GEOKON

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Instruction Manual

Model 3000

Load Cell

(Doc Rev H, 10/11)

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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 crosslot 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.

The load cell is frequently used:

- ⇨ 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 because of the many variables the agreement cannot be guaranteed better than +/-20%.**

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. Figures 1 and 2 show the two different installations.

1.2. Load Cell Design and Construction

The Model 3000 Load Cell is made from an annulus of high strength steel or aluminum. Electrical resistance strain gages are cemented around the outside of the annulus and connected in a Wheatstone Bridge circuit. Half the gages measure vertical strains; half the gages measure circumferential strain. Typical specifications are given in Appendix A. Appendix B illustrates typical wiring diagrams. Note that the GK-501 Readout Box uses a remote sensing technique to reduce the cable effects. This means that Load Cells for use with the GK-501 have 6 conductors cables (3 individually shielded twisted pairs). See Appendix B for connector wiring.

An outer shell protects the gages from damage and 'O'-rings on either side of the gages ensure that the load cell is fully waterproof. Figure 3 shows a typical load cell.

The cable is attached to the cell through a waterproof gland. A strain relief, in the form of a Kellem's grip, 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 either a GK-501 Readout Box manufactured by Geokon or a Model P3 Strain Indicator Box manufactured by Vishay which, when adjusted to "Full Bridge", a gage factor of 1.000 and a balance position of 5.00, gives the same reading as the GK-501. Alternatively the P3 can be set up to readout directly in engineering units – ponds, tons, kips, etc,

