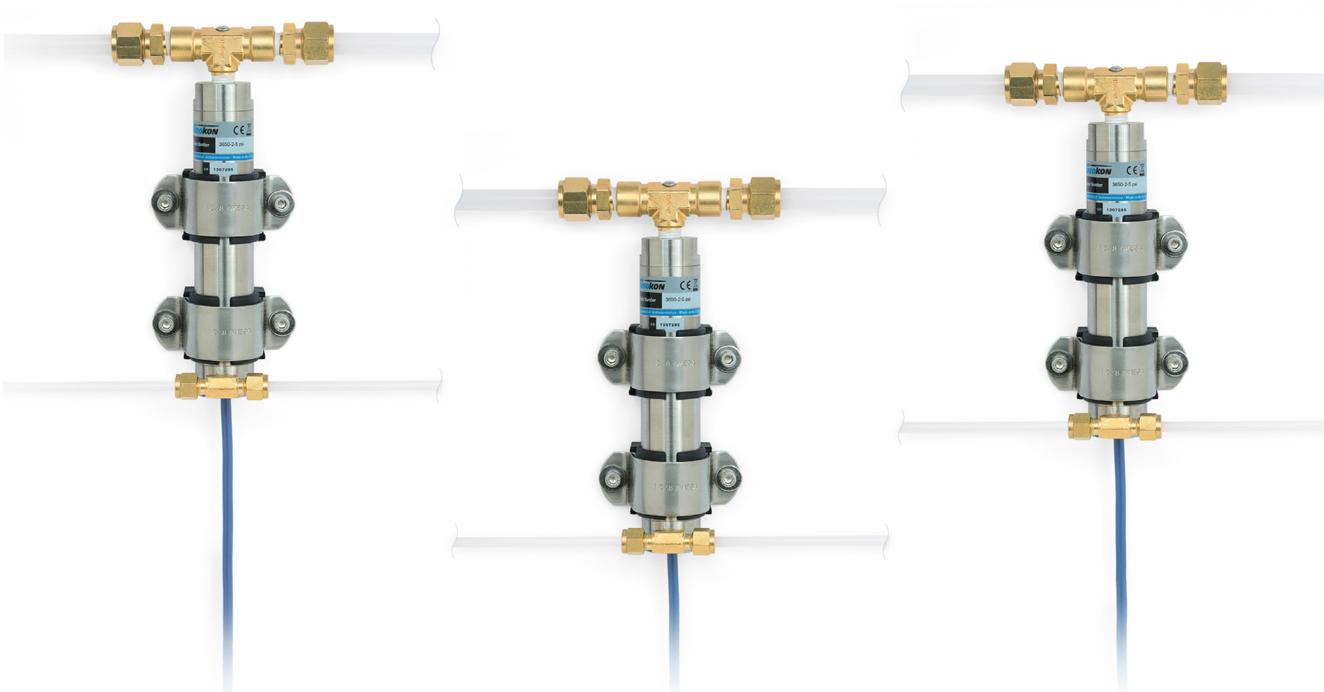
Model 4655 Series

Multipoint Settlement System

Instruction Manual



GEOKON®

Document Revision: I.2 | Release date: 11/21/24

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 that wear or are damaged by misuse are not warranted. This includes fuses and batteries.

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1. THEORY OF OPERATION

GEOKON Model 4655 Vibrating Wire Settlement Systems are multipoint settlement systems, comprising a series of sensitive vibrating wire pressure transducers connected by a nylon, liquid-filled tube, which in turn, is connected to a liquid reservoir. The reservoir has a large liquid capacity as compared to the volume required to fill the system, which helps to minimize the effects caused by small changes in tubing volume over varying temperatures.

In use, any change in elevation of a sensor will result in a change in the height of the liquid column between reservoir and sensor and in the pressure measured by that sensor. Since all the sensors share the same liquid line and are referenced to the same liquid elevation in the reservoir, changes in the sensor elevations, relative to one another, can be measured.

2. INSTALLATION

2.1 PROVIDED ACCESSORIES

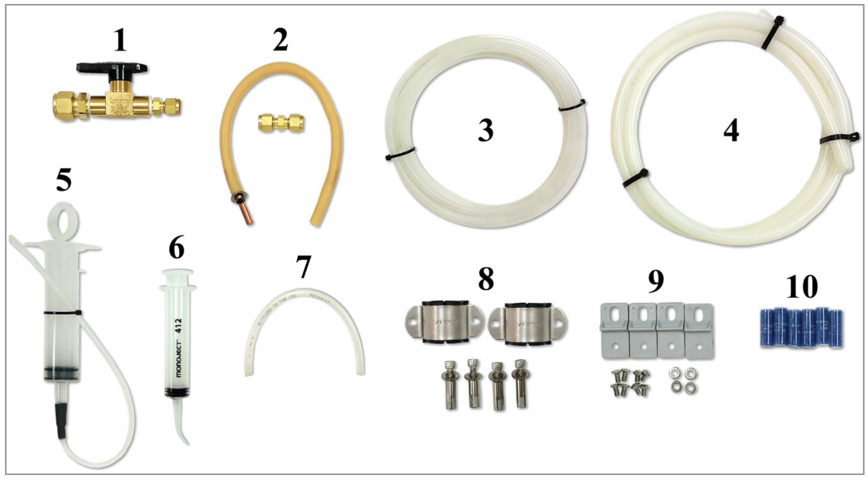

FIGURE 1: *Model 4655 Accessories*

The items shown in the figure above are as follows:

1. Bi-directional valve
2. Rubber tubing and union for vacuum pump attachment
3. ¼" polyethylene, vent line tubing
4. ½" nylon, liquid line tubing
5. Syringe for making small adjusting in the level of fluid in the reservoir through the Swagelok in the cap
6. Syringe for extracting air or liquid from the sensor through the seal screw hole
7. Jumper line for connecting the settlement system liquid reservoir to the desiccant chamber
8. Sensor mounting brackets and suppled hardware
9. Reservoir enclosure mounting feet and supplied hardware
10. Spare desiccant packs

2.2 INSTALLING THE RESERVOIR AND SENSORS

The first step is to determine the elevation of all the sensors and the reservoir. Remember that the reservoir should be above every sensor and that the difference in elevation between the reservoir and any sensor should be within the full-scale range of the pressure transducers. The reservoir should be attached to a stable structure or one that can be easily level surveyed.

