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*Instruction Manual*

# Model 4675

## Liquid Level Sensor

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## 1. Introduction and Theory of Operation

The Model 4675 Liquid Level 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 hydraulically connected together at the bottom by means of a liquid line (a water-filled tube), (see Figure 1). The water surface inside the each chamber is at the same level.

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 an decrease or increase of tension and frequency of vibration in the vibrating wire.

A very high resolution/accuracy of the order of 0.07mm can be attained. A vent line connects the airspace inside each transducers and the air space above the liquid in each of the chambers. This reduces, to a minimum, the effect of changing temperatures and barometric fluctuations on the readings. 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 tubing and the liquid result in equal changes in water level in all the chambers and thus is cancelled out when the data is reduced.

Readout of the instruments is accomplished with portable readouts such as the GK-403 or the GK-404 or one of the Geokon data acquisition systems such as the Micro-1000.

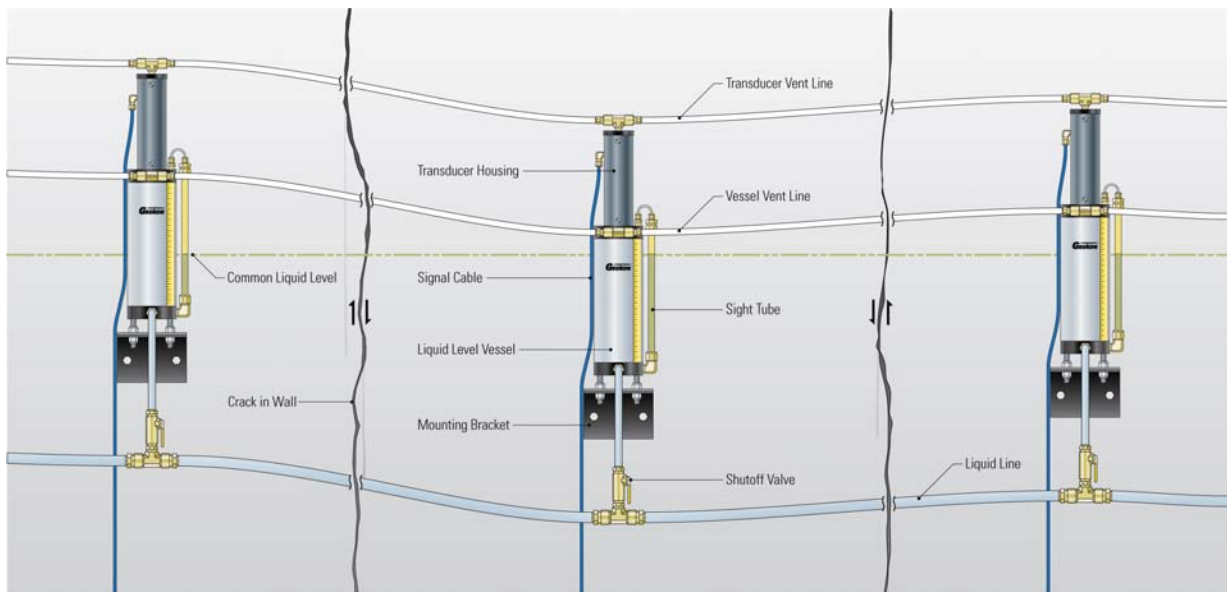
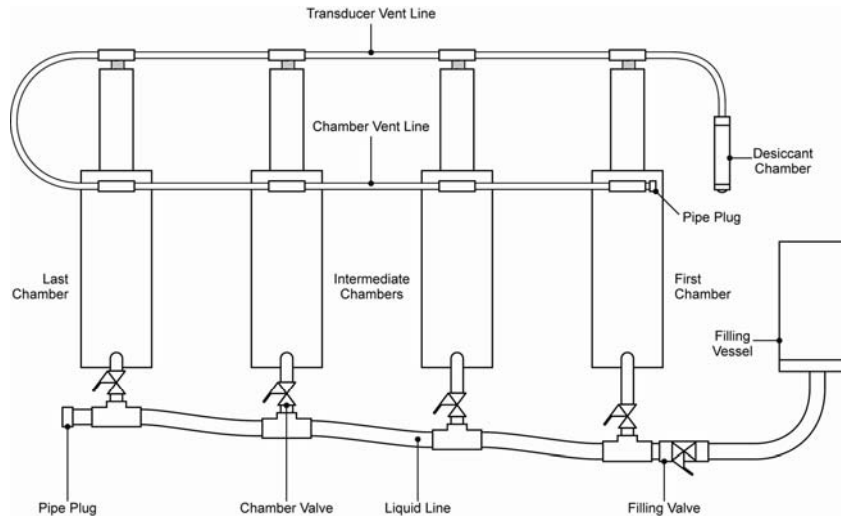


