center of the load cell, making the center of the load cell barrel outwards causing the load cell to over-register. Both effects are exacerbated by bearing plates that are too thin. For further details on this topic, see Appendix D.

Note: To protect the lead wires routed in a groove in one face of the load cell GEOKON does not allow the use of a washer made from lead, copper, rubber or other soft material bearing against this surface. If a soft washer is used be sure it is used only on the other face, i.e., the one that does not have the annular epoxy filled groove.

Minimum bearing plate thickness is 25 mm (1") where load cell size matches hydraulic jack size, i.e., the load bearing annulus of the load cell falls within the load bearing annulus of the hydraulic jack. For any other condition of size mismatch, the bearing plates should be at least two inches thick and even thicker where the size mismatch is extreme or the loads large.

Bearing plates should be flat and smooth. The normal rolled steel plate surface is adequate. It is not necessary to have machined or ground surfaces. Where plates are cut from larger plates, using cutting torches, the edges should be carefully cleaned to remove welding slag and solidified molten lumps.

Consideration should be given to calibrating the load cell using the same bearing plates as will be used in the field. In addition, it is possible to simulate the size of the hydraulic jack using a suitably sized metal donut between the upper platen of the testing machine and the upper bearing plate. Load cells calibrated in this way will be much more likely to agree with the hydraulic jack in the field.

1.2.3 ECCENTRIC LOADING

Eccentric loading of load cells is the rule rather than the exception. Rarely is the axis of the tieback, rockbolt, or strut at right angles to the surface on which the anchor plate or strut rests. With tiebacks using multiple tendons, it is quite common for loads in individual tendons to vary markedly, despite best efforts to avoid this happening. In addition, struts are rarely at right angles to the soldier piles they may be supporting.

These factors combine to produce conditions in which the load cell experiences loads that are higher on one side than on the other. This effect is compensated for by the individual electrical resistance strain gauges, cemented to the cell, being connected together in a full Wheatstone Bridge circuit. Thus, the higher strains on one side are balanced by lower strains on the other and the average strain is not affected. Thus, even gross amounts of load eccentricity cause only slight (< 5%) variations in the load cell output and calibration.

Eccentric loading can be minimized by using spherical bearing plates, but this is expensive and is rarely done. Spherical seats may be of some value during pile load testing where uniformity of the load on the top of the pile is highly desirable.

1.2.4 ELASTIC BEHAVIOR

It is important that a load cell behave elastically, i.e. that the no-load zero will not change with time. For this reason, use only the highest quality strain gauges and adhesives. GEOKON uses transducer-grade strain gauges, along with scrupulous observation of the best installation practices and adhesive post curing techniques.

GEOKON Model 4900 Load Cells are designed to keep the normal working stresses below 30% of the yield stress of the load cell material. Wherever possible load cells are cycled to 150% of the design load prior to calibration. As long as the load cell is never overloaded above this range, the no-load reading will not change. The normal over-range capacity of an aluminum load cell is 200% FSR and 300–400% FSR for a steel load cell before the load cell will begin to fail.

If a load cell is over-ranged and the no-load reading is shifted due to plastic yielding of the cell, then the cell should be returned to the factory for inspection and recalibration. Note, however, that while the no-load zero may shift, the calibration constant will probably not be affected.

1.2.5 TEMPERATURE EFFECTS

Temperature compensation is achieved by using strain gauges whose thermal coefficient is the same as that of the load cell material. Normally, the temperature coefficient of the load cell is insignificant. In special cases, if required, the coefficient can be measured at the factory. Note that temperature changes on the loaded rockbolt, tieback, or strut can produce real changes of load and these will be recorded by the load cell. See Section 4.2 for more information on correcting for temperature.

2. INSTALLATION

2.1 PRELIMINARY TESTS

Before installing the load cell, it should be checked by connecting it to the readout box and taking a no-load reading. This reading, when compared with that given in the calibration data provided with the load cell, will show if the cell is functioning properly. The two readings should agree within about 50 digits (assuming that the same readout box is used for both readings).

2.2 LOAD CELL INSTALLATION

2.2.1 TRANSPORTATION

When transporting load cells, do not pull on the cable and, in particular, do not carry the load cell by the cable. On the larger load cells, threaded holes are provided in the ends to allow eyebolts to be attached for lifting purposes.

2.2.2 INITIAL NO-LOAD READING

Before installing the load cell, be sure to take the no-load reading. This reading is very important, since it will be subtracted from all subsequent readings to calculate the load. Note that each load cell has a different no-load reading that is not zero. See Section 3 for operation of the readout boxes.

2.2.3 INSTALLATION ON TIE-BACKS AND ROCKBOLTS

Note: To protect the lead wires routed in a groove in one face of the load cell GEOKON does not allow the use of a washer made from lead, copper, rubber or other soft material bearing against this surface. If a soft washer is used, be sure it is used only on the other face, i.e., the one that does not have the annular epoxy-filled groove

Load cells should be installed between flat steel bearing plates of sufficient thickness; one inch thick where load cell and jack are about the same size, and two to three inches thick where size mismatches are greater. The normal rolled finish on the plates is good. Plates may need to be machined flat if they are warped. Make sure that the bearing plates completely cover the load-bearing surface of the load cell. Centralize the rockbolt or tieback inside the load cell. Where the load cell I.D. is much bigger than the rockbolt or tieback, a centralizer bushing can be used.

Where the anchor block of a multi-tendon tieback bears directly on the load cell, make sure that the load cell bearing surface is completely covered by the anchor block. If the load cell is not completely covered, then **make sure that the calibration was performed using the anchor block**. If the calibration was performed without the anchor block then for best results consideration should be given to recalibration with the anchor block. Shield the cable for possible damage from blasting or traffic. Protect the end of the cable or the cable connector from dirt by either using a cap on the connector or by storing the end of the cable and/or connector inside a small box. Section 1 shows a typical load cell system.