The sensors are installed by attaching the supplied brackets to the concrete or other surface using either the supplied drop-in style anchor, or bolts/studs that are welded to or screwed into the steel or other material as shown in Figure 2.

MOUNTING SENSORS TO CEMENT WITH THE PROVIDED DROP-IN ANCHORS

1. Use a leveling device to align the first mounting bracket vertically on the wall. Mark the locations where the two anchors will be installed.

2. Using a masonry drill (or other suitable equipment), drill two 12 mm (½") holes approximately 37 mm (1.5") deep. Clean the holes thoroughly, blowing out with compressed air if possible.
3. Insert the expansion anchors into the holes. (The threaded end should be closest to the opening.)
4. Insert the provided setting tool, small end first, into an anchor. Expand the anchor by hitting the large end of the setting tool with several sharp hammer blows. Repeat for the second anchor.
5. Repeat steps one through four for the second mounting bracket.
6. Attach the sensor to the wall using the mounting brackets and supplied hardware, as illustrated in the figure below.

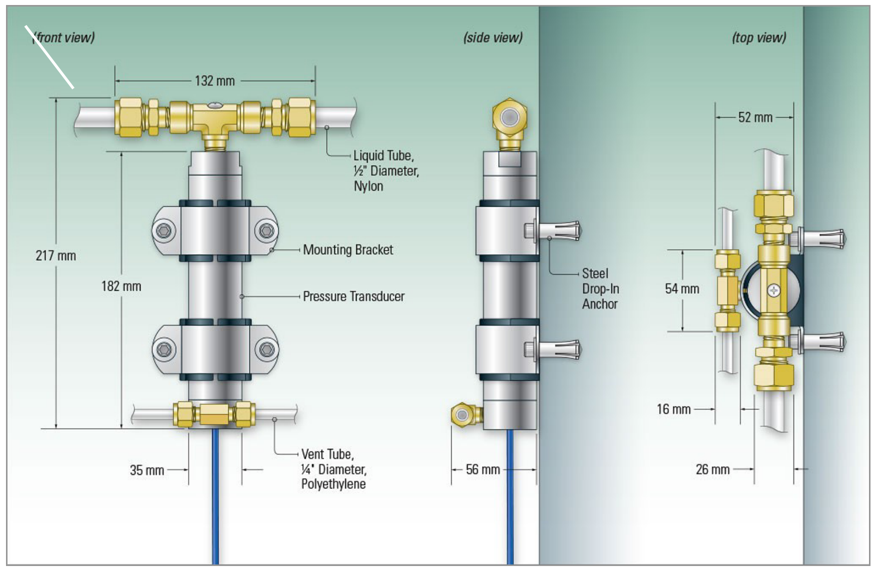

FIGURE 2: *Model 4655 Mounting Details*

2.3 INSTALLING THE TUBING

The tubing should be installed after the sensors and reservoir have been fixed in position.

Note: Fluctuating temperatures can change the specific gravity of the fluid, which can be difficult to correct. To avoid this problem, be sure to shield the tubing from direct sunlight.

Tee connectors are supplied for both the liquid and air lines; the reservoirs are delivered with both tubing connectors and caps, depending on whether the system is a series system, a "branch" system, or a combination of the two.

2.3.1 LIQUID LINE

Only nylon tubing should be used for the liquid line because it is the best material for keeping air out of the system thereby preventing the formation of bubbles in the liquid lines (which would adversely affect the readings). The liquid tubing runs should be as straight as possible, ideally within an elevation of ±9.5 mm (0.375"), without rises and dips. (Some minor dips in the line are allowable if using a vacuum to fill.) Siphons must be avoided at all cost. The minimum recommended bend radius for the liquid tubing is 31.8 mm (1.25").

2.3.2 VENT LINE

The routing of the vent line is much less critical than the routing of the liquid line. It may be run along any path, so long as it is installed below the liquid line. See Figure 3.) One end of the vent line is capped off at the tee fitting of the most remote sensor, while the other end terminates at a desiccant chamber located next to the reservoir.

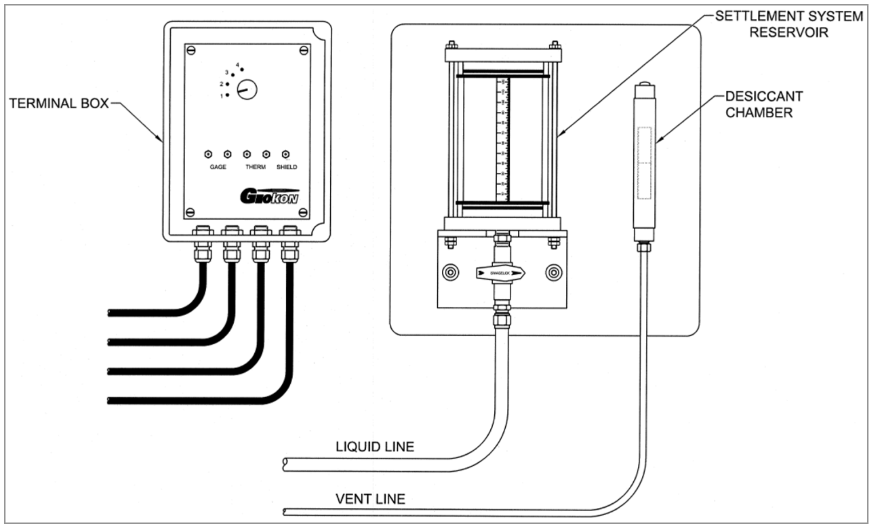

FIGURE 3: *Model 4655-1 Reservoir, Desiccant Chamber, and Terminal Box*

2.3.3 JUMPER LINE

Use the provided jumper line to connect the settlement system liquid reservoir to the desiccant chamber. Depending on site conditions, adding or removing the jumper may help to stabilize the sensor readings.