Figure 1. Model 4675 Liquid Level Sensor - Principle of Operation

## 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.



*Figure 2. Installation Details*

### 2.1 Install the mounting brackets and Chambers

The first step is to install the mounting brackets. It is important to install all chambers **at about the same elevation, +/- 10mm**, since the range of the transducers is limited and the amount of adjustment is small. The chamber mounting brackets are designed to be bolted to a wall or a pedestal and should be firmly attached with either anchor bolts or epoxy grouted studs. (These can be supplied if requested.) When all brackets have been installed, the chambers should be attached and leveled by placing a spirit level against the wall of the chamber cylinder. The chamber assembly has three threaded holes in the base and into these three holes must be threaded lengths of threaded rod supplied. Run one of the jam nuts up against the base to lock the threaded rods in place. Place another jam nut on each of the three rods and then push the rods through the holes in the mounting bracket. Then thread the remaining jam nuts onto the threaded rods below the bracket. Adjust the level with the nuts on the threaded rods that pass through the brackets. The chambers must be within +/- 1.5 degrees of vertical for proper operation. When the cylinder is level, tighten the nuts from both sides of the bracket.

### 2.2 Connecting the liquid line

The next step is to attach the liquid line. This is accomplished by running a 1 inch diameter plastic tube between chambers and having T connections and ball valves at each chamber location. The interconnecting tubing should be kept below the chambers and, if possible, be slightly inclined from one end to the other. The lowest end should have a valve for draining and filling. The one inch tubing is supplied in a coil and should be cut to the proper length and attached to the barb fittings on the T-valve assemblies. The T-valve assemblies are shipped separately and it is important to select the correct valve for each chamber, As shown in figure 1, the first chamber uses the T-

valve fitting with only one barb fitting and the filling valve already attached. The last chamber has only one barb fitting and a pipe plug. The intermediate chambers have T-valve assemblies equipped with two barb fittings.

Connect all the T-valve fittings and cut sections of one inch tubing and support them in place below the chambers. It helps to prevent air bubbles in the liquid line if the end of the tubing below the first chamber is lowest and the line is inclined upwards to the last chamber. Try to keep the liquid line as straight as possible. Avoid loops and there must be no siphons at all.

To connect the liquid line to the bottom of the chambers, cut short lengths of ½ inch tubing and connect one end to the ½ inch Swagelok fitting at the base of the chamber and the other end to the barb fitting on the T-valve fittings.

### **2.3 Installing the hanging weights.**

THIS OPERATION IS VERY CRITICAL AND SHOULD BE PERFORMED WITH EXTREME CARE. A spring and a stop protect the load sensor from over-range but severe dynamic shocks can destroy the vibrating wire element. The chambers are shipped fully assembled minus the hanging weights

Undo the Swagelok fitting that connects the copper tube to the top of the yellow sight tube. Unscrew the three cap screws holding the transducer housing to the top of the chamber and gently pull the top cap and transducer from the top of the chamber.

It is important that the **cylindrical weight serial number matches the transducer serial number**. The serial numbers will be found on the labels attached to the side of the cylindrical weights and to the transducer housings and also on the blue transducer cables. Select the proper hanging weight

***Before installing the cylindrical weight, remove the orange colored spacer from the hook assembly. (This releases the tension in the wire - a safety precaution which protects the sensor from damage during shipment.)***

*Next, the large o-ring, supplied separately should be placed into the groove on transducer housing. A light application of o-ring grease will help with the installation.*

While holding the transducer housing with both hands, hook the weight onto the hook on the transducer and gently lift the weight keeping the transducer housing vertical.