2.3 CABLE INSTALLATION AND SPLICING

The cable should be routed to minimize the possibility of damage due to moving equipment, debris or other causes. The cable can be protected by the use of flexible conduit, which can be supplied by GEOKON.

Terminal boxes with sealed cable entries are available from GEOKON for all types of applications. These allow many gauges to be terminated at one location with complete protection of the lead wires. The interior panel of the terminal box can have built-in jacks or a single connection with a rotary position selector switch. Contact GEOKON for specific application information.

Because the vibrating wire output signal is a frequency rather than a current or voltage, variations in cable resistance have little effect on gauge readings; therefore, splicing of cables has no ill effects, and in some cases may in fact be beneficial. The cable used for making splices should be a high quality twisted pair type, with 100% shielding and an integral shield drain wire. **When splicing, it is very important that the shield drain wires be spliced together**. Always maintain polarity by connecting color to color.

Splice kits recommended by GEOKON employ casts, which are placed around the splice and are then filled with epoxy to waterproof the connections. When properly made, this type of splice is equal or superior to the cable in strength and electrical properties. Contact GEOKON for splicing materials and additional cable splicing instructions.

Cables may be terminated by stripping and tinning the individual conductors and then connecting them to the patch cord of a readout box. Alternatively, a connector may be used which will plug directly into the readout box or into a receptacle on a special patch cord.

2.4 ELECTRICAL NOISE

Care should be exercised when installing instrument cables to keep them as far away as possible from sources of electrical interference such as power lines, generators, motors, transformers, arc welders, etc. Cables should never be buried or run alongside AC power lines; they will pick up the noise from the power cable, which will likely cause unstable readings. Contact the factory concerning filtering options available for use with the GEOKON dataloggers and readouts.

2.5 ENVIRONMENTAL FACTORS

Since the purpose of the load cell installation is to monitor site conditions, factors which may affect these conditions should be observed and recorded. Seemingly minor effects may have a real influence on the behavior of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to: blasting, rainfall, tidal or reservoir levels, excavation and fill levels and sequences, traffic, temperature and barometric changes, changes in personnel, nearby construction activities, seasonal changes, etc.

2.6 LIGHTNING PROTECTION

Unlike other types of instrumentation available from GEOKON, load cells do not have any integral lightning protection components, such as transorbs or plasma surge arrestors. Usually this is not a problem, however, if the instrument cable is exposed, it may be appropriate to install lightning protection components, as the transient could travel down the cable to the gauge and possibly destroy it.

Recommended lightning protection is as follows:

- If the instrument is connected to a terminal box or multiplexer, components such as plasma surge arrestors (spark gaps) may be installed in the terminal box/multiplexer to provide a measure of transient protection. Terminal boxes and multiplexers available from GEOKON provide locations for the installation of these components

- Lighting arrestor boards and enclosures are also available from GEOKON. These units install where the instrument cable exits the structure being monitored. The enclosure has a removable top to allow the customer to service the components or replace the board in the event that the unit is damaged by a lightning strike. A connection is made between the enclosure and earth ground to facilitate the passing of transients away from the load cell.
- Plasma surge arrestors can be epoxied into the instrument cable, close to the load cell. A ground strap then connects the surge arrestor to an earth ground, such as a grounding stake.

Consult the factory for additional information on available lightning protection.

3. TAKING READINGS

3.1 GK-404 VIBRATING WIRE READOUT

The Model GK-404 VW Readout is a portable, low-power, hand-held unit that is capable of running for more than 20 hours continuously on two AA batteries. It is designed for the readout of all GEOKON vibrating wire instruments, and is capable of displaying the reading in digits, frequency (Hz), period (µs), or microstrain (µε). The GK-404 also displays the temperature of the transducer (embedded thermistor) with a resolution of 0.1 °C.

FIGURE 6: *GK-404 Readout*

3.1.1 OPERATING THE GK-404

1. Attach the flying leads by aligning the red circle on the silver Lemo connector with the red line on the top of the GK-404 (see Figure 7). Insert the Lemo connector into the GK-404 until it locks into place.
2. Connect each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).
3. To turn on the GK-404, press the **On/Off** button on the front panel of the unit. The initial startup screen will display.
4. After a delay, the GK-404 will start taking readings and display them based on the settings of the **Pos** and **Mode** buttons.

FIGURE 7: *Lemo connector to GK-404*

The unit display (from left to right) is as follows:

- The current position: set by the **Pos** button, displayed as A through F.
- The current reading: set by the Mode button, displayed as a numeric value followed by the unit of measure.
- Temperature reading of the attached instrument in degrees Celsius.

Use the **Pos** and **Mode** buttons to select the correct position and display units for the model of equipment purchased.

The GK-404 will continue to take measurements and display readings until the unit is turned off, either manually or by the Auto-Off timer (if enabled).

For more information, consult the GK-404 manual.

3.2 GK-406 VIBRATING WIRE READOUT

The GK-406 VW Readout is a handheld unit ready to quickly measure a sensor, save the data, and communicate the results with custom PDF reports and spreadsheet output. GK-406 measurements are geo-located with an integrated GPS, allowing the device to verify locations and direct the user to each sensor. The GK-406 uses Campbell Scientific patented spectral-analysis technology (VSPECT®) to provide the best vibrating-wire measurement possible while filtering out environmental and electrical noise. The large color display offers an easy-to-view graphical presentation of the data.

