CGEO INSTRUMENTS

CGEO INTERNATIONAL LIMITED

Model CGEO-WP

Vibrating Wire Piezometer

Installation Manual

（REV B）

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1. BRIEF INTRODUCTION

CGEO-WP series Vibrating Wire Piezometers are intended primarily for long-term measurements of fluid and/or pore pressures in standpipes, boreholes, embankments, pipelines and pressure vessels. Its various properties are excellent, all exposed components are made of corrosion resistant stainless steel and, if proper installation techniques are used, the device should have an unlimited life. If perfected specially the cable protection, It can be buried in roller compacted concrete directly with higher requirement of instrument property. Standard filters are sintered stainless steel with 50 micron pore which is beneficial to air discharge from the cavum of Pizometer. CGEO-WP Model is commonly used piezometer. In the introduction below, they all are collectively called as CGEO-WP series pizometer.

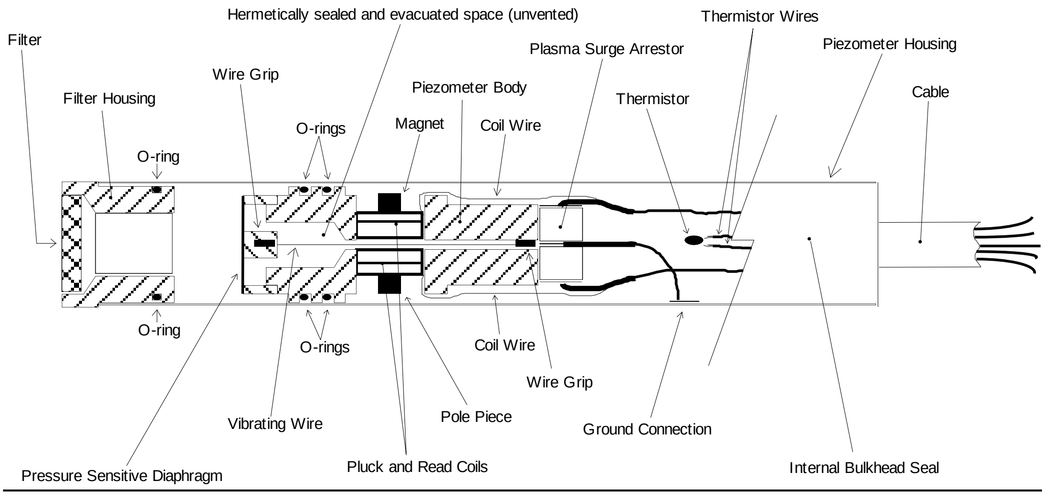


Figure 1-1 Vibrating Wire Piezometer

2. INSTALLATION

2.1 Premiarly Test and Calibration

Upon receipt the pezometer it is wise to check, measure and record readings(refer to Section 3 about taking readings)

Each instrument has supplied a calibration factor, including temperature correction factor(details see Appendix sample calibration sheet).

The following steps are basing on standpipe and well installation as an example to check the calibration factor supplied on calibration sheet.(see appendix B).

Prepare well tools beforehand: 1 bucket, 1 steel tape(hang a 200g load in front end of it).

1).After determining the installation date, proceed the following work in advance 24 hours: pour some proper mount of clear water into the bucket, take off permeable stone, submerge pizometer and permeable stone under water, exhaust air from piezometer, permeable socket and its cavum; resemble permeable socket and pizometer again under water so as to discharge air in the permeable stone. Immerse resembled pizometer into water until installed and lift the bucket to installation spot. Measure standpipe and well actual depth with steel tape and the depth of the water level with steel ruler water level gauge (accurate to mm). Immerse the saturated pizometer into standpipe or well, the immersion depth is less than borehole depth but ensure pizometer under water level, have pizometer thermal equilibrium 15~20 minutes, record the transducer stable reading in this position with readout. Lift the pizometer up to a known position and ensure it still under waterlevel, record the reading after it is stable, calculate out the field calibration factor. Compare it with that in calibration sheet, the deviation should be less than 1%. Repeat it if necessary.

