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Instruction Manual

Model 4675OC

Liquid Level Sensor

(Doc Rev H, 05/01/19)

Warranty Statement

Geokon warrants its products to be free of defects in materials and workmanship, under normal use and service for a period of 13 months from date of purchase. If the unit should malfunction, it must be returned to the factory for evaluation, freight prepaid. Upon examination by Geokon, if the unit is found to be defective, it will be repaired or replaced at no charge. However, the WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive corrosion or current, heat, moisture or vibration, improper specification, misapplication, misuse or other operating conditions outside of Geokon's control. Components which wear or which are damaged by misuse are not warranted. This includes fuses and batteries.

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EQUATIONS

1. INTRODUCTION AND THEORY OF OPERATION

The Model 4675OC System is designed to detect and measure very small changes of elevation at discrete locations. It has been used to measure differential settlements along tunnels, deflections of bridges and bridge piers, the settlement of building columns and floor slabs etc., i.e. situations in which high accuracy and resolution are essential.

A series of chambers, (vessels), are connected by means of pipe that is installed on a level plane and is half- filled with liquid. One reference chamber is located on stable ground or is at a point that can be surveyed to. The other chambers are located at the points where settlement or heave is to be measured. Each chamber contains a cylindrical weight suspended from a vibrating wire transducer. The common liquid level inside each chamber partially submerges the hanging weights so that settlement or heave of at any one of the chamber locations causes an apparent rise or fall of the water level in that chamber, leading to a greater or lesser buoyancy force on the weight and a decrease or increase of tension and frequency of vibration in the vibrating wire.