Lower the cylindrical weight into the chamber and hold the transducer housing just above the chamber. Now, line up the holes in the chamber with the screw holes in the cap. Gently lower the transducer housing into the chamber being careful not to jar it as the O-ring comes into contact with the tube. Force the housing down into the chamber being careful not to cut the O-ring as it passes the screw holes. When the cap is all the way in place, put the three screws in and tighten them. Do not over-tighten. Reattach the copper tube fitting to the top of the sight tube. Repeat this procedure for all the chambers.

### 2.3 Connecting the two vent lines.

The purpose of the chamber vent line is to allow the air pressure above the fluid in all the chambers to equilibrate. A separate transducer vent line for the transducer prevents any chamber liquid from accidentally getting into the transducer. The vent line is made from ½ inch tubing which is supplied in a coil. Cut off the correct lengths and connect them to the barb fitting on the chambers. The two vent lines should be connected together at the last chamber. (See figure 1). The pipe plug on the chamber vent line at the first chamber should be removed and left open until the filling process is completed.

### 2.4 Filling the liquid line.

The filling operation should be done very carefully to exclude air bubbles from the lines. The liquid can be either water or antifreeze solution: if the latter, then it is important to measure the specific gravity of the fluid and apply a correction to the gage factors for the sensors. **If water is used a small amount of antifreeze or bleach should be added to prevent the growth of algae.** The first step is to fill the liquid line from one end to the other, while **keeping the chamber valves closed.** The filling vessel supplied with the accessories should be connected using a short section of the supplied tubing to the filling valve which is connected to the T- valve at the base of the first chamber. Remove the pipe plug from the chamber valve below the last chamber, fill the filling vessel with fluid and open the filling valve to allow the liquid to slowly fill the liquid line. When the liquid line is full the plug at far end of the liquid line can be replaced. Make sure there are no air bubbles in the liquid line.

### 2.5 Filling the chambers.

Open the shut-off valve at the base of the first chamber and allow the chamber to fill to the mid height of the hanging weight as shown by the mark on the sight tube. Close the shut-off valve. Go to the next chamber in line and repeat this operation.

When all the chambers have been filled to this level and closed off, now close the filling valve. Now open all of the chamber shut-off valves and allow the liquid level to equilibrate in all the chambers. If any chamber is seen to be either too high or too low it should be adjusted now, using the threaded rod mounts if possible. If this is not possible the mounting bracket may need to be moved. The system liquid level can now be adjusted by adding or removing liquid through the filling valve. When the proper level, (usually the mid-range position of the weight as shown by the black mark on the sight tube), is achieved the filling valve is closed and the filling vessel can be disconnected. **To prevent tampering with the liquid level the handle should be removed from the filling valve.** The plug on the end of the chamber vent line at the first chamber can now be replaced. The desiccant chamber can be attached to the open end of the transducer vent line. (See figure 1).

### 2.6 Stringing the transducer signal cables,

The transducer cables can now be uncoiled and supported, at intervals on their passage to the readout location. The sensor operation can be checked now by taking readings on all sensors and, by reference to the calibration sheet supplied confirm that the readings are in the mid range position. A rough in-situ calibration check can be

made by adding or subtracting liquid and comparing the change in water level – as shown by the sight tube – with the change in level calculated using the calibrating gage factors.