Besides, using 0.05 class standard piston pressure gauges to calibrate is the best calibration method.

Note:

1).when monitoring the liquid level of standpipe or well, please have liquid level reach to equilibrium, especially when the diameter of standpipe or well is comparative small, the osmoses coefficient is small and cable lift altitude is bigger.(not taking penetration into consideration, place a CGEO-WP model piezometer into a diameter of 50 mm(inner diameter 45mm) standpipe 15m, it can make liquid level go up to 0.3m. So ensure enough time for liquid level to reach equilibrium. Also can use steel ruler gauge to check).

2). Every CGEO-WP series piezometer is supplied with a calibration sheet which records instrument important parameters and should be kept well. Appendix B is sample calibration sheet of CGEO-WP model. When installing and calculating, the parameters in calibration sheet are normally used for calibration and verification.

2.1.1 Establishing a Zero Reading

Vibrating Wire Piezometers differ from other types of pressure sensors in that they indicate a reading with no pressure exerted. It is imperative that an accurate zero reading be obtained for each piezometer as this reading will be used for all subsequent data reduction (unless Δ pressure is being monitored). Generally, it is obtained by reading the instrument prior to installation (with no pressure applied).

Following are various checks to ensure the obtaining of accurate zero readings of a piezometer;

✓ Has the temperature of the piezometer reached thermal equilibrium? Variations in temperature across the body of the piezometer will give rise to temperature transients and erroneous readings. Allow 15-20 minutes for the temperature of the piezometer to equilibrate.

✓ Is the filter stone saturated? If it is only partially saturated, then surface tension effects in the pores of the filter can seriously affect the readings (Section 2.6). This problem can appear particularly at low pressures (less than 5 psi). When performing preliminary tests involving the raising and lowering of the piezometer in fluid or the pressures are low, the filter housing should be removed.

✓ In the case of monitoring level in a standpipe or well, has the displacement of the water column by the piezometer and cable been accounted for? This is especially critical where the cable length is long and the borehole diameter small (2 or less inches).

√ if measuring liquid level, zero reading should be the stable reading in air. The practice as following: lift slowly and in even pace the pizometer saturated and reached thermal equilibrium out off liquid level in standpipe or well, record timely the stable reading when it is still(see figure 3). Lower piezometer into liquid and repeat above steps again 3 times in same speed. Comparing these 3 times of measurings. In normal situation, these 3 times measuring deviation not more than 1~2 digits. Take the average or middle value as zero reading. As to burring situation, zero reading is taken with bucket method.

Note: during taking initial reading, if lift pizometer out of liquid level and reading is not easily kept stable, you can not lift pizometer out of water completely, but make pizometer bottom immerse into water 1~2cm. This method can avoid water precipitation and is easy to get a stable reading.

As following the method of monitoring relative pressure: After installing saturated pizometer and have it reach to equilibrium, measure and record the stable reading then, consider this reading as initial value. Measure and record then the pressures, such as water pressure, barometer etc as for later on calculation

- ✓ Be sure to record the temperature & barometric pressure at the time the zero readings are taken.

