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Instruction Manual
Model 4500HT
High Temperature
Vibrating Wire Piezometer



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1. INTRODUCTION

Geokon's 4500HT Series High Temperature Piezometers are designed for monitoring downhole pressures and temperatures in oil recovery systems and geothermal applications. Each 4500HT pressure transducer is equipped with a Model 4700 Vibrating Wire Temperature Sensor which gives a varying resistance output as the temperature changes.

4500HT sensors are capable of operation under extreme conditions and at temperatures up to 250 °C. In thermal recovery applications such as Steam Assisted Gravity Drainage (SAGD) and Cyclic Steam Stimulation (CSS) they provide accurate, real-time, continuous monitoring of pressures in production and injection wells, thereby optimizing the recovery rate and reducing the cost of the steam injection process. In geothermal applications, they offer a means for in situ, continuous monitoring of pressures and temperatures over extended periods of time.

1.1 Theory of Operation

Geokon vibrating wire piezometers utilize a sensitive stainless steel diaphragm to which a vibrating wire element is connected. During use, changing pressures on the diaphragm cause it to deflect. This deflection is measured as a change in tension and frequency of vibration in the vibrating wire element. The square of the vibration frequency is directly proportional to the pressure applied to the diaphragm. A filter is used to keep out solid particles and prevent damage to the sensitive diaphragm. Standard filters are 50 micron stainless steel.

Two coils, one with a magnet insert, the other with a pole piece insert, are installed near the vibrating wire. In use, a pulse of varying frequency (swept frequency) is applied to these coils, causing the wire to vibrate primarily at its resonant frequency. When the excitation ends, the wire continues to vibrate. During vibration a sinusoidal signal is induced in the coils and transmitted to the readout box where it is conditioned and displayed. The 4500HT sensors are designed for static measurements only; at least one second is required to excite and read the sensor.

All exposed components are made of corrosion resistant stainless steel. If proper installation techniques are used, the device should have an unlimited life. In salt water it may be necessary to use special materials for the diaphragm and housing.

Portable readout units are available to provide the excitation, signal conditioning, and readout of the instrument. Datalogging systems are also available for remote unattended data collection of multiple sensors. Contact Geokon for additional information.

2. CABLES

4500HT series piezometers may be delivered with four conductor, 24-gauge, Teflon[®] insulated cable inside stainless steel tubing, or, four conductor, 22-gauge mineral insulated cable in a magnesium oxide jacket with 316 stainless steel sheath. (Sheath wall = 0.76 mm [0.03"]). Nominal O.D. = 4.76 mm [0.1875"]). Both cable types are delivered in coils, and can be terminated in bare leads (Figure 1), with a connector, a transition to a regular instrumentation cable (Figure 2), or other termination as determined by the customer. See Table 1 below for standard wiring.



Figure 1 - Cable Inside Stainless Steel Tubing



Figure 2 - Stainless Steel Tubing with Transition to 02-250V6 Cable

Function	02-156T Cable	02-187MI Cable	Cables that transition to 02-250V6 cable
Vibrating Wire Gauge +	Red	Red	Red
Vibrating Wire Gauge -	Black	Black	Black
Temperature Sensor	White	White	White
Temperature Sensor	Blue	Green	Green
Cable Shield	Shield	Shield	Shield

Table 1 - Standard Piezometer Wiring

3. PRELIMINARY TESTS

Upon receipt of the piezometer the zero reading should be checked and noted. A Model 4700 VW Temperature Sensor is included inside the body of the sensor for the measurement of temperature. (See Section 5 for readout instructions.)

Calibration data are supplied with each gauge and zero readings at six different temperatures and barometric pressure is included. Zero readings at the site should coincide with the calibration zero readings within ± 50 digits after barometric and temperature corrections are made. The factory elevation is +580 ft. Before March 21, 1995 factory barometric pressure readings were corrected to sea level; readings after this date represent absolute pressure. (Barometric pressure changes with elevation at a rate of $\approx 1/2$ psi per 1,000 ft.) See Section 6 for sample calibration reports.

4. INSTALLATION IN BOREHOLES

Before installing make sure both pressure and temperature sensors are working and record initial readings with a portable readout box (GK-403 or GK 404).