FIGURE 8: *GK-406 Readout*

The GK-406 converts measurements to engineering units, generates a printable PDF report, and saves a CSV summary file. The graphical display allows confirmation of sensor output and operation. VSPECT® technology eliminates disruptive noise interference and provides sensor diagnostics for the best measurement possible. VSPECT® noise immunity allows gages that are otherwise unreadable to be evaluated with confidence.

A Project File maintains Site/Sensor information for 40 unique sites with 22 sensors per site. Site/Sensor locations are geolocated, allowing the internal GPS to guide a user directly to a sensor location. Site/Sensor and user information can be created or edited on the device or with a computer using the free VwProjects software.

3.2.1 CONNECTING THE GK-406

Connect the load cell to the Model GK-406-MUX Load Cell Multiplexer using the cable with a 10-pin connector. Then connect the Model GK-406-MUX to the VW Analyzer using the cable with the 6-pin connector by aligning the pins, pushing the connector into place, and twisting the outer ring of the male connector until it locks into place.

3.2.2 OPERATING THE GK-406

1. Press the power button just under the left side of the readout screen on the VW Analyzer.
2. Select or add a user and the home screen is displayed.
3. Select Read & Record and then Site/Sensor to get a load cell reading.
4. Select the load cell location or add a new location. There is an option add a default sensor to the new location.
5. Select Next and then select the specific load cell model to be used or add the information as a new sensor.
6. Select Read and the readout screen is displayed.
7. Select Details in the readout screen to show more data. Select Gauge from the details screen to toggle between the average of all the vibrating wire sensors measurements in the load cell and the individual measurements of each sensor. Spectrum and Time graphs are also available from the Details screen.

Note: The power button is generally used as a back button and will lead back to the home screen when pressed enough.

3.2.3 ESTABLISHING A BASELINE AND SETTING A GAUGE FACTOR

1. In the Select Sensor screen, select **Edit Sensor Parameters**.
2. Select **Sensor Units** and then **Next**.
3. If you select **Baseline (digits)** and **Read Baseline**, the GK-406 will automatically take a baseline measurement. This will be the measurement that is used as R_o for the load calculations. You can also manually input a baseline instead of measuring one. Save the baseline to return to the previous screen.
4. Select **Gage Factor (G)** and input the gage factor found in the calibration sheet provided with the 4900-Series load cell. Pay attention to the sign of the gage factor.
5. Select **Save** until the Select Sensor screen and then select **Read** to get a current measurement.

3.2.4 READOUT AND DATA FILES

1. To view the data, view a graph of the data, or export the CSV file, select **Data** from the home screen.
2. Select **Site/Sensor** and choose from which site you want the data.
3. Select **Next** and choose the sensor from which you want the data.
4. Select **Next** and there will be the options to **View Data**, **View Graph**, or to **Export CSV**. The GK-406 must be connected to a computer for the **Export Data** function to work.

Note: It takes 20-30 seconds for the reports to generate after taking a measurement. If you connect the GK-406 to a PC during these 20-30 seconds, it may not complete the reports.

3.3 MEASURING TEMPERATURES

All GEOKON vibrating wire instruments are equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. The white and green leads of the instrument cable are normally connected to the internal thermistor.

The GK-404 and GK-405 readouts will read the thermistor and display the temperature in degrees Celsius.

TO READ TEMPERATURES USING AN OHMMETER:

1. Connect an ohmmeter to the green and white thermistor leads coming from the instrument. Since the resistance changes with temperature are large, the effect of cable resistance is usually insignificant. For long cables a correction can be applied equal to approximately 48.5Ω per km (14.7Ω per 1000') at 20 °C. Multiply these factors by two to account for both directions.
2. Look up the temperature for the measured resistance in Appendix B.

4. DATA REDUCTION

4.1 LOAD CALCULATION

The basic units utilized by GEOKON for measurement and reduction of data from vibrating wire load cells are digits. Calculation of digits is based on the following equation:

$$\text{Digits} = \left(\frac{1}{\text{Period(seconds)}}\right)^2 \times 10^{-3}$$

or

$$\text{Digits} = \frac{\text{Hz}^2}{1000}$$

EQUATION 1: *Digits Calculation*

To convert the digits readings to load, the gauge readings for each cell must be averaged, and then the change in reading average multiplied by the gauge factor supplied with the load cell.

$$L = (R_1 - R_0) \times G \times K$$

EQUATION 2: *Load Calculation Using Linear Regression*

Where:
L is the load in lb, kg, etc.
R_0 is the regression no-load reading in digits (average of all gauges).
R_1 is the current reading in digits (average of all gauges).
G is the gauge factor as supplied on the calibration sheet. As the load increases, the reading decreases, this gives G a negative sign when entered into the equation (see the example below).
K is the conversion factor (optional) as listed in the table below.

From / To	Lb	Kg	Kips	Tons	Metric Tons
Lb	1	2.205	1000	2000	2205
Kg	0.4535	1	453.5	907.0	1000
Kips	0.001	0.002205	1	2.0	2.205
Tons	0.0005	0.0011025	2.0	1	1.1025
Metric Tons	0.0004535	0.001	0.4535	0.907	1

TABLE 1: *Engineering Units Conversion Multipliers*

For example:

Model 4900 VW Load Cells have a regression no-load reading (R_0) of 7309 and a current average reading (R_1) of 5497, and the calibration factor is –397 lbs. per digit.

Inputting the values into Equation 2:

$$L = (5497 - 7309) \times -397 = 719{,}400 \text{ lbs.}$$

Note that the equations assume a linear relationship between load and gauge readings over the full load range, and the linear coefficient is obtained using regression techniques. Note that when using the calibration factor obtained from the regression formula it is necessary to use the regression zero. This may introduce substantial errors at very low loads. A measure of the amount of nonlinearity is shown on the calibration sheet in the column entitled Linearity. See Appendix F for additional information.