2.1.2 Cable Welding Lengthening

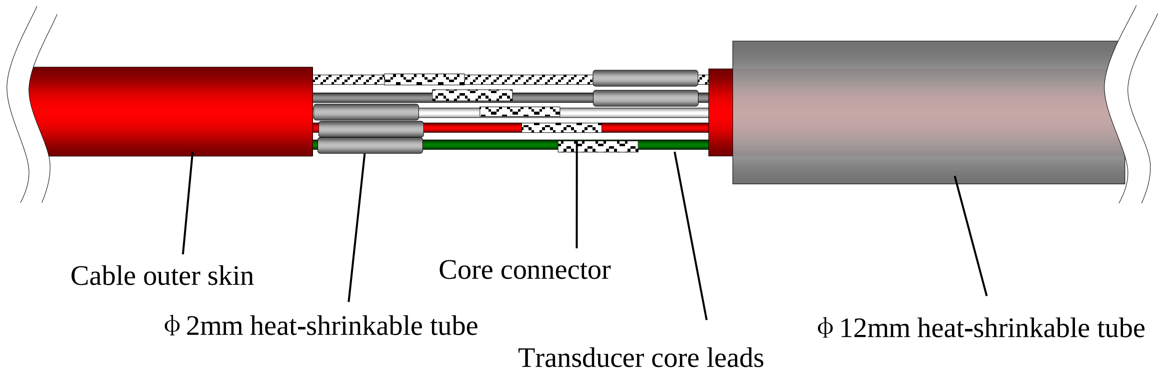
Because the output signal of Vibrating Wire instruments is frequency, a slight change of cable resistance and cable splice lengthening will not affect the readings of readout. A standard pizometer is equipped with 1m cable in ex-factory. Proceed lengthening basing on the field circumstance before installation. Avoid connection as possible as in the cable buried in soil.

The cable used for splice should be of high quality 100% shielded twisted cable (with overall shield antijamming core leads). When linking, all shield lines (naked leads) should also weld together and then lead to ground point. As following the details introduction of connection method of using dedicated heat-shrinkable connector.

Measure the resistance between cores of transducer with millimeter and note it before welding. Thereinto, the resistance between green and white core should be 3kΩ about at room temperature 25℃. The insulation resistance between red black and green white leads or shield line (naked lines) should be >50MΩ. (Use 100v DC megger to measure insulation resistance. The resistance should be ∞ with multimeter.)

Before welding , strip the outer leather of cable end part, length about 8cm, and expose the core leads, roughen rest cable outer leather part with emery cloth or sandpaper, length about 3 cm. Sleeve φ12mm heat-shrinkable tube onto outside cable (length about 14cm). Strip outer skin of cores 0.5~0.8 cm with stripping pliers, jacket φ2mm heat-shrinkable tube onto core leads. After twisting core leads together corresponding to colors, solder tin with electric soldering iron. Should avoid poor soldering and remove burrs during soldering process. **5 pieces of cores all are needed to solder, please note: 1). Stagger each core connector; 2). Ensure every core lead length the same and ensure each core uniformly forced when cable is pulled**. After soldering, naked core line length about 7cm, push φ2mm outer heat-shrinkable tube onto core leads connector part, and make it shrunk in connector part with heat wind gun. At last push φ12mm heat-shrinkable tube unto cable connector and heat- shrunk in connector part with heat wind gun. Φ12mm heat-shrinkable tube should be pressed 3 cm over each end of cable outer skin. Should control the temperature when using heat-wind gun so that heat-shrinkable tube internal in transparent, fluid status, and fully filled with connector internal. But too high temperature will melt core lead outer skin and cause core lead short and heat-shrinkable tube carbonization and brittle.

Note: after core leads welding work finishing, you must check the reading measurement with readout, and examine the resistance between cores of cable with millimeter in case welding work causes connector part short and cut



Cable welding splice diagram

2.2 Installation in Standpipes or Wells

A zero reading is first established (follow the procedures outlined in Section 2.1.1). The filter stone is saturated. The piezometer can then be lowered to the desired position in the standpipe using the cable to serve as a depth marker so that the position (elevation) of the piezometer tip is accurately known.