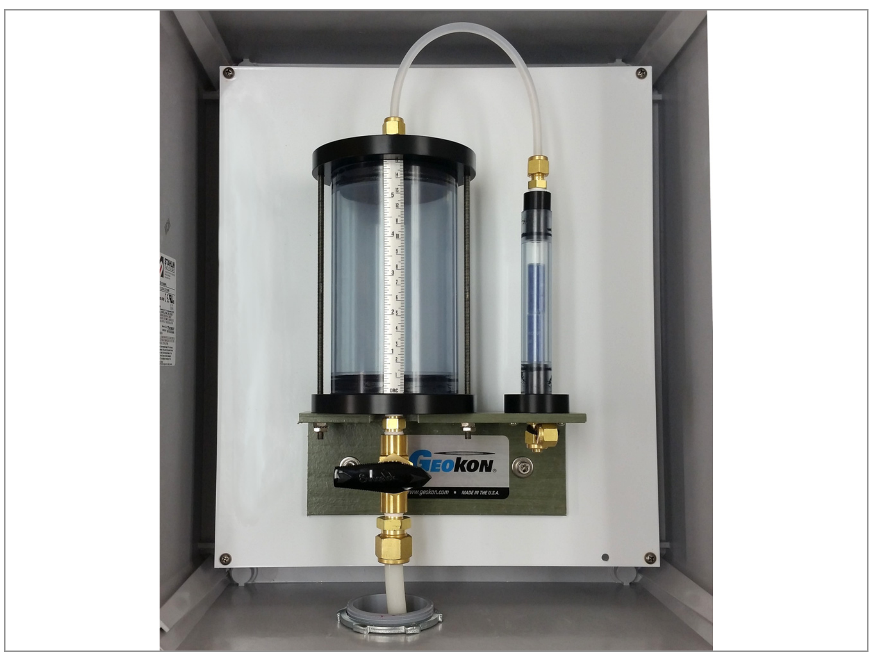

FIGURE 4: *Liquid Reservoir and Desiccant Chamber connected with Jumper*

3. FILLING THE SYSTEM

Eliminating air from the system is very important. The use of de-aired fluid is required, and this can be purchased from GEOKON. The liquid used in the system must be one of a known specific gravity to convert the sensor gauge factor, which is presented in kPa/mA to mm/mA. The conversion from kPa to mm of distilled water is: 1 kPa = 102.2 mm of water. If a mixture of distilled water and antifreeze, such as ethylene glycol, or propylene glycol, is used, the specific gravity of the fluid must be measured, and the gauge factor adjusted accordingly by dividing the 102.2 number by the specific gravity. If only distilled water or propylene glycol is used, a very small amount of ethylene glycol antifreeze, (5% by volume), or a couple of crystals of copper sulfate must be added to prevent the growth of algae. The liquid supplied by GEOKON is a 50/50 mix of propylene glycol and water with an algae suppressant added. The liquid has been de-aired, so keep the container capped up to the time that the liquid is poured into the reservoir. Avoid bubble formation when pouring.

Filling the system is the most difficult job due to the problems associated with entrapped air bubbles and the need to remove them. Two people will be needed for this process: one to tend to the reservoir and vacuum pump, and one to monitor the fluid as it enters the system.

An electric vacuum pump is essential if bubbles are to be avoided. (Vacuum pumps may be purchased from GEOKON.) Without a vacuum pump bubbles will form in the tubing and will need to be 'chased' out. If an electric vacuum pump is infeasible, then use a hand-operated Mytivac vacuum pump. (Available as an accessory or can be obtained from an automotive store.)

The systems can be filled from the reservoir or from the far end of the tubing, as described in the following sections.

3.1 FILLING FROM THE RESERVOIR

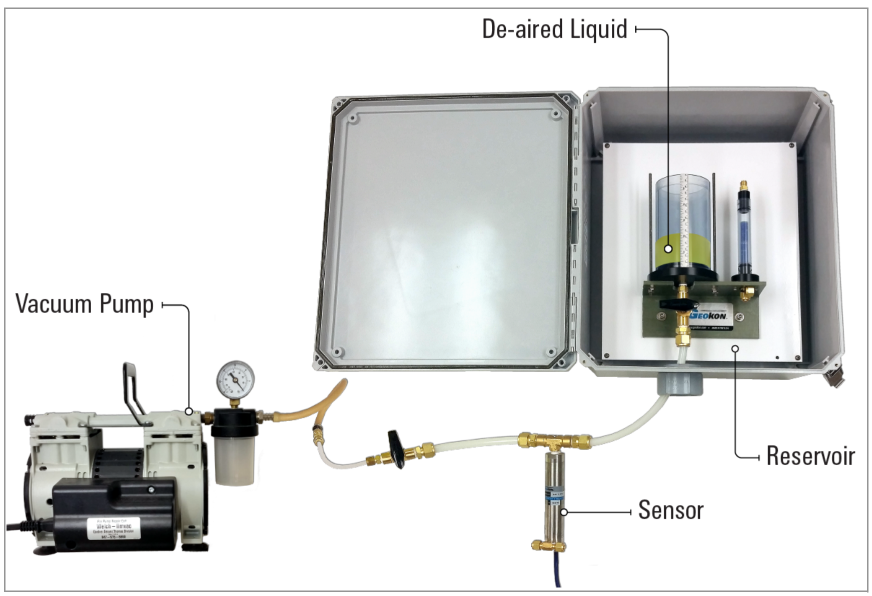

FIGURE 5: *Filling from the Reservoir*

First, attach a length of ½" tubing (three feet has been provided) to the last sensor in the string furthest from the reservoir. To that piece of tubing, swage on the provided bidirectional valve. (See Appendix C for Swagelok instructions.) Next, a length of 6.4 mm (¼") tubing, long enough to reach the vacuum pump, can be cut from the 3-meter (10') piece provided and attached to the opposing side of the valve. A piece of rubber tube and a union have been included which may aid in the connection of the pump.