Push the sensor into the borehole by whatever means are chosen. This may include attachment to grout pipes, special installation rods or other apparatuses being inserted into the borehole at the same time.

5. TAKING READINGS

The 4500HT is usually connected to a datalogger, but for initial set up it is often more convenient to use a portable readout box. When the 4500HT piezometer is connected to a datalogger the pluck voltage must be set to 12 volts.

5.1 GK-404 Readout Box

The Model GK-404 Vibrating Wire Readout is a portable, low-power, handheld unit that is capable of running for more than 20 hours continuously on two AA batteries. It is designed for the readout of all Geokon vibrating wire gauges and transducers, and is capable of displaying the reading in either digits, frequency (Hz), period (μ s), or microstrain (μ ϵ).

5.1.1 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 3). Insert the Lemo connector into the GK-404 until it locks into place.



Figure 3 - Lemo Connector to GK-404

To turn the GK-404 on, press the “ON/OFF” button on the front panel of the unit. The initial startup screen will 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) 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.

Use the **POS** button to select position **B** and the **MODE** button to select **Dg** (digits). (Other functions can be selected as described in the GK-404 Manual.)

The red and black clips of the GK-404-1 flying leads are used for taking both the pressure reading *and* the temperature reading. The white and green clips of the flying leads are not used with the 4500HT. Make sure the shield drain wire is connected to the blue clip on the flying leads for both readings.

To take a pressure reading, connect the red and black clips from the flying leads to the red and black leads of the 4500HT.

To take a temperature reading, connect the red and black clips from the flying leads to the white and green (or blue) leads of the 4500HT.

See Section 6 for information on Data Reduction.

The GK-404 will continue to take measurements and display readings until the unit is turned off, either manually, or if enabled, by the Auto-Off timer. If no reading displays or the reading is unstable see Section 7 for troubleshooting suggestions.

For further information consult the GK-404 manual.

5.2 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 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.



Figure 4 - GK-405 Readout Box

5.2.1 Operating the GK-405

- 1) Attach the GK-403-2 flying leads to the unit.
- 2) Press the button labeled "POWER ON".
- 3) A blue light will begin blinking, signifying that the Remote Module is waiting to connect to the handheld unit.
- 4) Launch the GK-405 VWRA program handheld PC by tapping on "Start", then "Programs", and then the GK-405 VWRA icon.
- 5) After a few seconds, the blue light on the Remote Module should stop flashing and remain lit, indicating that the remote module has successfully paired with the handheld PC.
- 6) The red and black clips of the GK-403-2 flying leads are used for taking both the pressure reading *and* the temperature reading. The white and green clips of the flying leads are not used with the 4500HT. Make sure the shield drain wire is connected to the blue clip on the flying leads for both readings.
- 7) To take a pressure reading, connect the red and black clips from the flying leads to the red and black leads of the 4500HT.

- 8) To take a temperature reading, connect the red and black clips from the flying leads to the white and green (or blue) leads of the 4500HT.
- 9) The Live Reading window on the handheld PC will display the vibrating wire output in digits. The last digit may change one or two digits while reading.
- 10) See Section 6 for information on Data Reduction.

If the no reading displays or the reading is unstable see Section 7 for troubleshooting suggestions. For further information consult the GK-405 Instruction Manual.

5.3 GK-403 Readout Box (Obsolete Model)

The GK-403 can store gauge readings and also apply calibration factors to convert readings to engineering units. The following instructions explain taking gauge measurements using Modes “B” and “F”. Consult the GK-403 Instruction Manual for additional information.

5.3.1 Operating the GK-403

- 1) Attach the GK-403-2 flying leads to the unit.
- 2) Turn the display selector to position “B” (or “F”).
- 3) Turn the unit on.
- 4) The red and black clips of the GK-403-2 flying leads are used for taking both the pressure reading *and* the temperature reading. The white and green clips of the flying leads are not used with the 4500HT. Make sure the shield drain wire is connected to the blue clip on the flying leads for both readings.
- 5) To take a pressure reading, connect the red and black clips from the flying leads to the red and black leads of the 4500HT.
- 6) To take a temperature reading, connect the red and black clips from the flying leads to the white and green (or blue) leads of the 4500HT.
- 7) The readout will display the vibrating wire output in digits. The last digit may change one or two digits while reading.
- 8) Press the “Store” button to record the value displayed.
- 9) See Section 6 for information on Data Reduction.