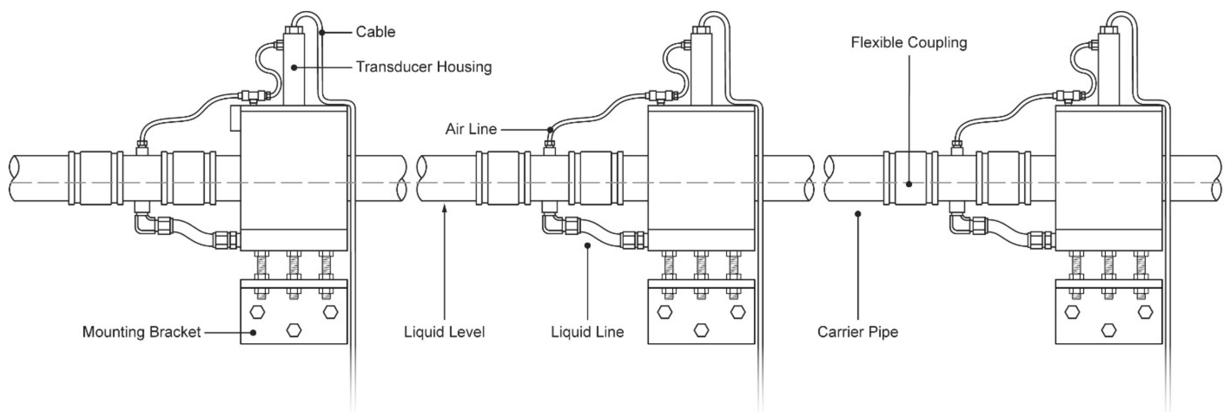

Figure 1 - 4675OC – Standard System

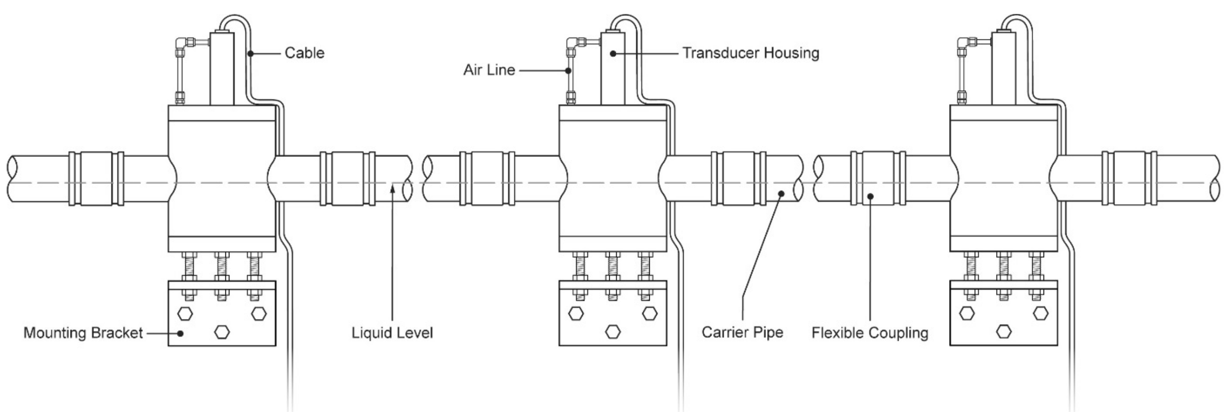

Figure 2 - 4675OC – In-Line System

A very high resolution/accuracy of the order of 0.02 mm can be attained. A vent line connects each transducer element to the air space above the liquid in each of the chambers and the carrier pipe and reduces the effect on the readings caused by changing temperatures and barometric fluctuations. It will be noted that the vibrating wire transducer is measuring a force and thus is itself not subject to temperature effects. Temperature effects on the connecting pipe and the liquid result in equal changes in water level in all the chambers and thus is cancelled out when the data is reduced.

2. INSTALLATION

Before any attempt is made to install the sensors, the following directions must be read and understood.

The vibrating wire transducer is very sensitive and correspondingly fragile and must be handled with great care.

2.1 Install the Mounting Brackets

The first step is to install the mounting brackets. It is important to install all chambers at the same elevation at the start of the monitoring program since the range of the transducer is limited and the amount of adjustment is small.

The chamber mounting bracket is designed to be bolted to a wall or a pedestal and should be firmly attached with either anchor bolts or epoxy grouted studs. The bracket can be attached to curved surfaces such as pillars by adding shims between the bracket and the surface to which it is bolted.

2.2 Installing the Sensors

After the mounting brackets have been installed the gauges can be mounted. The mounting bracket has three holes positioned to accept the threaded rods on the base of the liquid level chamber. These threaded rods are used to level the chamber on the bracket and allow a small amount of vertical positioning. Attach three of the jam nuts provided to the threaded rods and position them approximately one inch above the end of the rod. Now place the chamber on the bracket with the rods through the holes in the bracket and attach nuts to the rods on the lower side of the bracket. Using a spirit level on the side of the chamber, level the chamber assembly with the leveling nuts and then lock into place.

2.3 Installing the Carrier Pipe

The next step is to install the carrier pipe. This is usually accomplished by running a three- or four-inch diameter pipe, suspended from pipe brackets and connected with flexible couplers between chambers, with special couplings located at the chamber positions allowing the connection of the liquid and air lines to the sensor. The interconnecting pipe must be kept at a precise elevation to ensure that the transducer is at the midpoint in its range when the measurements commence. The centerline of the pipe should coincide with the midpoint of the sensors range which is indicated on the chamber housing.

Note: The In-line, through-the chamber, model has the carrier pipe mounted on the chamber itself and this system must be installed in a serial fashion to allow for connecting the pipe and sensors.

2.4 Filling the Carrier Pipe

Calculate the volume of liquid required to fill the total length of the carrier to the halfway point on the pipe, plus 21 cubic inches or 0.75 lbs. per sensor. The liquid normally used for filling the carrier is distilled water and if the area of measurements is expected to see freezing conditions a solution with a precisely know anti-freeze content is used. The amount of antifreeze should be kept to the minimum that will prevent freezing.

Connect the supply to the end of the carrier pipe and allow the liquid to flow into the pipe slowly.

Note: For the standard system where the sensor is connected to the carrier by a tube the liquid line should be connected to the carrier but not connected to the sensor at this time. Secure the end of this tube such that is above the carrier pipe. For the through system the stainless steel tube from the chamber to the transducer must be disconnected at the chamber end during this filling operation.