### 3. Calibration

Laboratory calibrations are performed on each individual sensor using a system of calibrated weights. Gage factors are presented for pure water applications. If mixtures other than this are used, the gage factor should be adjusted for the specific gravity of the fluid used. A typical calibration sheet is shown in Appendix B

### 4. Taking Readings

The Model 4675 is read using the GK-403 or GK-404 Readout Box in Position 'B'. or the Micro 1000 datalogger. The change in elevation for any particular chamber in a system is determined as follows:

$$\Delta EL_x = (R_{1_x} - R_{0_x}) G_x - (R_{1_{Ref}} - R_{0_{Ref}}) G_{Ref}$$

where:

$\Delta EL_x$  = Change in Elevation for Chamber x

$R_{1_x}$  = Current Reading Chamber x

$R_{0_x}$  = Initial Reading Chamber x

$G_x$  = Calibration Factor Chamber x

$R_{0_{Ref}}$  = Initial Reading Reference Chamber

$R_{1_{Ref}}$  = Current Reading Reference Chamber

$G_{Ref}$  = Calibration Factor Reference Chamber

Note: Negative values of  $\Delta EL_x$  indicate settlement. (Positive values of  $\Delta EL_x$  indicated heave).

Example: The initial readings and subsequent readings on a 4 chamber system (3 active and reference chamber) are as follows:

Chamber	Initial Reading	Subsequent Reading	Calibration Factor
1 (Ref)	7163	7118	0.002852
2	7858	7813	0.002856
3	7967	8628	0.002808
4	8028	7637	0.002852

The changes in elevation of Chambers 2, 3 and 4 are:

a) Chamber No. 2:  $\Delta EL_2 = (R_{1_2} - R_{0_2}) G_2 - (R_{1_1} - R_{0_1}) G_1$   
 $= (7813 - 7858) 0.002856 - (7118 - 7163) 0.002852$   
 $= -0.1285 - (-0.1283)$   
 $= -0.0002'' \quad (\text{No Movement})$

b) Chamber No. 3:  $\Delta EL_3 = (R_{1_3} - R_{0_3}) G_3 - (R_{1_1} - R_{0_1}) G_1$   
 $= (8628 - 7967) 0.002808 - (7118 - 7163) 0.002852$   
 $= 1.8561 - (-0.1283)$   
 $= 1.9843'' \quad (\text{Heave})$

c) Chamber No. 4:  $\Delta EL_4 = (R_{1_4} - R_{0_4}) G_4 - (R_{1_1} - R_{0_1}) G_1$   
 $= (7637 - 8028) 0.002852 - (7118 - 7163) 0.002852$   
 $= -1.1151 - (-0.1283)$   
 $= -0.9868'' \quad (\text{Settlement})$

## 5. 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 2. 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:

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

where: SG is the specific gravity of the fluid (water) at the measurement temperature

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 3.