If the no reading displays or the reading is unstable see Section 7 for troubleshooting suggestions.

The unit will automatically turn off after approximately two minutes to conserve power.

6. DATA REDUCTION

Each Model 4500HT pressure transducer is supplied with a calibration report showing the output of the temperature sensor at six different temperatures, ranging from room temperature to 250 °C (Figure 5). Also supplied are five calibration reports from the pressure transducer showing the output readings versus pressure change at five temperature intervals (Figure 6 through Figure 10).

The Model 4500HT pressure transducer and incorporated Model 4700 temperature sensor both operate on the vibrating wire principle. The output of the temperature sensor will yield the operating temperature directly using a second order polynomial. Calculation of pressure is not direct. The effect of the ambient temperature on both the zero reading and gauge factor must be taken into account. In essence the data interpretation proceeds as follows, using second order polynomials for greater accuracy.

To calculate the pressure (P) from any current reading (R_1) on the pressure transducer, complete the following:

- 1) Calculate the temperature (T) from the VW temperature sensor using the output reading (R_T) from the temperature sensor and the polynomial expression shown on the temperature gauge calibration report.
- 2) Use the temperature values and the zero pressure readings shown on the six calibration reports in an Excel spreadsheet to develop a polynomial that describes how the zero reading (R_0) varies with the temperature. (This polynomial will be supplied along with the calibration reports.)
- 3) Use the temperature values and linear gauge factors shown on the six calibration reports in an Excel spreadsheet to develop a polynomial that describes how the gauge factor (G) varies with the temperature. (This polynomial will be supplied along with the calibration reports.)
- 4) Using the calculated polynomial values of R_0 and G at the measured temperature (T) and with the current reading (R_1) find the pressure (P) from the equation:

$$P = (R_1 - R_0) G$$

Equation 1 - Pressure

An example using an Excel Spreadsheet and the Chart Wizard Trendlines, as well as the data from the sample Model 4700 temperature calibration report (Figure 5) and the five sample pressure calibration reports (Figure 6 through Figure 10) is shown below.

$$\text{Temperature (T)} = 3.7511\text{E-}07 R_T^2 + 0.03484 R_T - 124.98$$

Equation 2 - Temperature

$$\text{Zero Reading (R}_0\text{)} = -0.00193T^2 + 1.885T + 8367$$

Equation 3 - Zero Reading

$$\text{Gauge Factor (G)} = -8.61\text{E-}11\text{T}^2 - 2.038\text{E-}09\text{T} - 0,0002246$$

Equation 4 - Gauge Factor

For example, suppose that the reading on the temperature sensor (R_T) is 8400 and the reading on the pressure transducer (R_I) is 6500.

Then;

Temperature = 194.1 °C

Zero Reading = 8660

Gauge Factor = -0.0002282

From which Pressure = $(6500 - 8660) (-0.002282) = 0.493 \text{ MPa}$



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

Vibrating Wire Temperature Gage Calibration Report

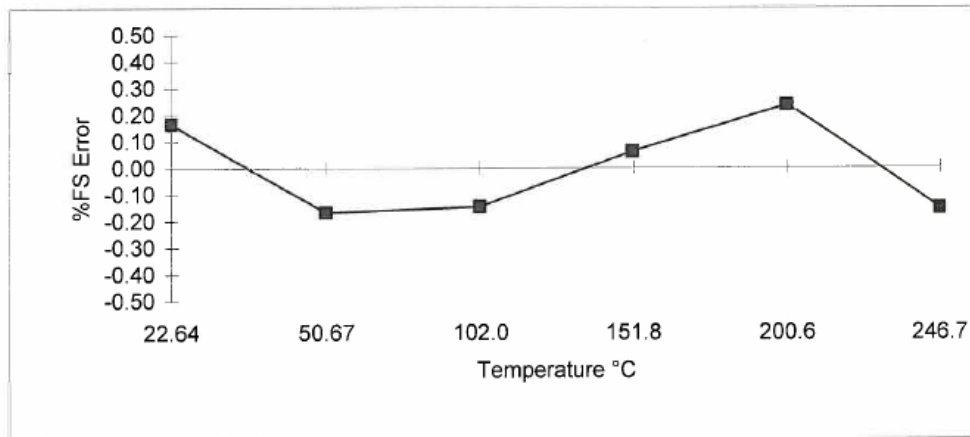
Model Number: 4500HT-1 MPaCalibration Date: January 20, 2012Serial Number: 1140741 / 1133911