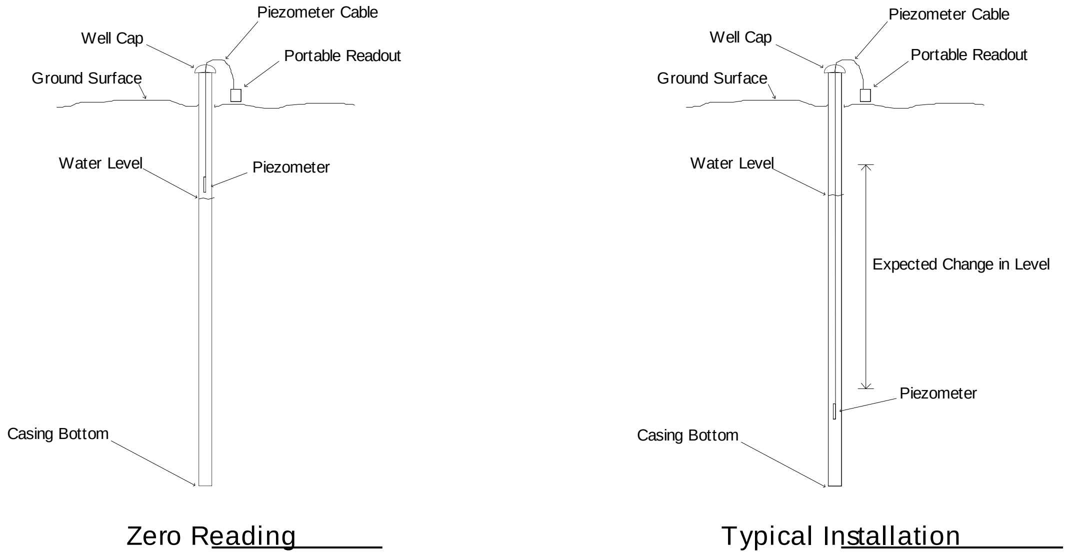


Figure 2-2 Typical Level Monitoring Installations

Be sure the cable is securely fastened at the top of the well or readings could be in error due to slippage of the piezometer into the well.

It is not recommended that piezometers be installed in wells or standpipes where an electrical pump and/or cable is present or nearby. Electrical interference from these sources can cause unstable readings.

In situations where packers are used in standpipes the same sequence as above should be noted and special care should be taken to avoid cutting the cable jacket with the packer since this could introduce a possible pressure leakage path.

2.3 Installation in Boreholes

Vibrating Wire piezometers can be installed in boreholes in either single or multiple installations per hole, in cased or uncased holes. See Figure 4. Careful attention must be paid to borehole sealing techniques if pore pressures in a particular zone are to be monitored.

Boreholes should be drilled either without drilling mud or with a material that degrades rapidly with time, such as Revert™. The hole should extend from 6 inches to 12 inches below the proposed piezometer location and should be washed clean of drill cuttings. The bottom of the borehole should then be backfilled with clean fine sand to a point 6 inches below the piezometer tip. The piezometer can then be lowered, as delivered, into position. Preferably, the piezometer may be encapsulated in a canvas cloth bag containing clean, saturated Ottawa sand and then lowered into position. While holding the instrument in position (a mark on the cable is helpful) clean sand should be placed around the piezometer and to a point 6 inches above it. Figure 4 details two methods of isolating the zone to be monitored.

Installation A

Immediately above the "collection zone" the borehole should be sealed with either alternating layers of bentonite and sand backfill tamped in place for approximately 1 foot followed by common backfill or by an impermeable bentonite-cement grout mix. If multiple piezometers are to be used in a single hole the bentonite-sand plugs should be tamped in place below and above the upper piezometers and also at intervals between the piezometer zones. When designing and using tamping tools special care should be taken to ensure that the piezometer cable jackets are not cut during installation.

Installation B

Immediately above the "collection zone" the borehole should be filled with an impermeable bentonite grout.