Close the valve on the bottom of the reservoir then fill the reservoir with de-aired liquid. Open the valve nearest to the vacuum pump and turn the pump on to start evacuating the system.

A general recommendation for the vacuum pressure level is below 10 Mbar when filling the settlement systems, but this may not be possible depending on how large the system is, and the strength of the pump that is being used. The lower pressure the better, to build confidence that there aren't any leaks in the connectors.

When the vacuum has been established, fill the reservoir with de-aired liquid and then open the valve at the base of the reservoir and allow the de-aired liquid to flow and fill the lines up to each sensor. Be sure to add de-aired liquid to the reservoir as it is draining into the system to prevent air from contaminating the tubing. Avoid forming bubbles when pouring. Monitor the liquid as it nears the vacuum pump and close the valve closest to it before the liquid is drawn in. Turn off the pump.

Caution: The pump can be damaged if the liquid is allowed to enter the pump.

If air becomes trapped inside any sensor, you must be bleed it off by removing the seal screw on the top of the tee fitting from each sensor in turn (Figure 6) and by extracting air or liquid from the sensor through the seal screw hole using the syringe supplied (Figure 7). When all the air has been removed from all sensors, replace the seal screws. If a bubble is observed in the liquid line, 'chase' the bubble back to the reservoir, or to one of the sensor fittings, where it can be allowed to escape by slightly opening the connector at this point and/or opening the seal screw on the tee. Adjust the level of fluid in the reservoir with the supplied syringe to approximately midway.

FIGURE 6: *Seal Screw Removal*

FIGURE 7: *Using Syringe for Air/Liquid Extraction*

3.2 FILLING FROM THE FAR END OF THE TUBING

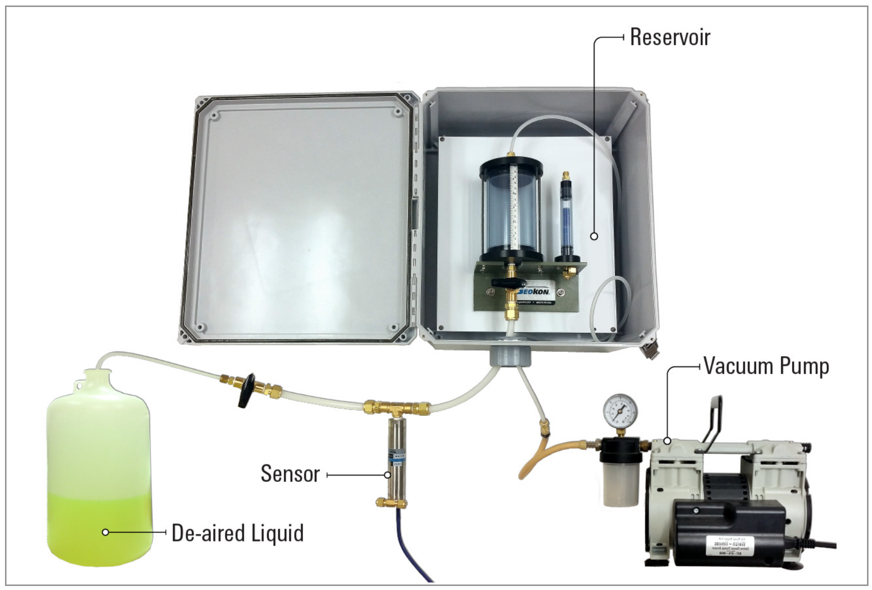

FIGURE 8: *Filling from the Far End*

First, attach a length of ½" tubing (three feet has been provided) to the last sensor in the string. To that piece of tubing, swage on the bidirectional valve provided. (See Appendix C for Swagelok instructions.) Next, cut a length of 6.4 mm (¼") tubing, long enough to reach the vessel containing the settlement fluid, from the 3-meter (10') piece provided and attached to the opposing side of the valve. Insert the free end of the tube into the fluid and close the valve.

At the reservoir end, swage to the top of the reservoir a length of the 6.4 mm (¼") tubing, long enough to reach the vacuum pump. Attach the free end to the vacuum pump and apply a vacuum to the system with the reservoir valve open. A piece of rubber tube and a union have been included which may aid in the connection of the pump. A general recommendation for the vacuum pressure level is below 10 Mbar when filling the settlement systems, but this may not be possible depending on how large the system is, and the strength of the pump being used. The lower pressure the better, to build confidence that there aren't any leaks in the connectors.

When a vacuum has been established, open the valve on the far end of the system to allow de-aired fluid to flow through. To prevent bubbles in the system, combine all the fluid into one large container or leave the fill line in one vessel and continue to add fluid into it, making sure the liquid level never falls below the end of the fill tube where air could then be introduced into the system. Once fluid has filled the entire system and has entered the reservoir, disconnect the vacuum pump and close the valve on the far end. Remove the 6.4 mm (¼") vacuum pump extension tube from the reservoir.

If air becomes trapped inside any sensor, you must be bleed it off by removing the seal screw on the top of the tee fitting from each sensor in turn (Figure 6 above) and by extracting air or liquid from the sensor through the seal screw hole using the syringe supplied (Figure 7 above). When all the air has been removed from all sensors, replace the seal screws. If a bubble is observed in the liquid line, 'chase' the bubble back to the reservoir, or to one of the sensor fittings, where it can be allowed to escape by slightly opening the connector at this point and/or opening the seal screw on the tee. Adjust the level of fluid in the reservoir with the supplied syringe to approximately midway.