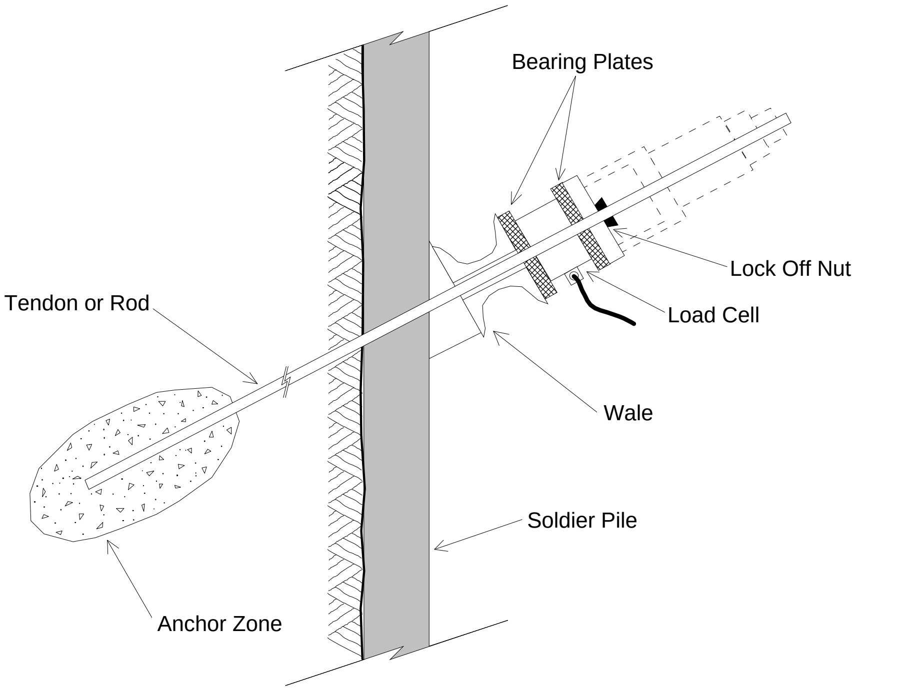

Figure 1 - Load Cells on Tiebacks for the Permanent Monitoring of Loads

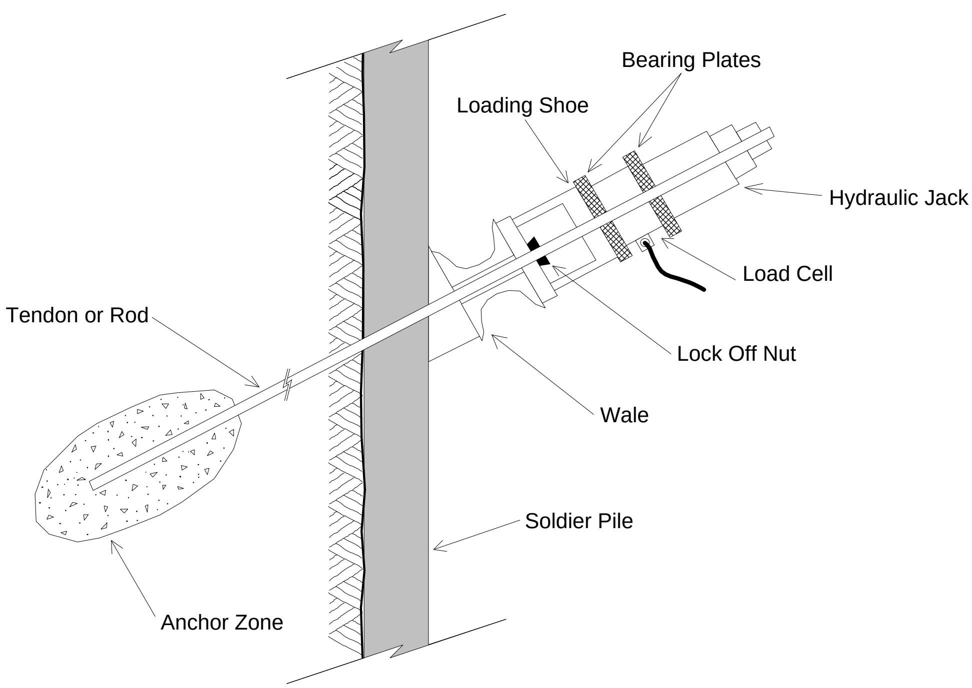

Figure 2 - Load Cells On Tiebacks For Proof Testing Only

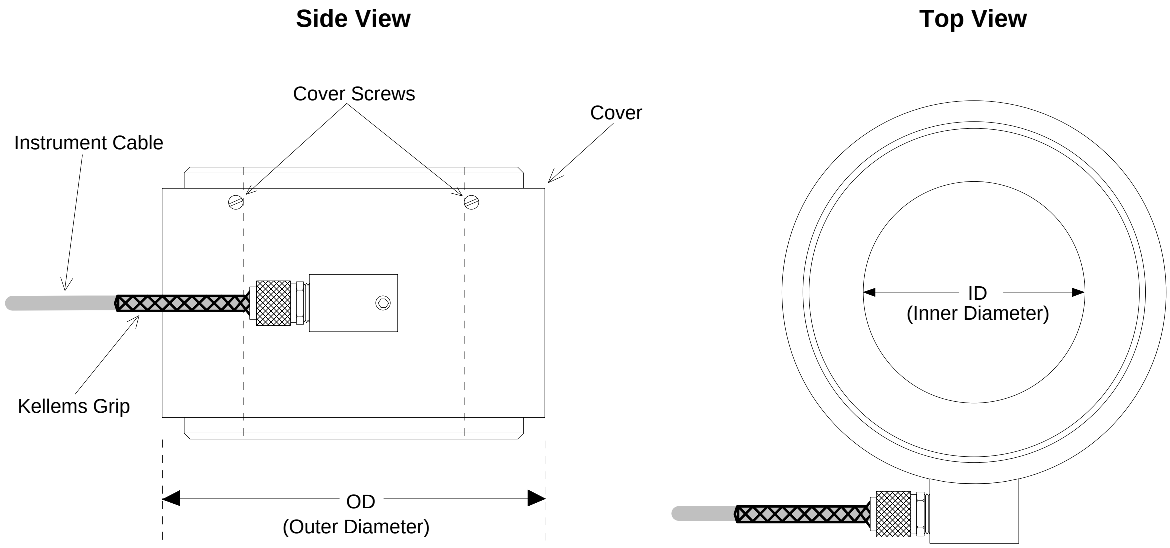

Figure 3 - Model 3000 Load Cell

Additional cable protection can be obtained by either using armored cable or by placing the cable inside flex conduit.

Figure 4 shows a typical load cell system.