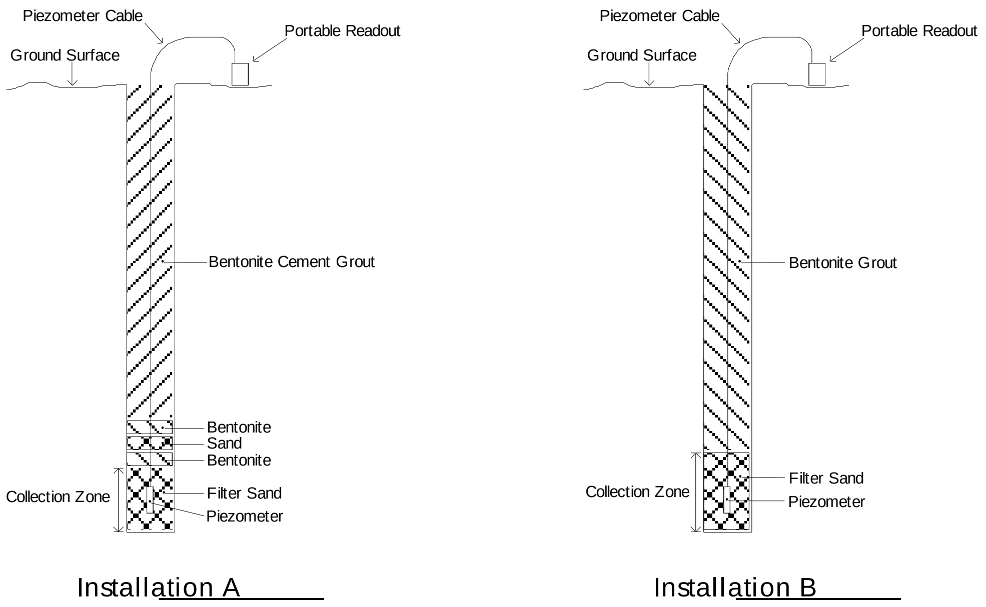


Figure 4 Typical Borehole Installations

It should be noted that since the vibrating wire piezometer is basically a no-flow instrument, collection zones of appreciable size are not required and the piezometer can, in fact, be placed directly in contact with most materials provided that the fines are not able to migrate through the filter.

2.4 Installation in Fills and Embankments

When reaching installation height and fillback layer roller compacted, dig up an instrument installation groove and cable trench. The digging depth should be equal to the maximum rolling thickness of rolling equipment in field. Level the bottom of instrument installation bottom and fillback 20mm with coarse sand removing out big aggregates and tamped by hand. If sand contains too much mud, it is necessary to use a sand packet wrapping up pizometer, the practice of sand packet as following: wrap up clean wet sand with non-woven Geotextile, sand particle diameter less than 1mm. Place pizometer(or pizometer sand packet) in installation position, fill back 20cm thickness layer with coarse sand removing out big aggregates, tamped with hand, layer by layer fill back with dam backfill materials and tamped with hand.
Vibrating Wire piezometers are normally equipped with direct burial cable suitable for placement in fills such as highway embankments and dams, both in the core and in the surrounding materials.
In installations in non-cohesive fill materials the piezometer may be placed directly in the fill or, if large size aggregates are present, in saturated sand pocket in the fill. If installed in large aggregate, additional measures may be necessary to protect the cable from damage.
Cables are normally installed inside shallow trenches with the fill material consisting of smaller size aggregate. This fill is carefully hand compacted around the cable. Bentonite plugs are placed at regular intervals to prevent migration of water along the cable path.

2.5 Lightning Protection

In exposed locations it is vital that the piezometer be protected against lightning strikes.

A tripolar plasma surge arrestor (Figure 1) is built into the body of the piezometer and protects against voltage spikes across the input leads. Following are additional lightning protection measures available;

1. If the instruments will be read manually with a portable readout (no terminal box) a simple way to help protect against lightning damage is to connect the cable leads to a good earth ground when not in use. This will help shunt transients induced in the cable to ground thereby protecting the instrument.

2. Terminal boxes available from Beijing Soil can be ordered with built in lightning protection. There are two levels of protection;
   - The terminal board used to make the gage connections has provision for installation of plasma surge arrestors (similar to the device inside the piezometer).
   - Lightning Arrestor Boards can be incorporated into the terminal box. These units utilize surge arrestors and transzorbs to further protect the piezometer.

   In the above cases the terminal box would be connected to an earth ground.

3. TAKING READINGS and DATA REDUCTION

The reading of CGEO-WP series Pizometer can use CGEO-PR-VW Readout Box, choose “B” level. Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the white and green leads are for the thermistor and the blue for the shield drain wire. As to requiring high accurate measures, it is necessary to record barometer measuring so that you can excise barometer correction if necessary. Please see section 3.1 about barometer correction.