For greater accuracy, the data given can be represented by a polynomial or can be treated as a series of segments over the entire load range. For instance, using the example calibration sheet, the load between 0 and 180,000 lb could be represented by the equation:

$L = ((7304 - 6860) \times 405 = 179{,}820$ tons.

The gauge factor –405 lb/digit is calculated from the slope of the line between a load of 0 and 180,000 lb, i.e., (0 – 180,000) / (7304 – 6860) = –405 lb/digit.

A polynomial expression to fit the data is shown in Equation 3.

$$L = AR_1^2 + BR_1 + C$$

EQUATION 3: *Load Calculation Using Polynomial*

Where:
L is the load in lb, kg, etc.
R_1 is the current reading (average of all gauges).
A, B, and C are the coefficients derived from the calibration data.

First calculate C from the initial average field zero reading.

For example: if $C = 7{,}305$ then $0 = -0.00247 \times 73{,}052 - 367 \times 7{,}305 + C$ from which $C = +2{,}812{,}740$. Therefore, when the applied load is $360{,}000$, $R_1 = 6{,}409$, and the calculated load = $-0.00247 \times 64{,}092 - 367 \times 6{,}409 + 2{,}812{,}740 = 359{,}180$ lbs.

4.2 TEMPERATURE CORRECTION FACTOR

A small correction can be made for change in temperature. As the temperature goes up the average reading of all the sensors will go down approximately one digit per °C. To calculate the load, corrected for temperature, use Equation 4.

$$L = G\,[(R_1 - R_0) + (T_1 - T_0)]$$

EQUATION 4: *Load, Corrected for Temperature*

The temperature effect shown above is for a load cell that has not been installed yet and is very minor. There is no telling what the actual temperature effect will be on a load cell that is installed on a tensioned bar or cable. This depends on the length of the bar or cable and on the properties of the surrounding ground. The actual temperature effect can only be arrived at empirically by simultaneous measurements of load and temperature over a short period of time.

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Vibrating Wire Load Cell Calibration Report

Model Number: 4900X-900-0 Calibration Date: May 04, 2012

Serial Number: 1139947 Calibration Instruction: CI-4900GP

Max. Range (lbs): 900000 Technician: [signature]

Cable Length: N/A

Initial Cycling Data

Load (lbs):	0	0	900000	0
Reading:	7358	7305	3902	7303

Applied Load in lbs	First Cycle				Second Cycle				Average (2 Cycles)	Linearity % Max Load	Polynomial Error (%FS)
	Gage 1	Gage 2	Gage 3	Average	Gage 1	Gage 2	Gage 3	Average			
0	7298	7311	7300	7303	7299	7312	7301	7304	7304	0.24	0.07
180000	6880	6899	6795	6858	6883	6899	6797	6860	6859	-0.14	-0.09
360000	6510	6481	6232	6408	6514	6479	6234	6409	6408	-0.27	-0.10
540000	6095	6044	5708	5949	6096	6033	5722	5950	5950	-0.03	0.13
720000	5689	5607	5189	5495	5691	5597	5202	5497	5496	-0.01	0.04
900000	5278	5170	4668	5039	5279	5161	4681	5040	5040	0.12	-0.05
0	7299	7311	7300	7303	7300	7312	7303	7305	7304		

GK-401 Pos. B Readout

Linear Gage Factor (G): -397.0 lbs/digit **Regression Zero (R_0):* 7309**

Polynomial Gage Factors: **A: -0.00247** **B: -367** **C:**

Calculate C by setting L=0 and R_1 = initial field zero reading in the polynomial equation

Calculated Load: **Linear, $L = G(R_1 - R_0)$**

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

Linearity = ((Calculated Load - Applied Load) / Max. Applied Load) x 100%

For additional accuracy the data could be analysed in segments, calculating gage factors for each segment

* Note: The above calibration uses a linear regression method. The Zero Reading shown is ideal for straight line computation and does not usually agree with the actual no-load reading.

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

FIGURE 9: *Typical Model 4900 Calibration Sheet*

5. TROUBLESHOOTING

Problems with the load cell are usually associated with cable damage or moisture getting into the system. Both problems can be minimized by protecting the cable from damage, by visual inspection of the cable if problems arise, and by always keeping the plug clean and dry.

Warning! Do not carry the load cell by the cable.

Consult the following list of problems and possible solutions should difficulties arise. Consult the factory for additional troubleshooting help.

SYMPTOM: LOAD CELL GAUGE READINGS ARE UNSTABLE

- ☐ Is the readout box position set correctly? (See Section 3.)
- ☐ If using a datalogger to record readings automatically, are the swept frequency excitation settings correct?
- ☐ Does the readout or datalogger work with another load cell? If not, the readout/datalogger may have a low battery or be malfunctioning.
- ☐ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, and antennas.
- ☐ Make sure the shield drain wire is connected to ground. Connect the shield drain wire to the readout using the blue clip.

SYMPTOM: LOAD CELL GAUGE FAILS TO READ

- ☐ Is the cable cut or crushed? This can be checked with an ohmmeter. Nominal resistance between the two-gauge leads is 45 to 50Ω (75, 90, or 180Ω, ±10Ω on some older models).
- ☐ Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 14.7Ω /1000' or 48.5Ω/km, multiply by two for both directions). If the resistance reads very high or infinite (megohms), a cut wire must be suspected. If the resistance reads very low (<20Ω), a short in the cable is likely.
- ☐ Does the readout or datalogger work with another load cell? If not, the readout or datalogger may be malfunctioning.

SYMPTOM: THERMISTOR RESISTANCE IS TOO HIGH

- ☐ Is there an open circuit? Check all connections, terminals, and plugs. If a cut is located in the cable, splice according to instructions above.