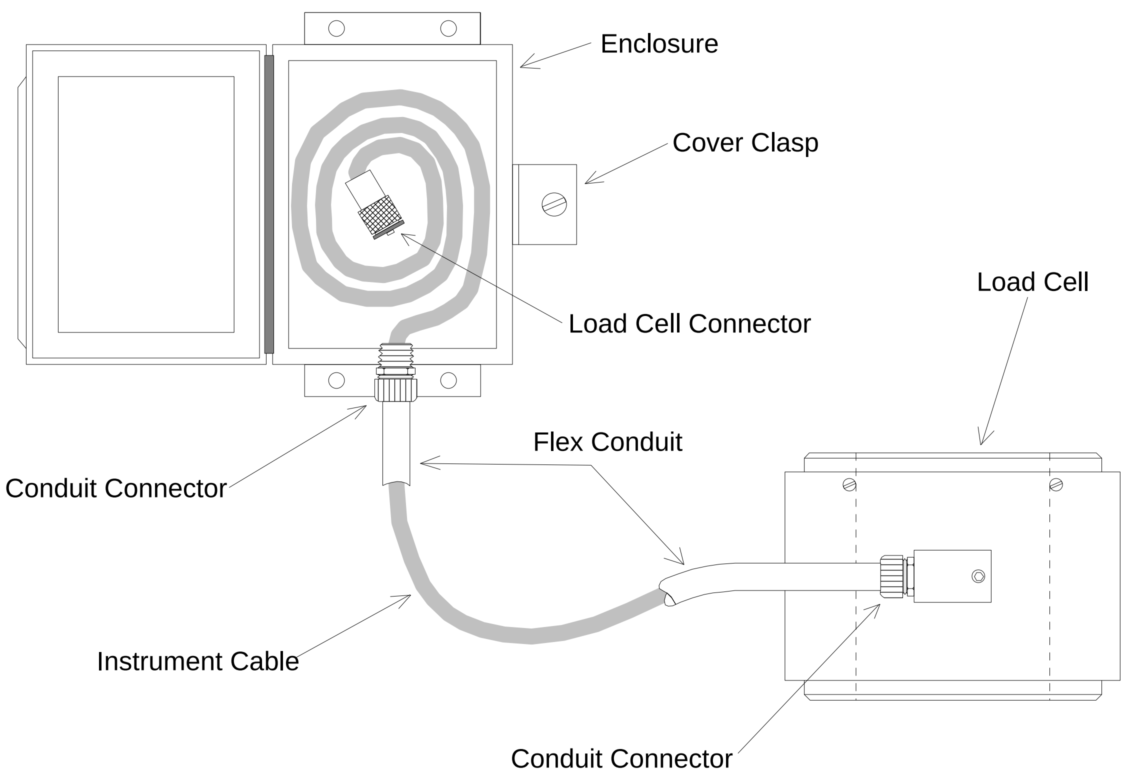

Figure 4 - Typical Load Cell System

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 end effects produced by:

a) **Warping of the bearing plates.**
b) **Friction between bearing plate and load cell.**
c) **Eccentric loading.**

All of these effects can be accumulative so that **the calibration can vary by as much as ±20%**, unless special precautions are taken. Considering each effect in turn:

1.2.1. 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 which are too thin.

For further details on this topic, the reader is referred to Appendices C and D.

Minimum bearing plate thickness is one inch (25 mm) 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. Also, 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.

1.2.2. Bearing Plate Friction

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 over-register, 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 4 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.

1.2.3. 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. In the case of tiebacks using multiple tendons, it is quite common for loads in individual tendons to vary markedly, one from the other, despite best efforts to avoid this happening. Also, 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 higher loads on one side than on the other. This effect is compensated for by the individual electrical resistance strain gages, 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 ($< \pm 5\%$) variations in the load cell output and calibration. This is certainly an attractive feature of the electrical resistance type load cell.

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. This can be achieved in two ways. First, it is important to use only the highest quality strain gages and adhesives. Geokon uses transducer grade strain gages along with scrupulous observation of the best installation practices and adhesive post curing techniques.

Geokon Model 3000 Load Cells are designed so as to keep the normal working stresses below 50% of the yield stress of the load cell material.

Wherever possible load cells are cycled to 150% of the design load prior to calibration so that 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% and for a steel load cell 300 to 400% FS Load 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 re-calibration. 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 gages 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. It should be remembered, however, 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.