4. ROUTING THE CABLES

Cables from each sensor can be routed to the readout location where they can be connected to a terminal box (as shown in Figure 3) for manual readout, or to datalogger as shown in the figure below.

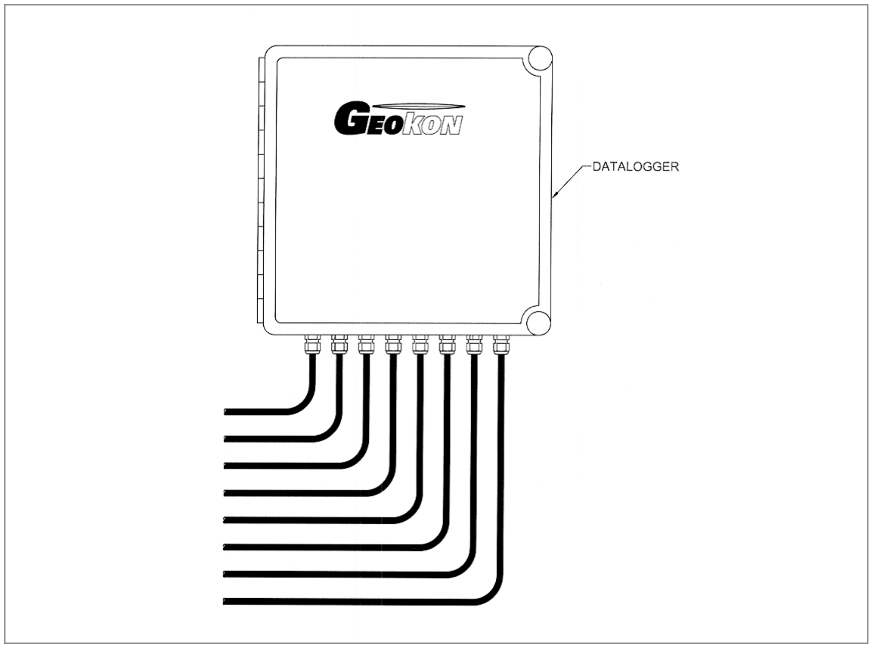

FIGURE 9: *Datalogger*

5. TAKING READINGS

After the system is installed and filled, the sensor system zero reading, R_0, should be taken. It is good practice to take several zero readings over the period of a day to get an idea how much the readings will fluctuate during the normal course of a day when no actual work is taking place at the site. (This data can be useful in computing a correction factor for temperature variations). Subsequent readings, R_1, on the system will yield the change in elevation of the sensors along the string relative to the elevation of the reservoir and to each other.

5.1 GK-404 VIBRATING WIRE READOUT

The Model GK-404 VW Readout is a portable, low-power, hand-held 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 instruments, and is capable of displaying the reading in 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.

FIGURE 10: *GK-404 Readout*

5.1.1 OPERATING THE GK-404

FIGURE 11: *Lemo Connector to GK-404*

1. Attach the flying leads by aligning the red circle on the silver Lemo connector with the red line on the top of the GK-404 (see Figure 11). Insert the Lemo connector into the GK-404 until it locks into place.
2. Connect each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).
3. To turn on the GK-404, press the **On**/**Off** button on the front panel of the unit. The initial startup screen will display.
4. After a delay, 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 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 instrument in degrees Celsius.

Use the **Pos** and **Mode** buttons to select the correct position and display units for the model of equipment purchased.

The GK-404 will continue to take measurements and display readings until the unit is turned off, either manually or by the Auto-Off timer (if enabled).

For more information, consult the GK-404 manual.

5.2 GK-405 VIBRATING WIRE READOUT

The GK-405 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.
- The GK-405 Remote Module, which is housed in a weather-proof enclosure.

***FIGURE 12:** GK-405 Readout*

The remote module can be wire-connected to the sensor by means of:

- Flying leads with alligator clips, if the sensor cable terminates in bare wires.
- A 10 pin connector.

The two units communicate wirelessly using Bluetooth®, a reliable digital communications protocol. Using Bluetooth, the unit can operate from the cradle of the remote module, or, if more convenient, can be removed and operated up to 20 meters away from the remote module.

The GK-405 displays the thermistor temperature in degrees Celsius.

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

5.2.1 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.

5.2.2 CONNECTING SENSORS WITH BARE LEADS

Attach the 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).

5.2.3 OPERATING THE GK-405

Press the power button on the Readout Unit. After start-up completes, a blue light will begin flashing, signifying that the two components are ready to connect wirelessly. Launch the GK-405 VWRA program by doing the following:

1. Tap Start on the hand-held PC's main window.
2. Select Programs.
3. Tap the GK-405 VWRA icon.

After a few seconds, the blue light should stop flashing and remain lit. The Live Readings window will display on the hand-held PC.

Set the Display mode to . For more information, consult the GK-405 Instruction Manual.

5.3 MEASURING TEMPERATURES

All GEOKON vibrating wire instruments are equipped with a thermistor for reading temperature. The thermistor 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-404 and GK-405 readouts will read the thermistor and display the temperature in degrees Celsius.

TO READ TEMPERATURES USING AN OHMMETER:

1. Connect an ohmmeter to the green and white thermistor leads coming from the instrument. 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 approximately 48.5Ω per km (14.7Ω per 1000') at 20 °C. Multiply these factors by two to account for both directions.
2. Look up the temperature for the measured resistance in Appendix B.

6. DATA REDUCTION

6.1 CALCULATION OF SENSOR ELEVATION

Readings can be used to calculate the elevation of the sensor and to plot them on a graph versus time. The graph should also show the elevation of the fill above the sensor at the time of each reading. A plot of temperature can also be included. For the standard 4655 settlement system, using type 4500SV or 4500ALV transducers, the readings will get smaller as the sensors settle relative to the reservoir.