The sensors can be monitored during the filling operation to determine the level of the liquid in the pipe and the chambers. In order to do this the locking mechanism must be released so the buoyancy cylinder hangs freely in the chamber. Note that the locking mechanism MUST BE ENGAGED whenever the sensor assembly is moved or transported. To release the buoyancy cylinder, use the 5/16" Allen hex wrench provided, (see Figure 3). Engage and rotate the recessed cap screw counterclockwise until it hits the stop and the resistance to turning goes up markedly. The sensor can now be read, and the water level checked electronically.

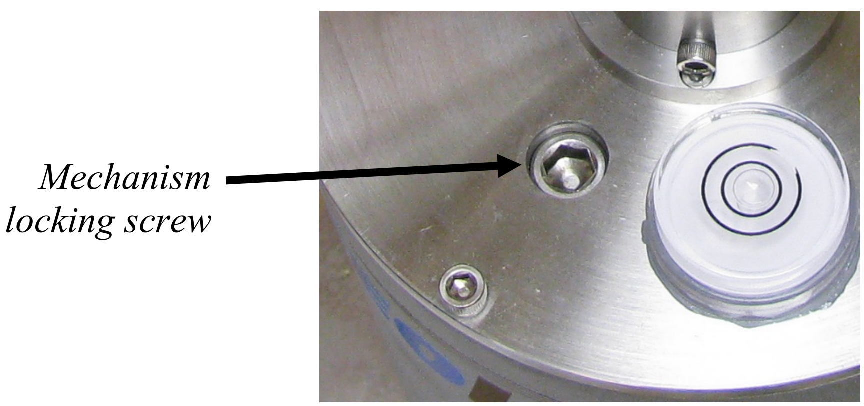

Figure 3 - Location of the Locking Screw

After filling, the sensor operation should be confirmed now by taking readings on all sensors and calculating the submersion of each sensor. This is accomplished by taking the change in output of the gauge from the zero reading, (R_0) with the weight hanging in air, and the current reading with the weight submerged and multiplying by the gauge factor. The gauge factor and zero reading, (R_0) are shown on the calibration reports, (a typical calibration report is shown in Appendix B, Page 10). The result should match the expected position of the water in the carrier pipe.

3. CALIBRATION

Laboratory calibrations are performed on each individual sensor using a system of calibrated weights. Gauge factors are presented for pure water applications. If mixtures other than this are used, the gauge factor should be adjusted for the specific gravity of the fluid used.

4. TAKING READINGS

4.1 GK-404 Readout Box

The Model GK-404 Vibrating Wire Readout is a portable, low-power, handheld unit that can run continuously for more than 20 hours on two AA batteries. It is designed for the readout of all Geokon vibrating wire gauges and transducers; and is capable of displaying the reading in either 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.

4.1.1 Operating the GK-404

Before use, attach the flying leads to the GK-404 by aligning the red circle on the silver "Lemo" connector of the flying leads with the red line on the top of the GK-404 (Figure 4). Insert the Lemo connector into the GK-404 until it locks into place.

Figure 4 - Lemo Connector to GK-404

Connect each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

To turn the GK-404 on, press the "ON/OFF" button. The initial startup screen will be displayed. After approximately one second, the GK-404 will start taking readings and display them based on the settings of the POS and MODE buttons.

The unit display (from left to right) of the GK-404 is as follows:

- The current Position: Set by the **POS** button, displayed as a letter 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 gauge in degrees Celsius.

Use the **POS** button to select position **B** and the **MODE** button to select **Dg** (digits). The GK-404 will continue to take measurements and display readings until the unit turned off, either manually, or if enabled, by the Auto-Off timer. For further information, consult the GK-404 manual.

4.2 GK-405 Readout Box

The GK-405 Vibrating Wire Readout is made up of two components: The Readout Unit, consisting of a Windows Mobile handheld PC running the GK-405 Vibrating Wire Readout Application; and the GK-405 Remote Module, which is housed in a weatherproof enclosure and connects via a cable to the vibrating wire gauge to be measured. The two components communicate wirelessly. The Readout Unit can operate from the cradle of the Remote Module, or, if more convenient, can be removed and operated up to 20 meters from the Remote Module.