SYMPTOM: THERMISTOR RESISTANCE IS TOO LOW

- ☐ Is there a short? Check all connections, terminals, and plugs. If a short is located in the cable, splice according to instructions above.
- ☐ Water may have penetrated the interior of the load cell. There is no remedial action.

APPENDIX A. SPECIFICATIONS

A.1 MODEL 4900 LOAD CELL SPECIFICATIONS

Rated Capacities:[1]	100 to 10,000 kN
Accuracy:[2]	±0.5% F.S.
Resolution:	0.025% F.S.
Repeatability:	0.1% F.S.
Temperature Effect:	0.02% F.S./°C
Temperature Range:	-20 to +80 °C
Frequency Range	1400-3500 Hz
Over range:	150%
Coil Resistance:	45 to 50Ω (70, 90, or 180Ω on some older models)
Cable Type (Three Gauge):[3]	Four twisted pair (six conductor) 22 AWG, Purple jacket Foil shield, PVC jacket, nominal OD=9.5 mm (0.375")
Cable Type (Four Gauge):[3]	Four twisted pair (eight conductor) 22 AWG, Purple jacket Foil shield, PVC jacket, nominal OD=9.5 mm (0.375")
Cable Type (Six Gauge):[3]	Six twisted pair (12 conductor) 22 AWG, Orange jacket Foil shield, PVC jacket, nominal OD=12.7 mm (0.5")

TABLE 2: *Model 4900 Load Cell Specifications*

Notes:

[1]Other capacities and diameters available on request. Calibrations that exceed GEOKON's NIST traceable capacity of approximately 10,675 kN are subcontracted to an accredited testing laboratory.

[2]Established under laboratory conditions. System accuracy depends on end loading conditions.

[3]Other cable types, e.g., armored, are available.

A.2 THERMISTOR

Range: -80 to +150 °C

Accuracy: ±0.5 °C

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

B.1 3KΩ THERMISTOR RESISTANCE

Thermistor Types:

- YSI 44005, Dale #1C3001–B3, Alpha #13A3001–B3
- Honeywell 192–302LET–A01

Resistance to Temperature Equation:

$$T = \frac{1}{A+B(LnR)+C(LnR)^3} - 273.15$$

EQUATION 5: *3kΩ Thermistor Resistance*

Where:
T = Temperature in °C
LnR = Natural Log of Thermistor Resistance
A = 1.4051 x 10^{-3}
B = 2.369 x 10^{-4}
C = 1.019 x 10^{-7}
Note: Coefficients calculated over the –50 to +150 °C span.

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	15.72K	-9	2221	32	474.7	73	137.2	114
187.3K	-49	14.90K	-8	2130	33	459.0	74	133.6	115
174.5K	-48	14.12K	-7	2042	34	444.0	75	130.0	116
162.7K	-47	13.39K	-6	1959	35	429.5	76	126.5	117
151.7K	-46	12.70K	-5	1880	36	415.6	77	123.2	118
141.6K	-45	12.05K	-4	1805	37	402.2	78	119.9	119
132.2K	-44	11.44K	-3	1733	38	389.3	79	116.8	120
123.5K	-43	10.86K	-2	1664	39	376.9	80	113.8	121
115.4K	-42	10.31K	-1	1598	40	364.9	81	110.8	122
107.9K	-41	9796	0	1535	41	353.4	82	107.9	123
101.0K	-40	9310	1	1475	42	342.2	83	105.2	124
94.48K	-39	8851	2	1418	43	331.5	84	102.5	125
88.46K	-38	8417	3	1363	44	321.2	85	99.9	126
82.87K	-37	8006	4	1310	45	311.3	86	97.3	127
77.66K	-36	7618	5	1260	46	301.7	87	94.9	128
72.81K	-35	7252	6	1212	47	292.4	88	92.5	129
68.30K	-34	6905	7	1167	48	283.5	89	90.2	130
64.09K	-33	6576	8	1123	49	274.9	90	87.9	131
60.17K	-32	6265	9	1081	50	266.6	91	85.7	132
56.51K	-31	5971	10	1040	51	258.6	92	83.6	133
53.10K	-30	5692	11	1002	52	250.9	93	81.6	134
49.91K	-29	5427	12	965.0	53	243.4	94	79.6	135
46.94K	-28	5177	13	929.6	54	236.2	95	77.6	136
44.16K	-27	4939	14	895.8	55	229.3	96	75.8	137
41.56K	-26	4714	15	863.3	56	222.6	97	73.9	138
39.13K	-25	4500	16	832.2	57	216.1	98	72.2	139
36.86K	-24	4297	17	802.3	58	209.8	99	70.4	140
34.73K	-23	4105	18	773.7	59	203.8	100	68.8	141
32.74K	-22	3922	19	746.3	60	197.9	101	67.1	142
30.87K	-21	3748	20	719.9	61	192.2	102	65.5	143
29.13K	-20	3583	21	694.7	62	186.8	103	64.0	144
27.49K	-19	3426	22	670.4	63	181.5	104	62.5	145
25.95K	-18	3277	23	647.1	64	176.4	105	61.1	146
24.51K	-17	3135	24	624.7	65	171.4	106	59.6	147
23.16K	-16	**3000**	**25**	603.3	66	166.7	107	58.3	148
21.89K	-15	2872	26	582.6	67	162.0	108	56.8	149
20.70K	-14	2750	27	562.8	68	157.6	109	55.6	150
19.58K	-13	2633	28	543.7	69	153.2	110		
18.52K	-12	2523	29	525.4	70	149.0	111		
17.53K	-11	2417	30	507.8	71	145.0	112		
16.60K	-10	2317	31	490.9	72	141.1	113		

TABLE 3: 3KΩ Thermistor Resistance

B.2 10KΩ THERMISTOR RESISTANCE

Thermistor Type: US Sensor 103JL1A

Resistance to Temperature Equation:

$$T = \frac{1}{A+B(LnR)+C(LnR)^3+D(LnR)^5} - 273.15$$

EQUATION 6: *10KΩ Thermistor Resistance*

Where:
T = Temperature in °C
LnR = Natural Log of Thermistor Resistance
$A = 1.127670 \times 10^{-3}$
$B = 2.344442 \times 10^{-4}$
$C = 8.476921 \times 10^{-8}$
$D = 1.175122 \times 10^{-11}$
Note: Coefficients optimized for a curve **J** Thermistor over the temperature range of 0 °C to +250 °C.