For these sensors, the elevation (E) of the sensor is given by:

$$E = E_0 - (R_1 - R_0)\,G + \Delta E_{RES}$$

EQUATION 1: *Elevation*

Where:
ΔE_{RES} is any change of the fluid level inside the reservoir sight glass. If the level of the fluid falls, ΔE_{RES} is negative. If the level of the fluid rises, ΔE_{RES} is positive.
E_0 is the sensor elevation at installation
R_0 is the initial sensor reading
R_1 is the subsequent sensor reading
G is the calibration factor supplied with the sensor

A typical calibration sheet as, supplied by the factory, is shown in Figure 13.

As an example:

E_0 = 541.62 meters
R_0 = 9030
R_1 = 8800
G = –0.001697 meters/digit
ΔE_{RES} = –10 mm (i.e. the level of water in the reservoir sight tube is 10 mm lower than the level measure at the time of the initial reading).

Therefore, the new sensor elevation is:

$$E = 541.62 - (8800 - 9030) \times (-0.001697) + (-0.010)$$
$$E = 541.22 \text{ meters}$$

In other words, there has been a settlement of 0.40 meters.

Note: The calibration sheet shown in Figure 13 was developed using a simple manometer and is good only over a range of three meters height differential between reservoir and sensor. If this range is exceeded by the initial setup or by large amounts of settlement, then there are two options:

1. Continue to use the settlement system calibration sheet shown in Figure 13.
2. Use the Pressure Transducer calibration sheet supplied with the equipment (Figure 14), which was developed by calibrating the pressure sensor itself over a wider range.

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

Settlement System Calibration Report

Model Number: 4655-70 kPa

Serial Number: 1400836

Transducer Range: 70 kPa

Cable: 3 m

Tubing: 5 m

Calibration Date: April 2, 2014

Temperature: 21.7 °C

Calibration Instruction: CI-4600-4650

Technician:

*tubing filled and gage calibrated with 50 / 50 mix water/anti-freeze, specific gravity 1.041

Height of Water Column m	Reading GK 401 Pos. B	Difference
0.5	9419.0	
1.0	9126.0	293.0
1.5	8832.0	294.0
2.0	8537.0	295.0
2.5	8242.0	295.0
3.0	7946.0	296.0

Calibration Factor G: -0.001697 m / digit

Calibration Factor G: -0.00557 ft. / digit

Thermal Factor K: 0.00384 m / °C

Thermal Factor K: 0.01261 ft. / °C

DO NOT EXCEED 7 m (23 feet) BETWEEN RESERVOIR & TRANSDUCER

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 13: *Typical Calibration Report*

GEOKON 48 Spencer St. Lebanon, NH 03766 USA

Vibrating Wire Pressure Transducer Calibration Report

Model Number: 4655-170 kPa

Date of Calibration: December 10, 2014

This calibration has been verified/validated as of 12/15/2017

Serial Number: 1435465

Temperature: 21.90 °C

Calibration Instruction: VW Pressure Transducers

Barometric Pressure: 980.7 mbar

Cable Length: 3 meters

Technician: Kathy Rogers

Applied Pressure (kPa)	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	10087	10088	10088	0.383	0.23	-0.004	0.00
34.0	9344	9345	9345	33.90	-0.05	34.00	0.01
68.0	8597	8597	8597	67.62	-0.21	67.97	0.00
102.0	7844	7844	7844	101.6	-0.22	101.9	-0.01
136.0	7083	7084	7084	135.9	-0.04	136.0	0.03
170.0	6319	6319	6319	170.4	0.24	170.0	0.01

(kPa) Linear Gage Factor (G): -0.04511 (kPa/ digit)

Polynomial Gage factors: A: -2.162E-07 B: -0.04157 C: 441.29

Thermal Factor (K): -0.03292 (kPa/ °C)

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

(psi) Linear Gage Factor (G): -0.006543 (psi/ digit)

Polynomial Gage Factors: A: -3.135E-08 B: -0.006029 C: 64.004

Thermal Factor (K): -0.004775 (psi/ °C)

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

Calculated Pressures:

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

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

*Barometric pressures expressed in kPa or psi. Barometric compensation is not required with vented transducers.

Factory Zero Reading: 10089 Temperature: 21.5 °C Barometer: 1005.8 mbar

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 14: *Typical Pressure Transducer Calibration Sheet*

6.2 CORRECTION FOR SETTLEMENT OR HEAVE OF THE RESERVOIR TERMINAL

Periodic level surveys should be made of the elevation of the fixture on which the reservoir terminal is located. Any measured settlement of the reservoir should be subtracted from the calculated sensor elevations.

6.3 CORRECTIONS FOR TEMPERATURE

Temperature effects on liquid volume (liquid density) and on the expansion and contraction of the liquid confines can be quite complex and, in some ways, self-canceling. Liquid lines in fills are generally well insulated; therefore, temperature effects tend to be insignificant. Systems exposed to the atmosphere and to sunlight can suffer from rapidly changing temperatures at different parts of the system causing significant fluctuation of the readings. In such cases, precautions may be necessary to obtain readings at times of maximum temperature stability.

Temperature effects on the sensor can be corrected for but are usually quite insignificant especially if the sensor is buried.

The temperature correction to the elevation (ET) is given by:

$$E = E_0 - [(R_1 - R_0) G + (T_1 - T_0) K] + \Delta E_{RES}$$

EQUATION 2: *Temperature Correction*

Where:
T_0 is the initial temperature.
T_1 is the current temperature in °C
K is the temperature correction factor in meters/°C.

A thermal factor for the sensor alone is given on the calibration sheet. A thermal factor for the entire system could be determined empirically by measuring the temperature as well as the sensor outputs at times when no settlement is taking place and then calculating the K factor from the slope of the line of a plot of temperature v readout digits x gauge factor.