For example： a Pizometer(series No 09060), current reading R1=8000， initial reading(or zero reading） B0=8932.5, current temperature T1=15℃, initial temperature T0=22℃, initial barometer s0=990.1 mbar, current barometer s1=101.035kpa, thermal coefficient K= -0.0881kpa/℃, calibration coefficient G = -0.116003kpa/Digit, A= -0.00000027813228, B= -0.111871426886, C= 1021.9376813(related coefficient, please refer to calibration sheet).

Linearity: $P = G\times(R_1-R_0)+K(T_1-T_0)-(S_1-S_0)$

$= -0.116003\times(8000-8932.5)+(-0.0881)\times(15-22)-(101.035-990.1\times0.1)$

$= 106.7644975$ kPa

Multinomial: $P = AR_1^2+BR_1+C+K(T_1-T_0)-(S_1-S_0)$

$P = -0.00000027813228\times8000^2+(-0.1118714526886)\times8000+1021.93768131+(-0.0881)\times(15-22)-(101.035-990.1\times0.1)$

$= 107.7572938812$kPa

You can see that the multinomial gets more accurate result than linearity formula, recommended is to use multinomial formula to calculate in water level measurement.

The calibration sheets give the pressure in certain engineering units. These can be converted to other engineering units using the multiplication factors shown in Table 4-1 below.

From → To												
psi	1	.036127	.43275	.0014223	1.4223	.49116	.019337	14.696	.014503	14.5039	.14503	145.03
"H_2O	27.730	1	12	.039372	39.372	13.596	.53525	406.78	.40147	401.47	4.0147	4016.1
'H_2O	2.3108	.08333	1	.003281	3.281	1.133	.044604	33.8983	.033456	33.4558	.3346	334.6
mm H_20	704.32	25.399	304.788	1	1000	345.32	13.595	10332	10.197	10197	101.97	101970
m H_20	.70432	.025399	.304788	.001	1	.34532	.013595	10.332	.010197	10.197	.10197	101.97
"HG	2.036	.073552	.882624	.0028959	2.8959	1	.03937	29.920	.029529	29.529	.2953	295.3
mm HG	51.706	1.8683	22.4196	.073558	73.558	25.4	1	760	.75008	750.08	7.5008	7500.8
atm	.06805	.0024583	.0294996	.0000968	.0968	.03342	.0013158	1	.0009869	.98692	.009869	9.869
mbar	68.947	2.4908	29.8896	.098068	98.068	33.863	1.3332	1013.2	1	1000	10	10000
bar	.068947	.0024908	.0298896	.0000981	.098068	.033863	.001333	1.0132	.001	1	.01	10
kPa	6.8947	.24908	2.98896	.0098068	9.8068	3.3863	.13332	101.320	.1	100	1	1000
MPa	.006895	.000249	.002988	.00000981	.009807	.003386	.000133	.101320	.0001	.1	.001	1

Table 4-1 Engineering Units Multiplication Factors

Note: Due to changes in specific gravity with temperature the factors for mercury and water in the above table are approximations!

3.1 Barometric Correction

Since the standard piezometer is hermetically sealed and unvented, it responds to changes in atmospheric pressure. That being the case, corrections may be necessary, particularly for the sensitive, low pressure models. Thus it is advisable to read and record the barometric pressure every time the piezometer is read. A separate pressure transducer (piezometer), kept out of the water, may be used for this purpose.

The user should be cautioned that this correction scheme assumes ideal conditions. In reality, conditions are not always ideal. For example, if the well is sealed, barometric effects at the piezometer level may be minimal or attenuated from the actual changes at the surface. Thus errors may result when applying a correction which is not required.

An alternative to making barometric correction is to use piezometers that are vented to the atmosphere.

4. ENVIRONMENT FACTORS

Since the purpose of the piezometer installation is to monitor site conditions, factors which may affect these conditions should always 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 the factors include, but are not limited to; blasting, rainfall, tidal levels, excavation and fill levels and sequences, traffic, temperature and barometric changes (and other weather conditions), changes in personnel, nearby construction activities, seasonal changes, etc.