Technician:

Calibration Data

Reading	Reading ²	Temperature °C	Calc Temperature	%FS Error
4070	16564900	22.64	23.05	0.17
4783	22877089	50.67	50.26	-0.17
6103	37246609	102.0	101.6	-0.14
7364	54228496	151.8	152.0	0.06
8570	73444900	200.6	201.2	0.24
9653	93180409	246.7	246.3	-0.15

Error Plot



$$\text{Temperature (°C)} = (A * R^2) + (B * R) + C$$

Where;



R = Reading in Digits**A = 3.7511E-07****B = 0.03484****C = -124.98**

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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Figure 5 - A Typical Model 4700 VW Temperature Sensor Calibration Report

		48 Spencer St. Lebanon, N.H. 03766 USA	
Vibrating Wire Pressure Transducer Calibration Report			
Type: <u>HT</u>		Date of Calibration: <u>January 20, 2012</u>	
Serial Number: <u>1140741 / 1133911</u>		Temperature: <u>22.64 °C</u>	
Pressure Range: <u>1 MPa</u>		Barometric Pressure: <u>998.9 mbar</u>	
		Calibration Instruction: <u>VW Pressure Transducers</u>	
		Technician: <u></u>	

Applied Pressure (MPa)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8409	8409	8409	0.001	0.10	0.000	0.01
0.2	7524	7524	7524	0.200	-0.02	0.200	0.00
0.4	6637	6637	6637	0.399	-0.09	0.400	-0.02
0.6	5746	5745	5746	0.599	-0.07	0.600	0.00
0.8	4853	4852	4853	0.800	0.00	0.800	0.00
1.0	3959	3958	3959	1.001	0.08	1.000	-0.02

(MPa) Linear Gage Factor (G): -0.0002247 (MPa/ digit)
 Regression Zero: 8413

Polynomial Gage Factors: A: -3.504E-10 B: -0.0002203 C:

Calculate C by setting P = 0 and R₁ = initial field zero reading into the polynomial equation

(psi) Linear Gage Factor (G): -0.03256 (psi/ digit)
 Regression Zero: 8413

Polynomial Gage Factors: A: -5.07845E-08 B: -0.03193 C:

Calculate C by setting P = 0 and R₁ = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0)^*$
 Polynomial, $P = AR_1^2 + BR_1 + C$ *



*Barometric pressures are absolute. Barometric compensation is not required with vented and differential pressure transducers.

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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Figure 6 - Typical Calibration Report at 25 °C

		48 Spencer St. Lebanon, N.H. 03766 USA	
Vibrating Wire Pressure Transducer Calibration Report			
Type: <u>HT</u>		Date of Calibration: <u>January 20, 2012</u>	
Serial Number: <u>1140741 / 1133911</u>		Temperature: <u>102.0 °C</u>	
Pressure Range: <u>1 MPa</u>		Barometric Pressure: <u>996.9 mbar</u>	
		Calibration Instruction: <u>VW Pressure Transducers</u>	
		Technician: <u></u>	

Applied Pressure (MPa)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8538	8538	8538	0.001	0.12	0.000	0.01
0.2	7660	7660	7660	0.199	-0.05	0.200	-0.03
0.4	6775	6775	6775	0.399	-0.07	0.400	0.02
0.6	5890	5890	5890	0.599	-0.09	0.600	0.01
0.8	5002	5002	5002	0.800	-0.04	0.800	-0.01
1.0	4110	4109	4110	1.001	0.12	1.000	-0.01

(MPa) Linear Gage Factor (G): -0.0002258 (MPa/ digit)
 Regression Zero: 8543

Polynomial Gage Factors: A: -4.353E-10 B: -0.0002203 C:

Calculate C by setting P = 0 and R₁ = initial field zero reading into the polynomial equation

(psi) Linear Gage Factor (G): -0.03272 (psi/ digit)

Polynomial Gage Factors: A: -6.30935E-08 B: -0.03193 C:

Calculate C by setting P = 0 and R₁ = initial field zero reading into the polynomial equation

Calculated Pressures: **Linear, P = G(R₁ - R₀)***

Polynomial, P = AR₁² + BR₁ + C *



*Barometric pressures are absolute. Barometric compensation is not required with vented and differential pressure transducers.