APPENDIX A. SPECIFICATIONS

A.1 4655 SPECIFICATIONS

Range	70 kPa (7.14 m) H_2O
Resolution	0.025% F.S.
Accuracy[1]	±0.1% F.S
Temperature Range[2]	−20 °C to +80 °C
Liquid Tubing	12.7 mm (½") Nylon
Vent Tubing	6.4 (¼") Polyethylene
Input	Swept frequency square wave
Output	Hz
Cable	02-250V6: Two twisted pairs, blue PVC jacket, 6.35 mm diameter

TABLE 1: *4655 Specifications*

Notes:

[1] Accuracy established under laboratory conditions

[2] Other ranges available upon request.

A.2 PRESSURE TRANSDUCER SPECIFICATIONS

Model	**4500S**	**4500AL**
Thermal Coefficient	<0.025% FS/°C	<0.1% FS/°C
OD	19.05 mm (0.75")	25.40 mm (1")
Length	133 mm (5.25")	133 mm (5.25")
Resolution	0.025% FS	
Linearity[1]	< 0.5% FS.	
Accuracy[2]	0.1% FS	
Overrange	1.5 × Rated Pressure	
Frequency Range	1400-3500 Hz	

TABLE 2: *Pressure Transducer Specifications*

Notes:

[1] 0.1% FS linearity available upon request

[2] Derived using second order polynomial

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

B.1 3KΩ THERMISTOR RESISTANCE

Thermistor Types:

- YSI 44005, Dale #1C3001–B3, Alpha #13A3001–B3
- Honeywell 192–302LET–A01

Resistance to Temperature Equation:

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

EQUATION 3: *3kΩ Thermistor Resistance*

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

TABLE 3: *3KΩ Thermistor Resistance*

B.2 10KΩ THERMISTOR RESISTANCE

Thermistor Type: US Sensor 103JL1A

Resistance to Temperature Equation:

$$T = \frac{1}{A+B(LnR)+C(LnR)^3+D(LnR)^5} - 273.15$$

EQUATION 4: *10KΩ Thermistor Resistance*

Where:

T = Temperature in °C

LnR = Natural Log of Thermistor Resistance

$A = 1.127670 \times 10^{-3}$

$B = 2.344442 \times 10^{-4}$

$C = 8.476921 \times 10^{-8}$

$D = 1.175122 \times 10^{-11}$

Note: Coefficients optimized for a curve **J** Thermistor over the temperature range of 0 °C to +250 °C.

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
32,650	0	7,402	32	2,157	64	763.5	96	316.6	128	148.4	160	76.5	192	42.8	224
31,029	1	7,098	33	2,083	65	741.2	97	308.7	129	145.1	161	75.0	193	42.1	225
29,498	2	6,808	34	2,011	66	719.6	98	301.0	130	142.0	162	73.6	194	41.4	226
28,052	3	6,531	35	1,942	67	698.7	99	293.5	131	138.9	163	72.2	195	40.7	227
26,685	4	6,267	36	1,876	68	678.6	100	286.3	132	135.9	164	70.8	196	40.0	228
25,392	5	6,015	37	1,813	69	659.1	101	279.2	133	133.0	165	69.5	197	39.3	229
24,170	6	5,775	38	1,752	70	640.3	102	272.4	134	130.1	166	68.2	198	38.7	230
23,013	7	5,545	39	1,693	71	622.2	103	265.8	135	127.3	167	66.9	199	38.0	231
21,918	8	5,326	40	1,637	72	604.6	104	259.3	136	124.6	168	65.7	200	37.4	232
20,882	9	5,117	41	1,582	73	587.6	105	253.1	137	122.0	169	64.4	201	36.8	233
19,901	10	4,917	42	1,530	74	571.2	106	247.0	138	119.4	170	63.3	202	36.2	234
18,971	11	4,725	43	1,480	75	555.3	107	241.1	139	116.9	171	62.1	203	35.6	235
18,090	12	4,543	44	1,432	76	539.9	108	235.3	140	114.5	172	61.0	204	35.1	236
17,255	13	4,368	45	1,385	77	525.0	109	229.7	141	112.1	173	59.9	205	34.5	237
16,463	14	4,201	46	1,340	78	510.6	110	224.3	142	109.8	174	58.8	206	33.9	238
15,712	15	4,041	47	1,297	79	496.7	111	219.0	143	107.5	175	57.7	207	33.4	239
14,999	16	3,888	48	1,255	80	483.2	112	213.9	144	105.3	176	56.7	208	32.9	240
14,323	17	3,742	49	1,215	81	470.1	113	208.9	145	103.2	177	55.7	209	32.3	241
13,681	18	3,602	50	1,177	82	457.5	114	204.1	146	101.1	178	54.7	210	31.8	242
13,072	19	3,468	51	1,140	83	445.3	115	199.4	147	99.0	179	53.7	211	31.3	243
12,493	20	3,340	52	1,104	84	433.4	116	194.8	148	97.0	180	52.7	212	30.8	244
11,942	21	3,217	53	1,070	85	421.9	117	190.3	149	95.1	181	51.8	213	30.4	245
11,419	22	3,099	54	1,037	86	410.8	118	186.1	150	93.2	182	50.9	214	29.9	246
10,922	23	2,986	55	1,005	87	400.0	119	181.9	151	91.3	183	50.0	215	29.4	247
10,450	24	2,878	56	973.8	88	389.6	120	177.7	152	89.5	184	49.1	216	29.0	248
10,000	**25**	2,774	57	944.1	89	379.4	121	173.7	153	87.7	185	48.3	217	28.5	249
9,572	26	2,675	58	915.5	90	369.6	122	169.8	154	86.0	186	47.4	218	28.1	250
9,165	27	2,579	59	887.8	91	360.1	123	166.0	155	84.3	187	46.6	219		
8,777	28	2,488	60	861.2	92	350.9	124	162.3	156	82.7	188	45.8	220		
8,408	29	2,400	61	835.4	93	341.9	125	158.6	157	81.1	189	45.0	221		
8,057	30	2,316	62	810.6	94	333.2	126	155.1	158	79.5	190	44.3	222		
7,722	31	2,235	63	786.6	95	324.8	127	151.7	159	78.0	191	43.5	223		

TABLE 4: *10KΩ Thermistor Resistance*

APPENDIX C. SWAGELOK TUBE FITTING

These instructions apply to 25 mm (1") and smaller fittings.