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
32,650	0	7,402	32	2,157	64	763.5	96	316.6	128	148.4	160	76.5	192	42.8	224
31,029	1	7,098	33	2,083	65	741.2	97	308.7	129	145.1	161	75.0	193	42.1	225
29,498	2	6,808	34	2,011	66	719.6	98	301.0	130	142.0	162	73.6	194	41.4	226
28,052	3	6,531	35	1,942	67	698.7	99	293.5	131	138.9	163	72.2	195	40.7	227
26,685	4	6,267	36	1,876	68	678.6	100	286.3	132	135.9	164	70.8	196	40.0	228
25,392	5	6,015	37	1,813	69	659.1	101	279.2	133	133.0	165	69.5	197	39.3	229
24,170	6	5,775	38	1,752	70	640.3	102	272.4	134	130.1	166	68.2	198	38.7	230
23,013	7	5,545	39	1,693	71	622.2	103	265.8	135	127.3	167	66.9	199	38.0	231
21,918	8	5,326	40	1,637	72	604.6	104	259.3	136	124.6	168	65.7	200	37.4	232
20,882	9	5,117	41	1,582	73	587.6	105	253.1	137	122.0	169	64.4	201	36.8	233
19,901	10	4,917	42	1,530	74	571.2	106	247.0	138	119.4	170	63.3	202	36.2	234
18,971	11	4,725	43	1,480	75	555.3	107	241.1	139	116.9	171	62.1	203	35.6	235
18,090	12	4,543	44	1,432	76	539.9	108	235.3	140	114.5	172	61.0	204	35.1	236
17,255	13	4,368	45	1,385	77	525.0	109	229.7	141	112.1	173	59.9	205	34.5	237
16,463	14	4,201	46	1,340	78	510.6	110	224.3	142	109.8	174	58.8	206	33.9	238
15,712	15	4,041	47	1,297	79	496.7	111	219.0	143	107.5	175	57.7	207	33.4	239
14,999	16	3,888	48	1,255	80	483.2	112	213.9	144	105.3	176	56.7	208	32.9	240
14,323	17	3,742	49	1,215	81	470.1	113	208.9	145	103.2	177	55.7	209	32.3	241
13,681	18	3,602	50	1,177	82	457.5	114	204.1	146	101.1	178	54.7	210	31.8	242
13,072	19	3,468	51	1,140	83	445.3	115	199.4	147	99.0	179	53.7	211	31.3	243
12,493	20	3,340	52	1,104	84	433.4	116	194.8	148	97.0	180	52.7	212	30.8	244
11,942	21	3,217	53	1,070	85	421.9	117	190.3	149	95.1	181	51.8	213	30.4	245
11,419	22	3,099	54	1,037	86	410.8	118	186.1	150	93.2	182	50.9	214	29.9	246
10,922	23	2,986	55	1,005	87	400.0	119	181.9	151	91.3	183	50.0	215	29.4	247
10,450	24	2,878	56	973.8	88	389.6	120	177.7	152	89.5	184	49.1	216	29.0	248
10,000	**25**	2,774	57	944.1	89	379.4	121	173.7	153	87.7	185	48.3	217	28.5	249
9,572	26	2,675	58	915.5	90	369.6	122	169.8	154	86.0	186	47.4	218	28.1	250
9,165	27	2,579	59	887.8	91	360.1	123	166.0	155	84.3	187	46.6	219		
8,777	28	2,488	60	861.2	92	350.9	124	162.3	156	82.7	188	45.8	220		
8,408	29	2,400	61	835.4	93	341.9	125	158.6	157	81.1	189	45.0	221		
8,057	30	2,316	62	810.6	94	333.2	126	155.1	158	79.5	190	44.3	222		
7,722	31	2,235	63	786.6	95	324.8	127	151.7	159	78.0	191	43.5	223		

TABLE 4: *10KΩ Thermistor Resistance*

APPENDIX C. WIRING AND CONNECTOR PINOUTS

C.1 LOAD CELL CONNECTOR AND CABLE (STANDARD WIRING)

10-pin Bendix PT06A-12-10P	Function	3 Gauge VW Load Cell GEOKON Purple Cable	4 Gauge VW Load Cell GEOKON Purple Cable	6 Gauge VW Load Cell GEOKON Orange Cabl e
A	Gauge #1	Red	Red	Red
B	Gauge #2	Red's Black	Red's Black	Red's Black
C	Gauge #3	White	White	White
D	Gauge #4	NC	White's Black	White's Black
E	Gauge #5	NC	NC	Green
F	Gauge #6	NC	NC	Green's Black
G	Shield	All Shields	All Shields	All Shields
H	Common	White's Black[1]	Green	Blue
J	Thermistor	Green[1]	Blue	Yellow
K	Thermistor	Green's Black	Blue's Black	Yellow's Black

TABLE 5: *Standard Load Cell Wiring*

Notes:

[1] White's black and Green wires are switched on GEOKON three-gauge VW load cells prior to serial number 3313.