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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Figure 7 - Typical Calibration Report at 100 °C

		48 Spencer St, Lebanon, N.H. 03766 USA	
Vibrating Wire Pressure Transducer Calibration Report			
Type: <u>HT</u>		Date of Calibration: <u>January 20, 2012</u>	
Serial Number: <u>1140741 / 1133911</u>		Temperature: <u>151.8 °C</u>	
Pressure Range: <u>1 MPa</u>		Barometric Pressure: <u>995.1 mbar</u>	
		Calibration Instruction: <u>VW Pressure Transducers</u>	
		Technician: <u></u>	

Applied Pressure (MPa)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8609	8609	8609	0.001	0.11	0.000	0.00
0.2	7734	7734	7734	0.200	-0.04	0.200	-0.02
0.4	6854	6854	6854	0.399	-0.07	0.400	0.02
0.6	5973	5973	5973	0.599	-0.08	0.600	0.00
0.8	5090	5089	5090	0.800	-0.04	0.800	-0.03
1.0	4201	4202	4202	1.001	0.11	1.000	0.02

(MPa) Linear Gage Factor (G): -0.0002269 (MPa/ digit)
 Regression Zero: 8614

Polynomial Gage Factors: A: -4.131E-10 B: -0.0002216 C:

Calculate C by setting P = 0 and R₁ = initial field zero reading into the polynomial equation

(psi) Linear Gage Factor (G): -0.03288 (psi/ digit)

Polynomial Gage Factors: A: -5.98652E-08 B: -0.03212 C:

Calculate C by setting P = 0 and R₁ = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0)^*$

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


*Barometric pressures are absolute. Barometric compensation is not required with vented and differential pressure transducers.

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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Figure 8 - Typical Calibration Report at 150 °C

		48 Spencer St. Lebanon, N.H. 03766 USA	
Vibrating Wire Pressure Transducer Calibration Report			
Type: <u>HT</u>		Date of Calibration: <u>January 19, 2012</u>	
Serial Number: <u>1140741 / 1133911</u>		Temperature: <u>200.6 °C</u>	
Pressure Range: <u>1 MPa</u>		Barometric Pressure: <u>995.8 mbar</u>	
		Calibration Instruction: <u>VW Pressure Transducers</u>	
		Technician: <u><i>[Signature]</i></u>	

Applied Pressure (MPa)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8669	8669	8669	0.001	0.10	0.000	-0.01
0.2	7798	7798	7798	0.200	-0.01	0.200	0.02
0.4	6926	6927	6927	0.399	-0.10	0.400	0.00
0.6	6049	6050	6050	0.599	-0.08	0.600	0.02
0.8	5172	5172	5172	0.800	-0.04	0.800	-0.01
1.0	4288	4291	4290	1.001	0.12	1.000	0.04

(MPa) Linear Gage Factor (G): -0.0002284 (MPa/ digit)
 Regression Zero: 8674

Polynomial Gage Factors: A: -4.345E-10 B: -0.0002227 C:

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

(psi) Linear Gage Factor (G): -0.03310 (psi/ digit)

Polynomial Gage Factors: A: -6.29669E-08 B: -0.03228 C:

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

Calculated Pressures: Linear, $P = G(R_i - R_0)^*$
 Polynomial, $P = AR_i^2 + BR_i + C^*$


*Barometric pressures are absolute. Barometric compensation is not required with vented and differential pressure transducers.