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). At the same time a reading should be taken of the reference standard when plugged into the readout box. A reference standard is provided with all Geokon Load Cell Readout Boxes; it is located inside the lid. With the Geokon GK-501 Readout Box, plug the standard in and take a reading. With the Vishay Model P3 Strain Indicator, follow the instructions of the Model P3 manual to obtain the output in engineering units or, set the gage factor to 1.00 and the balance control to 5.00. These controls should always be left in these positions. Take note of the reference standard reading for future reference. The reading of this standard should not vary with time and provides a means of checking the stability of the readout box. It also provides a means of going from one readout box to another in the event that this is necessary. All load cell users should ensure that such a reference standard is kept on hand at all times and is used in the manner suggested.

If the readout box is changed during the period that the load cell is being read out, then this may entail some apparent change in the load cell readings. Geokon's GK-501 and Vishay P3 Readout Boxes are manufactured to close tolerances, and all readout boxes of this types will give practically the same readings with the standard plugged in. The magnitude of the change can be determined by first plugging the reference standard into the old box, and then into the new box, the difference in the readings will provide a measure of the correction which must be applied to all the load cell readings taken by the new readout box.

Note that the Vishay Model P3 Strain Indicator can also be made to give the readout directly in engineering units, i.e., kips or tons etc. Follow the instructions that are supplied by Vishay.

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 is the reading that will be subtracted from all subsequent readings in order to calculate the load. Note that each load cell has a different no-load reading which is not zero. See Section 3 for operation of the GK-501 and Vishay P3 Readout Boxes.

2.2.3. Installation on Tie-Backs and Rockbolts

Load cells should be installed between flat steel bearing plates of sufficient thickness: 1 inch thick where load cell and jack are about the same size and 2" to 3" 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 tie-back inside the load cell. Where the load cell I.D. is much bigger than the rockbolt or tie-back, a centralizer bushing can be used.

Where the anchor block of a multi-tendon tie-back 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. Figure 4 shows a typical load cell system.

3. TAKING READINGS

3.1. Using the Geokon GK-501 Readout Box

The user is referred to the GK-501 Instruction Manual for additional information on the following instructions: The GK 501 readout box displays mV/V x 4000

1. Connect the load cell to the readout box by means of the 10 pin input connector.
2. Switch the power switch to the "ON" position.
3. Switch the selector switch to the "x1" position.
4. Read the display and record.
5. If the applied load is so high that the display recording goes above 19,999 then move the selection switch to x 0.5" and read the display. When recording the data, remember to multiply the reading by 2.
6. See the GK-501 Instruction Manual for further instructions.

3.2. Using the Vishay Micro-Measurements P3 Readout Box

(For a complete description see the P3 Manual)

3.2.1 Multiple load cells

The simplest way to read multiple load cells using the P3 Readout Box is to read the output in mV/V and then use the mV/V gage factor given on the calibration sheet.

The P3 set up procedure is as follows:
From the Main Menu
Select **Channel 1**
Select Bridge type **FB v opp**
Select Gage Factor Scaling units **mV/V**
Select Balance and **Chan: 1** and then **Disable.** (This is important: if auto balance or manual balance is chosen the settings for one load cell will carry over to the next. Also it is only possible to use the auto or manual setting when the load cell has no load on it. Auto balance must not be initiated with a load cell already under load).
Now the readings will be in mV/V and the gage factor given by the calibration sheet can be use to convert to engineering units.

3.2.2 Single Load Cell Load - output in engineering units,

If a single load cell is is in use and it is desirable to see the readout directly in engineering units then referring to the P3 Instruction manual;

From The Main Screen select '**Bridge Type'** and then select '**Ch 1 FB v opp**
From The Main Menu screen and select '**Gage Factor/Scaling**'

- Set the **Units** to lbs, tons or kilograms
- Set the **Full Scale** to the **full scale value of the load** in engineering units taken from the Geokon Calibration Sheet. E.g. if the load cell has a maximum calibrated load of 750,000 lbs enter 375 tons in accordance with the units previously chosen. (Note that because the max allowable number here is 99999, lb units cannot be used if the full scale load is greater than 100,000 lbs)
- Set the **F.S. mV/V** to the **Full Scale mv/V** given on the Geokon Calibration Sheet. (If no value is given then the mV/V Gage Factor can be calculated by dividing the Full Scale change of digits by 4000. (E.g. a load cell reads -237 at no load and 4216 at the full load of 750 kips the F.S. mV/V is (4452)/4000 = 1.113 mV/V
- Set the **Dec. Places** to the correct number in accordance with the Units and the Full Scale reading previously chosen.
- **Now record the no load zero reading – it may be needed later.**