5. TROUBLESHOOTING

Maintenance and troubleshooting of vibrating wire piezometers is confined to periodic checks of cable connections and maintenance of terminals. The transducers themselves are sealed and not user serviceable. Following are typical problems and suggested remedial action.

- **Piezometer fails to give a reading**

1. Check the resistance of the coils by connecting an ohmmeter across the gage terminals. Nominal resistance is 180Ω (±5%), plus cable resistance at approximately 15Ω per 1000' of 22 AWG wire. If the resistance is very high or infinite the cable is probably broken or cut. If the resistance is very low the gage conductors may be shorted. If a cut or a short is located in the cable, splice according to instructions.
2. Check the readout with another gage.
3. The Piezometer may have been over-ranged or shocked. Inspect the diaphragm and housing for damage. Contact the factory.

6. SPECIFICATIONS

Main Specifications

Model	CGEO-WP
Standard Range	0.35, 0.7, 1.0, 2.0, 3.0MPa 0.5, 1.5MPa can be customized
Resolution	0.035%F.S.
Accuracy	0.1%F.S.
Over Range	50%×F.S.
Diameter	19mm
Length	133mm

Table Vibrating Wire Piezometer Specifications

APPENDIX A－THERMISTOR TEMPERATURE DERIVATION

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

Resistance to Temperature Equation:

$$T = \frac{1}{A + B(LnR) + C(LnR)^3} - 273.2$$

Equation A-1 Convert Thermistor Resistance to Temperature

Where; T = Temperature in °C.

LnR = Natural Log of Thermistor Resistance

A = 1.4051 × 10^{-3} (coefficients calculated over the −50 to +150° C. span)

B = 2.369 × 10^{-4}

C = 1.019 × 10^{-7}

Resistan	Temp℃	Resi(Ω)	Temp℃	Resi(Ω)	Temp℃	Resis(Ω	Temp℃	Resis(Ω	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 A-1 Thermistor Resistance versus Temperature

APPENDIX- B SAMPLE CALIBRATION SHEET

Model:CGEO-WP-35-SS-T **Series No:09060**

Ambient Condition： Temperature： 21℃ Humidity：43%RH

Testing results

Measure Range：**(0---350)kPa**

Readout：CGEO-PR-VW Readout（B）

Standard (kPa)	**Each measure**			**Average**	**Accuracy**	
	1	**2**	**3**		**Linear**	**Polynomial**
0.0	8936.5	8933.9	8936.6	8935.7	0.120%	0.023%
70.0	8338.4	8337.1	8338.4	8338.0	-0.070%	-0.051%
140.0	7733.6	7734.3	7733.6	7733.8	-0.047%	0.031%
210.0	7131.8	7132.4	7131.9	7132.0	-0.100%	-0.023%
280.0	6525.1	6524.9	6524.9	6525.0	0.020%	0.039%
350.0	5920.1	5919.1	5920.3	5919.8	0.077%	-0.020%
/	/	/	/	/	/	/

Formula

Linear P (kPa)= $G(R_1-R_0)+K(T_1-T_0)-(S_1-S_0)$

Polynomial P (kPa)= $AR_1^2 + BR_1 + C + K(T_1-T_0)-(S_1-S_0)$

Linear Coefficient

G = -0.116003 kPa/Digit **Zero Point**： 8939.3

Polynomial Coefficient

A = -0.00000027813228 **B =** -0.1118714526886

C = 1021.93768131

Thermal Coefficient

K = -0.088100 kPa/℃

R_0 ....Initial Reading **R_0:** 8928

T_0 ....Initial Temperature **T_0:** 27.2℃

S_0 ....Initial Barometer **S_0:** 990.1mbar

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Note：1). The initial reading R_0， initial temperature T_0 initial barometer S_0 in table above are given by factory

2). The calibration sheet of other model pizometers is same as above.