4.2.1 Connecting Sensors

Sensors with 10-pin Bulkhead Connectors Attached:
Align the grooves on the sensor connector (male), with the appropriate connector on the readout (female connector labeled senor or load cell). Push the connector into place, and then twist the outer ring of the male connector until it locks into place.

Sensors with Bare Leads:
Attach the GK-403-2 flying leads to the bare leads of a Geokon vibrating wire sensor by connecting each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

4.2.2 Operating the GK-405

Press the button labeled "POWER ON". A blue light will begin blinking, signifying that the Remote Module is waiting to connect to the handheld unit. Launch the GK-405 VWRA program by tapping on "Start" from the handheld PC's main window, then "Programs" then the GK-405 VWRA icon. After a few seconds, the blue light on the Remote Module should stop flashing and remain lit. The Live Readings Window will be displayed on the handheld PC. Choose display mode "B".

Figure 5 shows a typical vibrating wire output in digits and thermistor output in degrees Celsius.

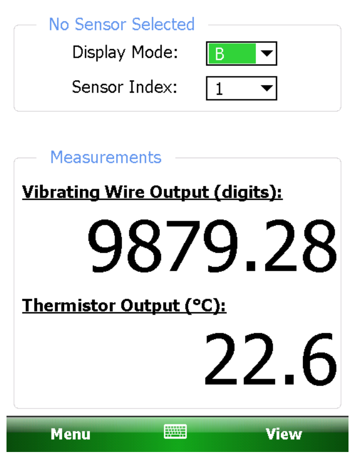

Figure 5 - Live Readings – Raw Readings

For further information, consult the GK-405 Instruction Manual.

4.3 GK-403 Readout Box (Obsolete Model)

The GK-403 can store gauge readings and apply calibration factors to convert readings to engineering units. The following instructions explain taking gauge measurements using Mode "B".

4.3.1 Connecting Sensors to the GK-403

Connecting Sensors with 10-pin Bulkhead Connectors Attached:
Align the grooves on the sensor connector (male), with the appropriate connector on the readout (female connector labeled senor or load cell). Push the connector into place, and then twist the outer ring of the male connector until it locks into place.

Connecting Sensors with Bare Leads:
Attach the GK-403-2 flying leads to the bare leads of a Geokon vibrating wire sensor by connecting each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

4.3.2 Operating the GK-403

1) Turn the display selector to position "B".

2) Turn the unit on.

3) The readout will display the vibrating wire output in digits. The last digit may change one or two digits while reading.

4) The thermistor reading will be displayed above the gauge reading in degrees centigrade.

5) Press the "Store" button to record the value displayed.

The unit will automatically turn off after approximately two minutes to conserve power. Consult the GK-403 Instruction Manual for additional information.

4.4 Measuring Temperatures

All liquid level sensors are equipped with a thermistor that 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-403, GK-404, and GK-405 readout boxes will read the thermistor and display the temperature in degrees C.

To read temperatures using an ohmmeter:

1) Connect an ohmmeter to the green and white thermistor leads coming from the transducer. (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 14.7Ω per 1000 ft. (48.5Ω per km). Multiply this factor by two to account for both directions.)
2) Look up the temperature for the measured resistance in Appendix B, Table 1.

5. DATA REDUCTION

The change in elevation for any chamber in a system is determined as follows:

$$\Delta EL_x = (R1_x - R0_x)\,G_x - (R1_{Ref} - R0_{Ref})\,G_{Ref}$$

Equation 1 – Change in Elevation

Where;
ΔEL_x = Change in Elevation for Chamber x (Note: Negative values of ΔEL_x indicate settlement, positive values of ΔEL_x indicated heave.)
$R1_x$ = Current Reading Chamber x
$R0_x$ = Initial Reading Chamber x
G_x = Calibration Factor Chamber x
$R0_{Ref}$ = Initial Reading Reference Chamber
$R1_{Ref}$ = Current Reading Reference Chamber
G_{Ref} = Calibration Factor Reference Chamber

For Example:

If the initial readings and calibration factors on a four-chamber system (three active and one reference chamber) are:

Chamber#	Initial Reading	Calibration Factor
1 (Ref)	7163	0.002852
2	7858	0.002856
3	7967	0.002808
4	8028	0.002852

With subsequent readings on the chambers as follows:

Chamber#	Reading
1 (Ref)	7118
2	7813
3	8628
4	7637

Then the changes in elevation of Chambers two, three, and four are calculated as follows:

Chamber No. 2:
$\boldsymbol{\Delta EL_2 = (R1_2 - R0_2)\,G_2 - (R1_1 - R0_1)\,G_1}$
= (7813 – 7858) 0.002856 – (7118 – 7163) 0.002852
= – 0.1285 – (– 0.1283)
= – 0.0002″ *(No Movement)*

Chamber No. 3:

$$\Delta EL_3 = (R1_3 - R0_3)\, G_3 - (R1_1 - R0_1)\, G_1$$

= (8628 – 7967) 0.002808 – (7118 – 7163) 0.002852

= 1.8561 – (– 0.1283)

= 1.9843″ (*Heave)*

Chamber No. 4:

$$\Delta EL_4 = (R1_4 - R0_4)\, G_4 - (R1_1 - R0_1)\, G_1$$

= (7637 – 8028) 0.002852 – (7118 – 7163) 0.002852

= – 1.1151 – (– 0.1283)

= – 0.9868″ (*Settlement)*

6. CORRECTIONS FOR TEMPERATURE CHANGES

The vibrating wire sensor itself is insensitive to temperature changes within the normal operating range. The system, however, is not entirely unaffected by changes in water temperature which influence the density and therefore, the buoyancy of the fluid. The influence is relatively minor and can be accounted for to some degree by measuring the water temperature and making density corrections. A temperature/density curve for water is shown in Figure 4. As can be seen from the data, the density changes very little in the normal operating range of the sensor. The following equation is used to correct for temperature/density changes:

$$\Delta H = (R_1 - R_0)\ G / (SG)$$

Equation 2 - Temperature/Density Correction

Where;
SG is the specific gravity of the fluid (water) at the measurement temperature.

Density and Compressibility:
Density is defined as the mass per unit volume, and it depends upon the temperature and pressure intensity. The density of pure water is given in Figure 4.