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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Figure 9 - Typical Calibration Report at 200 °C

 48 Spencer St. Lebanon, N.H. 03766 USA	
Vibrating Wire Pressure Transducer Calibration Report	
Type: <u>HT</u>	Date of Calibration: <u>January 19, 2012</u>
Serial Number: <u>1140741 / 1133911</u>	Temperature: <u>246.7 °C</u>
Pressure Range: <u>1 MPa</u>	Barometric Pressure: <u>998.2 mbar</u>
Calibration Instruction: <u>VW Pressure Transducers</u>	
Technician: <u><i>[Signature]</i></u>	

Applied Pressure (MPa)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8712	8715	8714	0.001	0.08	0.000	0.03
0.2	7848	7850	7849	0.200	-0.01	0.200	0.03
0.4	6983	6985	6984	0.399	-0.08	0.400	0.01
0.6	6114	6116	6115	0.599	-0.06	0.600	0.03
0.8	5244	5245	5245	0.800	-0.01	0.800	0.02
1.0	4372	4373	4373	1.001	0.08	1.000	0.01

(MPa) Linear Gage Factor (G): -0.0002304 (MPa/ digit)
 Regression Zero: 8717

Polynomial Gage Factors: A: -3.259E-10 B: -0.0002261 C:

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

(psi) Linear Gage Factor (G): -0.03338 (psi/ digit)
 Regression Zero: 8717

Polynomial Gage Factors: A: -4.72282E-08 B: -0.03277 C:

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

Calculated Pressures:

Linear, $P = G(R_i - R_0)^*$
Polynomial, $P = AR_i^2 + BR_i + C$ *

*Barometric pressures are absolute. Barometric compensation is not required with vented and differential pressure transducers.

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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Figure 10 - Typical Calibration Report at 250 °C

7. 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 are not user serviceable. **Gauges should not be opened in the field.**

Should difficulties arise, consult the following list of problems and possible solutions. For additional troubleshooting and support contact Geokon.

Symptom: Piezometer reading unstable

- ✓ Make sure the shield drain wire is connected to the blue clip on the flying leads. (Green for the GK-401.)
- ✓ Isolate the readout from the ground by placing it on a piece of wood or other insulator.
- ✓ Check for sources of nearby electrical noise such as motors, generators, antennas, or electrical cables. Move the piezometer cable away from these sources if possible. Contact the factory for information on available filtering and shielding equipment.
- ✓ The Piezometer may have been damaged by overranging or shock. Inspect the housing for damage.
- ✓ The body of the Piezometer may be shorted to the shield. Check the resistance between the shield drain wire and the Piezometer housing. If the resistance is very low the gauge conductors may be shorted.

Symptom: Piezometer fails to give a reading

- ✓ Check the resistance of the cable by connecting an ohmmeter to the sensor leads. If the resistance is very high or infinite the cable is probably broken or cut. If the resistance is very low the gauge conductors may be shorted.
- ✓ Check the readout with another gauge to ensure it is functioning properly.
- ✓ The Piezometer may have been overranged or shocked. Inspect the housing for damage.

APPENDIX A. SPECIFICATIONS

A.1 4500HT Piezometer

Standard Ranges¹	350, 700 kPa ² ; 1, 2, 3, 5, 7.5, 10, 20, 35, 50, 75, 100 MPa ²
Resolution	0.025% F.S. (minimum)
Linearity	< 0.5% F.S. ($\pm 0.1\%$ F.S. optional)
Accuracy³	$\pm 0.1\%$ F.S.
Overrange	1.5 \times Rated Pressure
Temperature Range	0 °C to +250 °C
Thermal Zero Shift	<0.05% F.S./ °C
Diaphragm Displacement	<0.001 cm ³ at F.S.
Dimensions (L \times ϕ)⁴	191 \times 19 mm (350, 700 kPa; 1, 2, 3, 5, 7.5, 10 MPa)
Frequency Range	1400-3500 Hz

Table 2 - HT Vibrating Wire Piezometer Specifications

¹ Piezometers with a range of 350 kPa and higher are capable of reading negative pressures to -100 kPa. Contact GEOKON for more information. Other ranges available on request.

² PSI = kPa \times 0.14503 or MPa \times 145.03

³ Accuracy established under laboratory conditions.

⁴ Please contact Geokon for dimensions of ranges higher than 10 MPa.

⁵ Pressure connections are female $7/16$ -20 UNF medium pressure 60° cone.