Now go back to the main Menu screen and select '**Balance**'

- Select the **Mode: Auto** and depress the Balance button on the face plate.
- Now depress the balance button on the face panel,a second time to select auto. This will trigger the auto balnce procedure. Which when completed will auotomatically bring up the Saving Settings menu.
- Save the settings by depressing the Record button on the face plate.
- The P3 readout box display should now read zero and is ready to display the load directly in the engineering units chosen.

Note that this configuration must be erased if the P3 Readout Box is used in like manner with a second load cell. To erase the settings go to the Main Menu select Options and then Advanced, and the Factory Defaults the press the Record Button on the face panel. Note however that the auto balance feature only works when the loadcell is under zero load. So you cannot switch from one load cell to another if the load cells are under load.

4. DATA REDUCTION

4.1. Load Calculation when reading the output in digits on the GK501

The basic units utilized by Geokon for measurement and reduction of data from Model 3000 Load Cells when read using the GK501 readout box are "digits". The calculation of digits is based on the following equation;

$$\text{Digits} = \text{mV/V} \times 4000$$

Equation 1 - Digits Calculation

Where; mV is the output of the Wheatstone bridge circuit in millivolts.
V is the excitation supplied to the Wheatstone bridge circuit in volts.

Load is calculated from digits by determining a change in reading (in digits) and then multiplying by the appropriate calibration factor. See the following equation:

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

Equation 2 - Load Calculation Using Linear Regression

Where; L is the load in lbs. or kg.
R_0 is the initial no load reading
R_1 is the current reading.
K is the Linear Gage Factor as supplied on the Calibration Sheet (see Figure 5).
CF is the conversion factor (optional) as listed in Table 1.

This equation is the same as the one shown on the calibration sheet; see Figure 5.

From→ To↓	Lbs.	Kg.	Kips	Tons	Metric Tons
Lbs.	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, a Model 3000 has an initial no-load reading (R_0) of - 237 (see Figure 5) and a current reading (R_1) of 2050. The Calibration Factor is 168.3 lbs. per digit.

$$L = (2050 - -237) \times 168.3 = 384{,}900 \text{ lbs.}$$

Note that the equations assume a linear relationship between load and strain readings, and the linear coefficient is obtained using regression techniques which may introduce a substantial non-linearity around the zero reading.

For greater accuracy a polynomial expression to fit the data can be used:

$$\mathbf{L = AR_1^2 + BR_1 + C}$$

Equation 3 - Load Calculation Using Polynomial

Where; L is the load in lbs. or kgms etc.
R_1 is the current reading.
A, B and are the coefficients derived from the calibration data. The C coefficient is derived by plugging the initial no load reading into the polynomial equation.

For example, a Model 3000 Load Cell has a current reading (R_1) of 2050. The polynomial coefficients, A, B and C are 6.16E-04, 165.85 and 39,272, respectively. (C was derived by substituting R_1 = -237 into the polynomial equation while setting P to zero)

$$\mathbf{L = 2591 + 339{,}993 + 39272 = 381{,}856\ lbs.}$$

4.2. Load Calculation when reading the output in mV/V on the P3.

The load is calculated using the following equation;

$$\mathbf{Load = (M_1 - M_0) \times G \times CF}$$

Equation 4 - Load Calculation Using mV/V

Where; L is the load in lbs. or kg. or units chosen
M_0 is the initial no load mV/V reading.
M_1 is the current mV/V reading.
G is the mV/V Gage Factor as supplied on the Calibration Sheet (see Figure 5).
CF is the conversion factor (optional) as listed in Table 1.