C.2 GK-403 TO MODULE CONNECTOR

Module 10-pin Bendix Plug (PT06F-12-10P)	Interconnect Wire Color (Six Pair)	Interconnect Wire Color (Belden)	Description	Module Board Connection
A	Brown	Brown	VW Gauge	JP1-2
B	Brown's Black	Red	VW Gauge Ground	JP1-1
C	Red	Orange	Thermistor	JP1-3
D	Red's Black	Yellow	Thermistor Ground	JP1-1
E	Yellow	Green	Shield	JP1-1
F	Yellow's Black	Blue	+12 VDC	JP1-4
G	Green	Violet	Ground	JP1-9
H	Green's Black	Grey	Mux Sense	JP1-9
J	Blue	White	Mux Clock	JP1-8
K	Blue's Black	Black	Mux Type	JP1-9

TABLE 6: *Module Wiring*

APPENDIX D. LOAD CELL GAUGE FACTOR RECALCULATION

D.1 OVERVIEW

This appendix describes how to recalculate the gauge factor for a load cell and then approximate the load where one or more strain gauges in the cell have failed after installation. This is not a foolproof method. For example, if the load distribution changes during monitoring, the calculations based on the method described above will be in error.

D.2 PROCEDURE

If the load is applied uniformly to the load cell then, as the load changes the change in reading on each gauge will be the same and, should one gauge fail, the gauge factor given on the calibration sheet can be applied to the average change of the remaining gauges.

Note the following example, where gauge number three in a six-gauge load cell has failed. The load cell gauge factor for the six gauges is 0.2439 tons/digit. If the load is uniformly applied to the load cell, then to calculate the load this gauge factor would be applied to the average reading change of the remaining five active gauges. In the example below the load on 7/1/02 would be calculated to be 0.2439(7298-6139) = 282.7 tons. However, in the field it rare to have the cell uniformly stressed, therefore, it may be more accurate to calculate a new gauge factor using only the active gauges.

In cases where the load is eccentric (in the present example the reading change on gauge number was higher than the other five gauges), the new gauge factor can be calculated for the remaining five active gauges as follows:

Date	Gauge #1	Gauge #2	Gauge #3	Gauge #4	Gauge #5	Gauge #6	Avg	Load
Initial	7318	7363	7247	7448	7222	7191	7298	0
6/1/02	6485	6363	6220	6618	6362	6331	6396	220.2 tons
7/1/02	6202	6034	No Reading	6324	6075	6058	6139	293.8 tons

TABLE 7: *Gauge Factor for Remaining Gauges*

1. Calculate a **new zero load average** using only the initial readings of the five remaining active gauges **= 7308**
2. Using only the readings of the active gauges: #1, #2, #4, #5, and #6 from the time of the last reading when all six gauges were active (6/1/02), calculate the average reading = **6432**.
3. Calculate the **new gauge factor** for the remaining five active gauges by dividing the calculated load at the last time when all gauges were active, (6/1/02), by the change in the five gauge average readings calculated in steps one and two, = 220.2 /(7308-6432) **= 0.2514**. This is the new gauge factor to be applied to all subsequent changes of the remaining five active gauges.
4. Using the averages of the current and initial five-gauge readings, calculate the load on 7/1/02 by using the new gauge factor. Thus on 7/1/02: (**7308** – **6139**) x **0.2514** = 293.9 tons. This gives a better result than applying the old gauge factor for the six gauges to the average reading of the five active gauges. (The applied load was 291 tons).
5. Repeat step four for subsequent readings or repeat all steps if more gauges in the load cell fail.

APPENDIX E. LOAD CELL CALIBRATIONS - EFFECTS OF BEARING PLATE WARPING

E.1 INTRODUCTION

Load cells used to measure loads during testing of tiebacks, driven piles, and drilled shafts, give calculated loads that are frequently in disagreement with loads calculated based on hydraulic jack pressure and piston area. Because of this, there is a general lack of confidence in load cell data and the fault is often ascribed to manufacturing defects, or to improper, inaccurate calibration procedures. Nevertheless, it is also well known that the effects of eccentric loading and uneven and/or warped bearing plates do have a profound effect on load cell readings. The purpose of this technical note is to provide some insight into these effects.

E.2 LOAD CELL CALIBRATION PROCEDURES

The usual calibration procedure is to use a testing machine to apply a load to a load cell. The measured load cell output is then correlated against the known applied load as measured by the testing machine. Usually, the testing machine has a hydraulic pressure applied to a piston of known cross section area. The testing machine is checked out periodically by running tests on a load cell traceable to NIST and there is generally little doubt about the accuracy of the testing machine. Accuracy's of ¼% FS ½% FS or 1% FS are normal.

Usually, the calibration tests are performed between large, flat parallel platens in the testing machine so that there is no bending of the platens, only the elastic compression in the zone immediately bearing against the load cell.

E.3 FIELD ARRANGEMENT

Such a state of affairs may not exist on the job site since the bearing surfaces next to the load cell are usually much less rigid, and liable to bending.

This bending is particularly apparent if there is a mismatch in size between the load cell and the hydraulic jack. If the hydraulic jack is larger than the load cell there is a tendency for it to try to wrap the intervening bearing plate around the load cell. If the hydraulic jack is smaller than the load cell it will try to push the intervening bearing plate through the hole in the load cell.

Thicker bearing plates will bend less, but the effect will never be entirely eliminated. The consequence of this bending can be quite large since the effect on the load cell is to cause it to either barrel out at its midsection if the jack is too small, or pinch in at its midsection if the jack is too big. For vibrating wire load cells, the gauges are usually located in the center of the cell wall, on the neutral axis, thereby minimizing these effects.