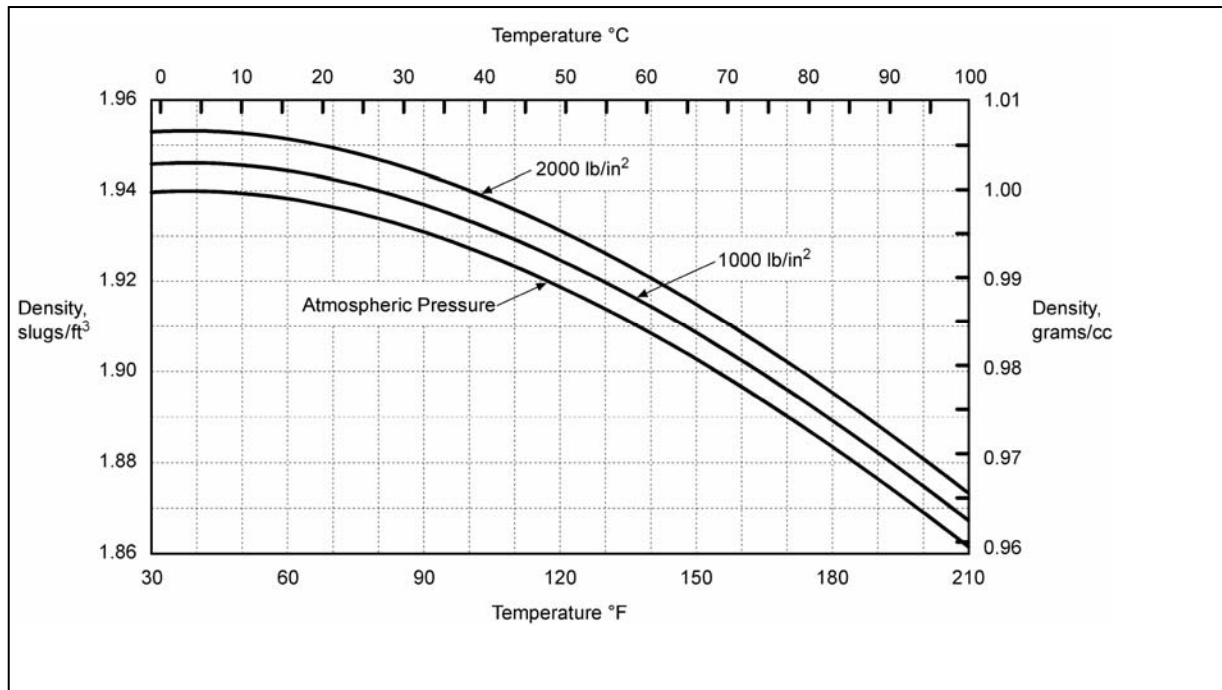


Figure 3. Density  $\rho$  of pure water as a function of temperature and pressure intensity. By permission from *Fluid Mechanics for Hydraulic Engineers*, by Hunter Rouse, copyright 1938, McGraw-Hill Book Company, Inc.

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.

## 6. Troubleshooting

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

1. Check the coil resistance. Nominal coil resistance is  $180\Omega \pm 10$  plus cable resistance (22 gage copper = approximately  $20\Omega$  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.

## 7. Specifications

Standard ranges	150, 300, 600 mm	
Resolution	0.07, 0.07, 0.15mm	
System accuracy	$\pm 0.1$ to $\pm 0.4$ mm	
Temperature Range	-20°C to +80°C	
Frequency Range	1400-3500Hz	

## Appendix A: Thermistor Chart

### *Thermistor Linearization using Steinhart and Hart Log Equation*

Tech Memo 91-03 Doc Rev 6-94, Geokon, Inc.

**Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3**

**Basic Equation:** 
$$T = \frac{1}{A + B(\text{Ln}R) + C(\text{Ln}R)^3} - 273.2$$

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 -50° to +150° C. span.*

*Resistance versus Temperature Table*

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	<b>3000</b>	<b>25</b>	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

## Appendix B: Typical Calibration Sheet

		48 Spencer St. Lebanon, N.H. 03766 USA	
<b>Vibrating Wire Liquid Level Sensor Calibration Report</b>			
Model Number: <u>4675-2-100 mm</u>		Temperature: <u>24.9 °C</u>	
Serial Number: <u>55066 / 00-L132</u>		Calibration Date: <u>April 28, 2009</u>	
Calibration Instruction: <u>CI-4675</u>		Technician: _____	

Applied Load (lbs)	Reading 1st Cycle	Reading 2nd Cycle	Average Reading (R)	Change	Linearity (%FS)
1.463	5100	5101	5101		
2.136	6774	6774	6774	1674	0.34
2.806	8421	8422	8422	1648	0.41
3.477	10058	10058	10058	1637	0.30
4.146	11680	11679	11680	1622	0.02

Weight Factor (C): 0.00041 (lbs / digit)  
 Factory reading with the cylindrical weight hanging in air = 10392

Cylinder Dimensions (inches):			Range: <u>4 inches</u>	Weight
Top	1	2	3	Manufacturing Number: <u>HW2000-67</u>  Average Diameter (D): <u>2.990</u>  Volume Factor (K): <u>3.945</u> (inches / lb)
	2.993	2.991	2.993	
Middle	2.987	2.984	2.987	
Bottom	2.991	2.990	2.990	

**Calibration Factor (G): 0.001617 (inches / digit) or 0.04108 (mm / digit)**

Change in Sensor Elevation =  $G(R_1 - R_0)$   
 $G = C \times K$

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

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

Note that the Volume Factor, K, is used to convert the Calibration factor, C, into the Calibration Factor, G.