A.2 Mineral Insulated Cable

Conductors	4-conductors, 22 AWG, solid copper
Sheath	Stainless Steel
Sheath Wall	0.76 mm
Nominal O.D.	4.76 mm
Coil ID	1 m / 3 ft.

Table 3 - Mineral Insulated Cable Specifications

A.3 Tubular Encapsulated Cable (TEC)

Conductors	4-conductors, 24 AWG, stranded, tinned, copper
Insulation	PFA
Sheath	316L Stainless Steel
Nominal O.D.	4 mm
Sheath Wall	0.76 mm
Coil Diameter	1 m

Table 4 - Tubular Encapsulated Cable Specifications

APPENDIX B. 4500HT 4 MM TO 4 MM CABLE SPLICE

If this splice will be subjected to high temperatures, all permanent pieces and materials utilized in the splice need to be rated for the anticipated temperature.

B.1 Tools and Supplies

High temperature solder
 High temperature heat shrink
 Pipe cutter able to cut 4 mm (0.16") diameter stainless steel
 Torch
 Soldering iron
 Wire cutters/strippers
 Vice grip
 5 mm (13/16") Wrench
 23 mm (7/8") Wrench
 (2 ea.) 12 mm (1/2") Wrenches

B.2 Procedure

- 1) Separate the two parts of the 4 mm to 4 mm splice via the 13 mm (1/2") Swagelok using the 5 mm (13/16") and 23 mm (7/8") wrench.
- 2) Slide one piece over a length of cable to be spliced and the other piece over the other length of cable. Make sure the orientation and order of the ferrules in the 4 mm and 13 mm (1/2") Swageloks is correct.
- 3) Use the pipe cutter to score the tubing approximately 25 mm (1") from the ends of each cable. Do NOT cut through the stainless steel casing.
- 4) Use the vice grips to work that 25 mm (1") piece back and forth until it breaks from the main cable line. Discard this piece and ensure there are no nicks in the sheathing of the internal signal wires.
- 5) Strip the jacket off each of the four signal wires approximately 3 mm to 6 mm (0.12" to 0.24") on both cables to be spliced.
- 6) Pre-tin the exposed ends with the high temp solder. For Geokon solder a temperature of approximately 415 °C is recommended. NOTE: High temperature solder contains lead (Pb).
- 7) Slide a 12 mm (0.5") length piece of heat shrink on each of the four signal wires on only one of the cables.
- 8) Overlap the pre-tinned parts of the corresponding signal wires from each cable and apply enough heat to melt the solder and adhere the wires together.
- 9) Position the high temperature heat shrink so that it is centered on each of the solder joints and, using a torch, shrink the heat shrink until it is securely bonded with the signal wires.

- 10) Check continuity from each end of a signal wire, or to a transducer, and ensure there are no shorts to each other, or to the stainless steel cable housing.
- 11) Slide the 13 mm (0.5") diameter tube section of the splice so that it is centered on the solder joint.
- 12) Using the two 12 mm (0.5") wrenches, tighten the 4 mm (0.16") Swagelok onto this piece until it is approximately 270 degrees past finger tight. (See Appendix C for Swagelok instructions.)
- 13) Slide the other piece of the splice (the one that has the 13 mm (1/2") Swagelok), until it comes to a positive stop on the 13 mm (1/2") tube.
- 14) Using the 5 mm and 23 mm (13/16" and 7/8") wrenches, tighten the 13 mm (1/2") Swagelok 450 degrees past finger tight.
- 15) Using the two 12 mm (0.5") wrenches, tighten the remaining 4 mm (0.16") Swagelok until it is approximately 270 degrees past finger tight.
- 16) Perform a continuity and short check to verify a successful splice was made.

APPENDIX C. SWAGELOK TUBE FITTING INSTRUCTIONS

These instructions apply to one inch (25 mm) and smaller fittings.

C.1 Installation

- 1) Fully insert the tube into the fitting until it bumps against the shoulder.