E.4 EFFECTS OF JACK SIZE ON LOAD CELL READING

A series of tests were conducted in a testing machine to investigate the magnitude of the effect of jack size on load cell readings.

A load cell with a bearing surface of 4" ID, 5¾" OD was used.

Simulated jack A had a bearing surface of 2" ID, 4" OD.

Simulated jack B had a bearing surface of 4" ID, 5¾" OD.

Simulated jack C had a bearing surface of 6" ID, 8" OD.

The maximum applied load was 150 tons.

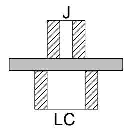
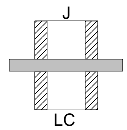
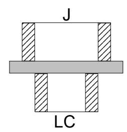
Jack		Load Cell response to applied load (100%)	
		1" thick plate	2" thick plate
A (smaller)		108%	102%
B (same size)		100%	100%
C (bigger)		96%	98%

TABLE 8: *Effects of Jack Sizing on Readings*

From the results, it can be seen that if the jack is smaller than the load cell, the load cell will over-register, while a jack bigger than the load cell will cause the load cell to under-register. The effect is bigger if the bearing plate between jack and load cell is thinner.

The correct bearing plate thickness will of course depend on the extent of the mismatch between jack and load cell. However, as a rough rule of thumb the following thickness should be required:

100-200 kip load: 25 mm (1") thick

Up to 400 kip load: 37 mm (1.5") thick

Up to 1000 kip load: 50 mm (2") thick

Up to 2000 kip load: 75 mm (3") thick

E.5 CONCLUSION

The consequences of all this would seem to indicate that, for best results, the load cell calibration should be performed with the actual hydraulic jack that will be used, both being placed in the testing machine at the same time. If that is not possible, the load cell should be loaded through a ring, having the same dimensions as the hydraulic jack bearing surface, positioned on the other side of a bearing plate of the correct thickness. In this way, one of the variables affecting the agreement between load cell readings and hydraulic jack readings can be removed and the agreement should be that much closer.

This technical note has addressed only the subject of the size mismatch between load cells and hydraulic jacks. Other factors affecting the agreement between load cell readings and hydraulic jack load are important, thus frictional losses within the hydraulic jack can cause under-registering of jack load indications by as much as 15%. (Dunnicliff 1988' Section 13.2.6)

Also, annular style load cells are susceptible to end effects and eccentrically applied loads. The height of the load cell should exceed four times the wall thickness of the annulus, and at least three strain gauges should be used, increasing in number as the size of the load cell increases, up to six total.

REFERENCES:

J. Dunnicliff. 1988. Geotechnical Instrumentation for Monitoring Field Performance, John Wiley & Sons, New York, NY: 577pp.

APPENDIX F. USE OF THE REGRESSION ZERO WHEN USING THE LINEAR GAUGE FACTOR

It is normal for load cells, having an annular design and for solid load cells that do not have ‘button heads’ or spherical seated bearing plates, to be susceptible to irregular load distributions at low loads. This is because there is a 'bedding in' process that takes place while the surfaces at both ends of the load cell conform to the surfaces they bear against causing the load cell to deform in an unpredictable way giving rise to strange strain patterns and faulty readings at low loads.

This irregularity of load disappears once the load cell surfaces have bedded in and from that point on the load cell behaves in the a more linear fashion such that there is a constant relationship between the applied load and the observed change in readout as quantified by the linear gauge factor shown on the calibration sheet.

Because of this the linear gauge factor shown on the calibration sheet has been calculated after excluding the often anomalous zero reading from the data points. And this gauge factor best describes the performance of the load cell at moderate to higher loads

This linear gauge factor describes the slope of the best fit line drawn through the calibration data points and the reading where the line intersects the zero load point on the load axis is called the 'Regression Zero' shown on the calibration sheet.

It is important when using the linear gauge factor to calculate loads that the value of R_0 in the linear equation be equal to the regression zero.

For greater accuracy, a second order polynomial can be used to map the data points. In this case, the regression zero is replaced by the factor C shown on the calibration sheet.

It may be, for a variety of reasons (for example if the load cell is used repeatedly on a number of jobs), that the no load zero reading might change significantly. Again, for greater accuracy, the value of the Regression Zero can be adjusted by an amount equal to the observed change in the no load zero from that shown on the calibration sheet. Similarly, the C factor of the polynomial can be adjusted by the amount of the zero load change multiplied by the linear gauge factor to convert it into the corresponding load change.

APPENDIX G. MODEL 8032-27 AND LOAD CELL WIRING

Connect the load cell **common** VW– conductor to the jumper as follows:

1. Lift up on the orange tab located on the opposite side of the six black conductors.
2. Fully insert the common conductor into the 8032-27 Jumper Wire Assembly.
3. Push down on the orange tab until it snaps into place.

Refer to Appendix C to identify which conductor of the load cell carries the common VW– signal.

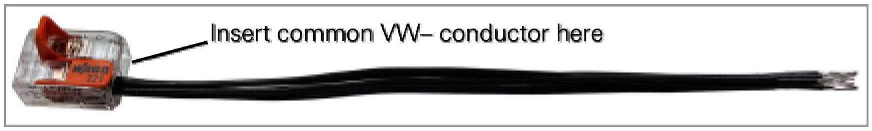


FIGURE 10: *Model 8032-27 Jumper Wire Assembly*

After attaching the common conductor from the load cell to the 8032-27, the black conductors supplied with the 8032-27 may be wired into a GEOKON terminal or multiplexer board where the VW– signal would normally go. Wire in one black conductor from the 8032-27 for each gauge of the load cell.