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Load Cell Calibration Report

Model Number: 3000-750-5.5 Calibration Date: June 22, 2011

Max.Range (lbs.): 750,000 No-Load Reading at Shipment: -250

Serial Number: 1112427 Calibration Instruction: CI-3000GP

Cable Length: 61.5 m Technician: KLBellavance

Initial Cycling Data

Load (lbs.):	0	0	1,125,000	0
Reading:	-248	-240	6344	-243

Calibration

Applied Load in lbs.	Readings from GK-501 readout box				Linearity % Max.Load	Polynomial Error (%FS)
	Cycle 1	Cycle 2	Average	Change		
0	-237	-237	-237		-0.17	0.05
150,000	660	658	659	896	-0.05	-0.10
300,000	1561	1561	1561	902	0.18	0.01
450,000	2456	2453	2454	894	0.24	0.07
600,000	3338	3335	3337	882	0.03	-0.01
750,000	4217	4215	4216	880	-0.23	-0.01
0	-237	-237				

GK-501 Readout

Linear Gage Factor (K): 168.30 lbs./ digit **Regression Zero (R_0):* -230**

Polynomial Gage Factors: A: 6.166E-04 B: 165.85 C: ______

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

Calculate C by setting P = 0 and R_1 = initial field zero reading into the polynomial equation

P3 Readout

Gage Factor (G): 673,631 lbs./ mV/ V **Regression Zero (M_0):* -0.0575 mV/ V**

Full Scale mV/ V: 1.113 mV/ V

Polynomial Gage Factors: A: 1.541E-07 B: 0.04146 C: ______

* 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 5 - Model 3000 Calibration Sheet

5. TROUBLESHOOTING

5.1. Readouts

Problems with the readout box can be resolved by reading the standard reference plug. If the reading here is seen to change appreciably, this could be an indication of readout box instability. It is frequently advisable to have a back-up readout available In any event, the readout box should be kept clean and dry at all times. Replace batteries as required and store the box in a warm dry place when not in use so that any moisture is driven from the interior as much as possible.

Both the GK-501 and P3 Readout Boxes have low battery voltage indicators. **In the case of the GK-501, when not in use the batteries should be kept charged as per the instruction manual.** In the case of the P3 the two 'D' size alkaline batteries should be changed following the instructions of the Model P3 manual.

Instability caused by electrical interference from nearby power lines, generators, welders, etc. can be minimized by making sure that the cable shield is connected to the readout box ground.

5.2. Load Cells

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 in the event that problems arise and by keeping the plug clean and dry at all times. **Avoid carrying the load cell by the cable.**

Check the cable for damage such as pulling out of the load cell or connector, crushed spots, cuts or kinks. If there is cable damage, the cable should be repaired by cutting and splicing. All splices should be soldered, mechanically strong, well insulated and protected from dirt and moisture with an epoxy based splice kit such as the such the 3M Scotchcast™, model 82-A1. These kits are available from the factory. Alternately, a mastic type sealant, such as Aqua Seal (Cooper Power Systems Cat. No.104742-2 (pads) or 104742 (roll)), wrapped in vinyl tape, may be used to cover a splice.

Check the load cell wiring. The wiring diagram and pin-out are shown on pages 13 and 14. If the load cell is working properly the resistances between the various pins should be as follows:
For the larger load cells, between pins A and D, B and C = 700 ohms, between pins A and B, A and C, B and D, C and D = 525 ohms. Between pins J and B, C and K = 0 ohms, between pin F and any of the other pins = infinite ohms
For the smaller load cells, the same as above except substitute 350 for 700 and 260 for 525.

Failure of the load cell to agree with the load as indicated by a hydraulic jack could be caused by one or more of the factors discussed in Section 2.

APPENDIX A - SPECIFICATIONS

A.1. Model 3000 Load Cell Specifications

Available Ranges[1]:	100, 150, 200, 300, 500, 600, 1000, 1500, 2000 kips
Accuracy[2]:	see footnote below
Linearity:	0.5% FSR
Resolution[3]:	0.025% FSR
Repeatability[4]:	0.1% FSR
Temperature Effect:	0.02% FSR/°C
Temperature Range:	–20 to +80° C 0 to 110° F
Overrange:[5]	200% for aluminum 300 to 400% for steel
Input Resistance:	350 or 700 Ω
Output Resistance:	350 or 700 Ω
Excitation Voltage:	2 to 15 VAC or DC
Maximum Excitation Voltage:	30 V
Cable Type[6]:	3 twisted pair (6 conductor) 22 AWG Foil shield, PVC jacket, nominal OD=9.5 mm (0.375")

Table A-1 Model 3000 Load Cell Specifications

Notes:

[1] Other ranges available.