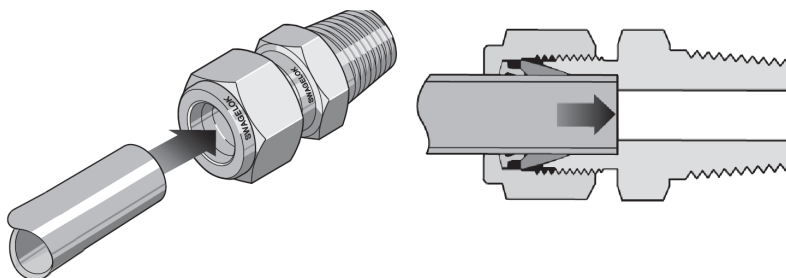


Figure 11 - Tube Insertion

- 2) Rotate the nut until it is finger-tight. (For high-pressure applications as well as high-safety-factor systems, further tighten the nut until the tube will not turn by hand or move axially in the fitting.)
- 3) Mark the nut at the six o'clock position.

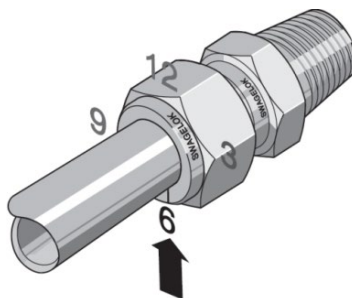


Figure 12 - Make a Mark at Six O'clock

- 4) While holding the fitting body steady, tighten the nut one and one quarter turns, until the mark is at the nine o'clock position. (Note: For 1/16", 1/8", 3/16", and 2, 3, and 4 mm fittings, tighten the nut three-quarters of a turn until the mark is at the three o'clock position.)

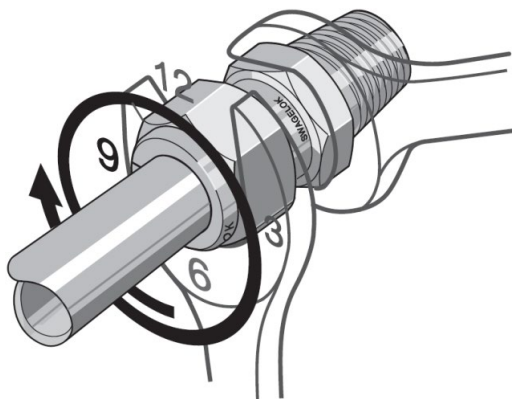


Figure 13 - Tighten One and One-Quarter Turns

C.2 Reassembly Instructions

Swagelok tube fittings may be disassembled and reassembled many times.

Warning! Always depressurize the system before disassembling a Swagelok tube fitting.

- 1) Prior to disassembly, mark the tube at the back of the nut, then make a line along the nut and fitting body flats. *These marks will be used during reassembly to ensure the nut is returned to its current position.*

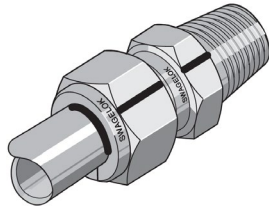


Figure 14 - Marks for Reassembly

- 2) Disassemble the fitting.
- 3) Inspect the ferrules for damage and replace if necessary. **If the ferrules are replaced the connector should be treated as a new assembly. Refer to the section above for installation instructions.**
- 4) Reassemble the fitting by inserting the tube with preswaged ferrules into the fitting until the front ferrule seats against the fitting body.

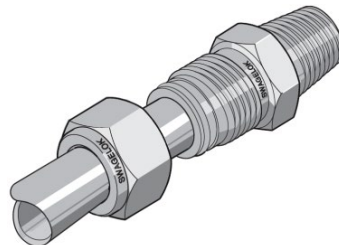


Figure 15 - Ferrules Seated Against Fitting Body

- 5) While holding the fitting body steady, rotate the nut with a wrench to the previous position as indicated by the marks on the tube and the connector. At this point, there will be a significant increase in resistance.
- 6) Tighten the nut slightly.

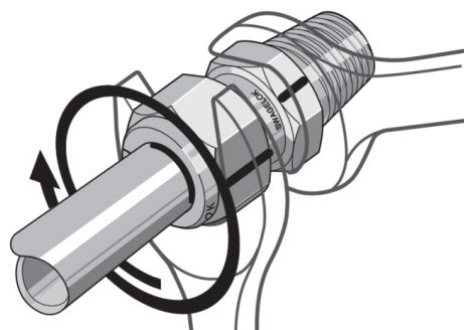


Figure 16 - Tighten Nut Slightly