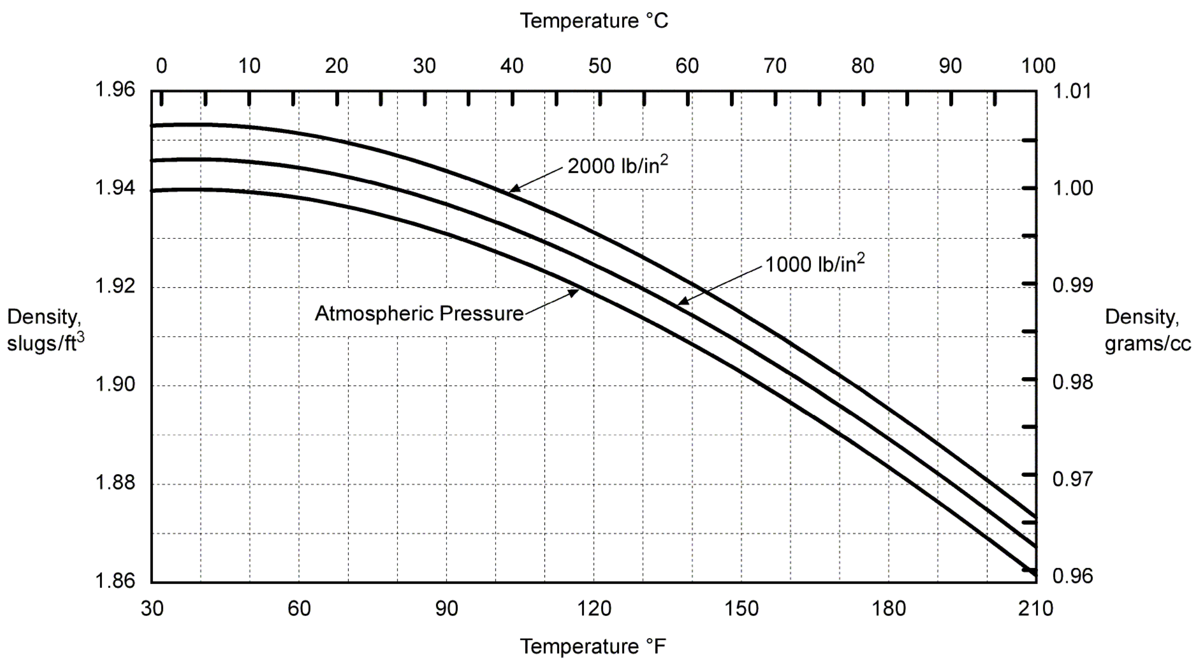

Figure 6- Density of water as a function of temperature and pressure intensity

(Figure 6 used with permission from *Fluid Mechanics for Hydraulic Engineers,* by Hunter Rouse, copyright 1938, McGraw-Hill Book Company, Inc.)

Expansion and contraction of the liquid line, the liquid itself and the chambers can cause the water level to fluctuate. However, the fluctuations are the same at all chambers and cancel out on data reduction.

7. TROUBLESHOOTING

If a transducer fails to read, the following steps should be taken:

1) Check the coil resistance. Nominal coil resistance is 180Ω ± 10 plus cable resistance (22-gauge copper = approximately 20Ω per 1000 feet).
   a) If the resistance is high or infinite, a cut cable must be suspected.
   b) If the resistance is low or near zero, a short must be suspected.
   c) If resistances are within nominal and no readings are obtainable on any transducer, the readout is suspect, and the factory should be consulted.
   d) If all resistances are within nominal and no readings are obtainable on any transducer, the readout is suspect, and the factory should be consulted.

2) If cuts or shorts are located, the cable may be splices in accordance with recommended procedures.

8. SPECIFICATIONS

Standard range	75 mm
Resolution	0.025 mm
System accuracy	±0.1 to ±0.4 mm
Temperature Range	-20 ºC to +80 ºC
Frequency Range	1400-3500 Hz

Table 1 - Specifications

APPENDIX A. THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3
Resistance to Temperature Equation:

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

Equation 3 - Resistance to Temperature

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

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

Table 2 - Thermistor Resistance versus Temperature

APPENDIX B. TYPICAL CALIBRATION REPORT

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

Vibrating Wire Liquid Level Sensor Calibration Report

Model Number: 4675OC

Temperature: 24.1 °C

Serial Number: 1141486

Calibration Date: December 29, 2011

Calibration Instruction: CI-4675

Technician:

Applied Load L (lbs)	Equivalent inches H_2O	Reading 1st Cycle	Reading 2nd Cycle	Average Reading (R)	Change	Linearity (%FS)	Polynomial Fit % (FS)
1.430	3.158	6544	6546	6545			
1.760	3.887	7824	7829	7827	1282	0.19	0.01
2.090	4.617	9105	9102	9104	1277	0.22	-0.02
2.422	5.349	10379	10380	10380	1276	0.20	0.02
2.752	6.078	11644	11640	11642	1263	0.01	-0.01

Factory reading with the cylindrical weight hanging in air = 10849

Mid-range reading = 8231

Equivalent inches of H_2O = L x K

Weight

Cylinder Dimensions (inches): Range: 3 inches

	1	2	3
Top	3.996	3.994	3.995
Middle	3.993	3.995	3.997
Bottom	3.996	3.994	3.999

Manufacturing Number: HW-11-172

Average Diameter (D): 3.995

Volume Factor (K): 2.209 (inches / lb)

$K = 1/(0.02836 \times D^2)$

Calibration Factor (G): 0.000573 (inches / digit) or 0.01455 (mm / digit)

Change in Sensor Elevation = $G(R_1-R_0)$

Polynomial Gage Factors: **A: 1.0754E-09** **B: 0.0005533** **C: -0.5096**

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

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

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

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

Figure 7 - Typical 4675OC Calibration Report