[2] The accuracy of the testing machine used to calibrate the cells is ±¼% F.S. traceable to NIST. The system accuracy depends on end loading conditions as described in the text. If field conditions are well duplicated during actual calibration the accuracy should be within ±5 F.S. Failure to duplicate conditions can cause calibration variations of ±20% in extreme cases.

[3] Minimum, depends on the readout instrument and technique.

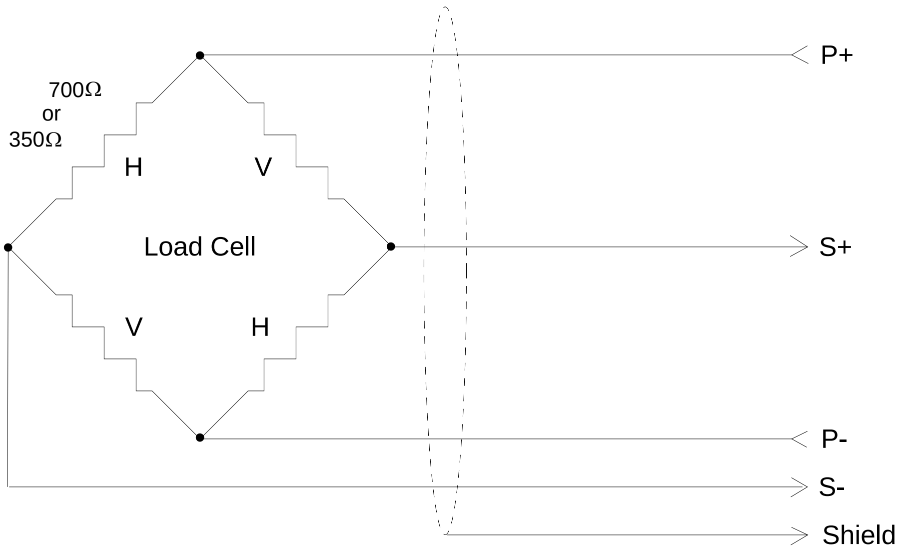
[4] Repeatability under the same loading conditions. This does not take into account hysteresis and any changes in the loading conditions.

[5] Maximum over-range without failure but both the no load zero and the calibration may change if the load exceeds 150% FS

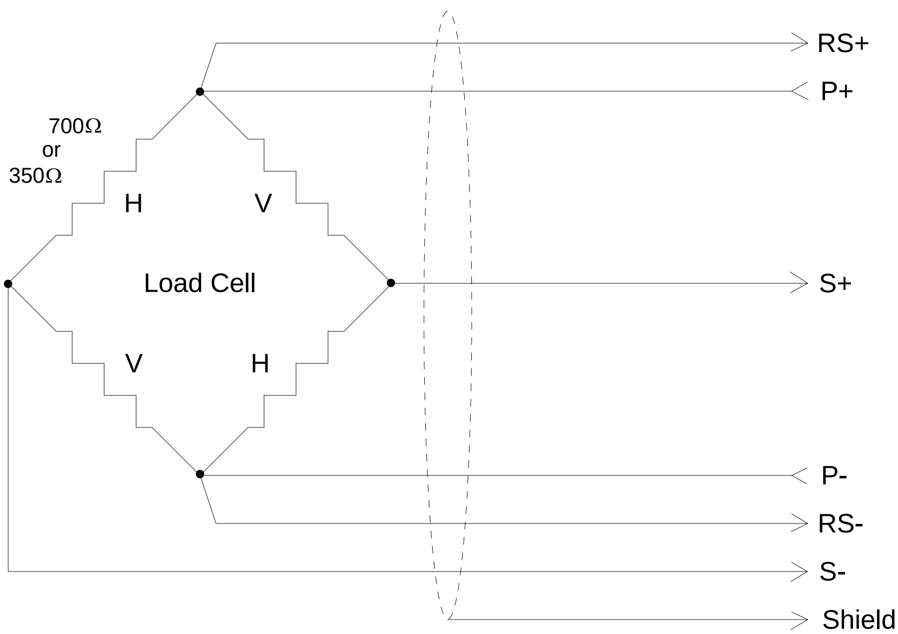
[6] Other cable types available.

APPENDIX B - WIRING AND CONNECTOR PINOUTS

B.1. Model 3000 Load Cell Wiring Diagram with P3 Readout



B.2. Model 3000 Load Cell Wiring Diagram With Remote Sense (GK 501 Readout)



B.3. Model 3000 Load Cell Wiring

Bendix (10 pin)	Amp (6 pin)	Circuit Label	Description	Internal Load Cell Wiring	Geokon Purple Cable
A	C	S-	Bridge Output -	White	White's Black
B	B	P+	Bridge Excitation +	Red	Red
C	A	P-	Bridge Excitation -	Black[1]	Red's Black
D	D	S+	Bridge Output +	Green[1]	White
E		NC	No Connection		NC
F	E	G	Ground for shield		Bare Drain Wires
G		NC	No Connection		NC
H		NC	No Connection		NC
J		RS+	Remote Sense +	Red[2]	Green
K		RS-	Remote Sense -	Black[2]	Green's Black

Notes:
[1] Green and black wires switched on Geokon load cells prior to serial number 1190.
[2] Non-remote sense is optional and must be specified at the time of ordering.

Note that the GK-501 is set up for remote sense of the excitation voltage at the load cell, which requires a 6 conductor cable (3 twisted pairs). If the load cell is not set up for remote sense and only has 4 conductors, then it will be necessary to modify the cable plug so that pins J and B and pins K and C are shorted together, otherwise the load cell cannot be read. **Note also that the P3 readout box will not read remote sense therefore load cells that have been wired for remote sense must be rewired at the connector for non-remote sense**

B.4. P3 Connection

Binding Post Color	Bendix Pin	Label	Description	Geokon Purple Cable
Red	B	P+	Bridge Excitation +	Red
Black	D	P-	Bridge Excitation -	Red's Black
White	A	S-	Bridge Output -	White's Black
Green	C	S+	Bridge Output +	White
Yellow		D120	No Connection	NC
Yellow		D150	No Connection	NC
Silver	F	Shield	Shield Connection	Bare Drain Wires

APPENDIX C - LOAD CELL CALIBRATIONS - EFFECTS OF BEARING PLATE WARPING

Introduction

Load cells used to measure loads during testing of tiebacks, driven piles and drilled shafts give calculated loads which are frequently in disagreement with loads calculated on the basis of 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, throughout the industry, that the effects of eccentric loading and uneven and/or warped bearing plates, frictional effecfs on the bearing surfaces, do have a profound effect on load cell readings. The purpose of this technical note is to provide some insight into these effects.

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 itself 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, perhaps with the addition of a spherical seat, so that there is little or no eccentric loading and no bending of the platens; only the elastic compression in the zone immediately bearing against the load cell.

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.

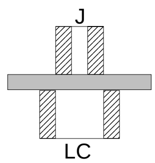
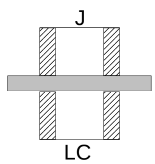
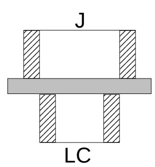
This bending is particularly apparent if there is a mismatch in size between the load cell and the hydraulic jack. If the hydraulic jack is larger than the load cell there is a tendency for it to try to wrap the intervening bearing plate around the load cell. If the hydraulic jack is smaller than the 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 mid-section if the jack is too small, or pinch in at its mid-section if the jack is too big. For electrical resistance strain gage load cells, the gages are usually located on the outer surface of the load bearing cylinder at its mid-section.

Report on Recent Testing

A series of tests were conducted in a testing machine to investigate the magnitude of this effect.

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%

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;

200 ton capacity ....1.5" thick
500 ton capacity ....2" thick
1000 ton capacity ....3" to 4" thick

Conclusion

The consequences of all this would seem to indicate that, **for best results, the load cell calibration should be performed in the field with the actual hydraulic jack that will be used**; or in the laboratory, with both load cell and jack being placed in the testing machine at the same time. Or failing that, 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 some 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 4 times the wall thickness of the annulus and at least 4 strain gages should be used (Dunnicliff 1988' Section 13.2.6) increasing to 8 or 12 in number as the size of the load cell increases.

References

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