C.1 INSTALLATION

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

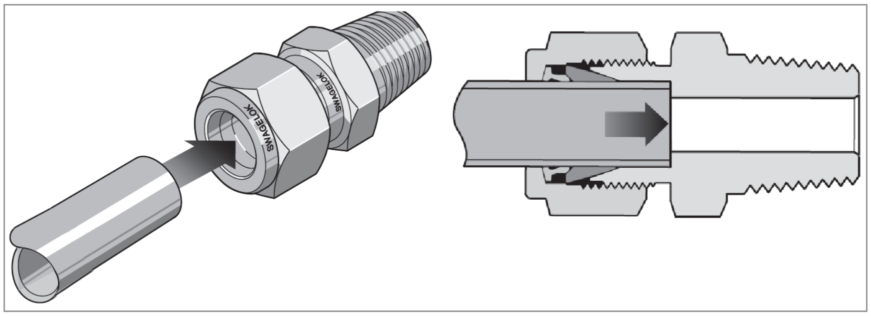

FIGURE 15: *Tube Insertion*

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.

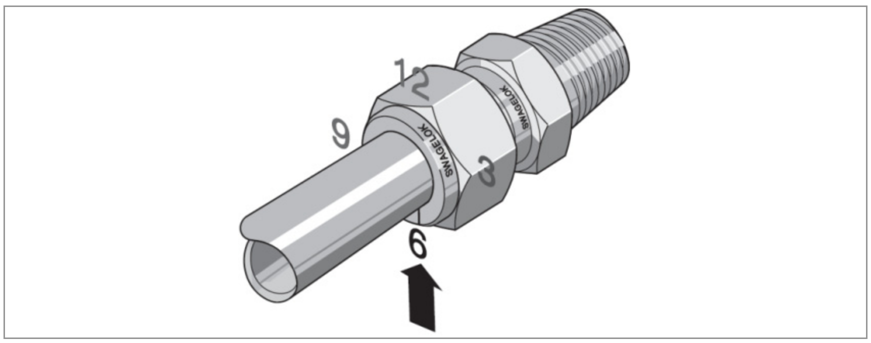

FIGURE 16: *Make a Mark at Six O'Clock*

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 $^{1}/_{16}$", ⅛", $^{3}/_{16}$", 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.

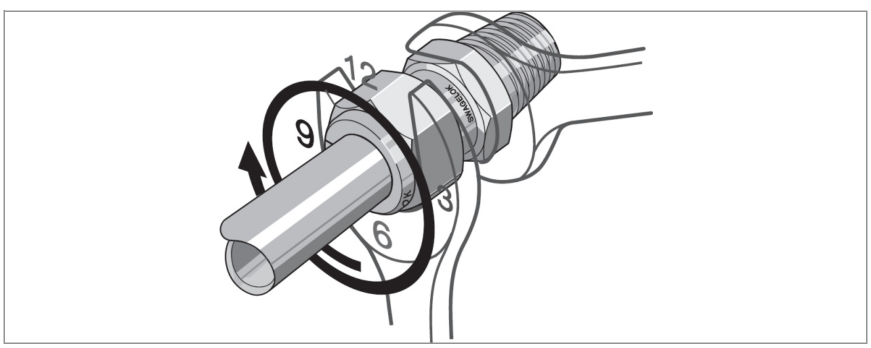

FIGURE 17: *Tighten One and One-Quarter Turns*

C.2 REASSEMBLY INSTRUCTIONS

Swagelok tube fittings can 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.**

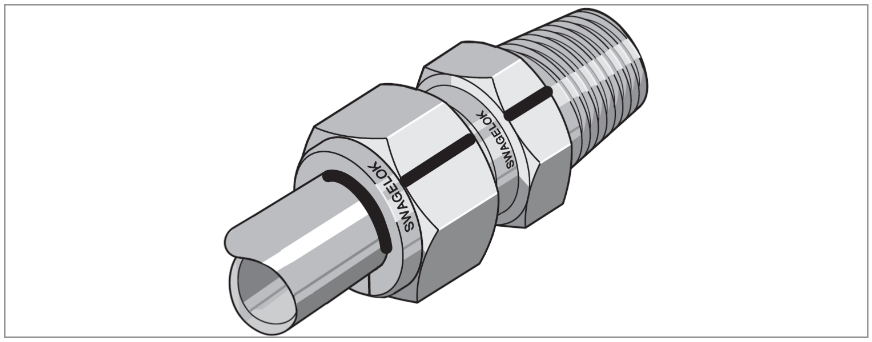

FIGURE 18: *Marks for Reassembly*

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.

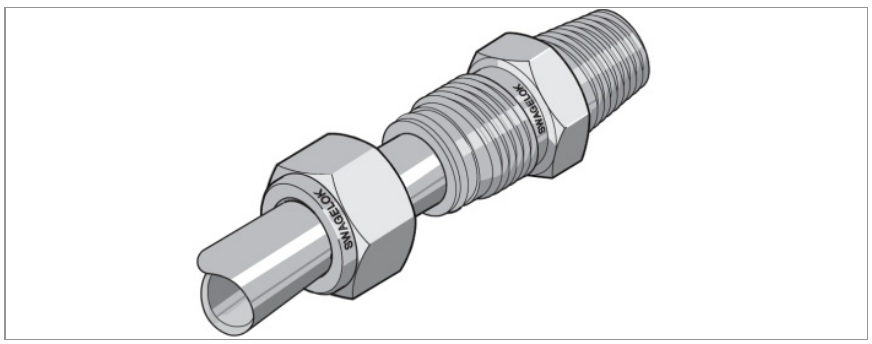

FIGURE 19: *Ferrules Seated Against Fitting Body*

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.

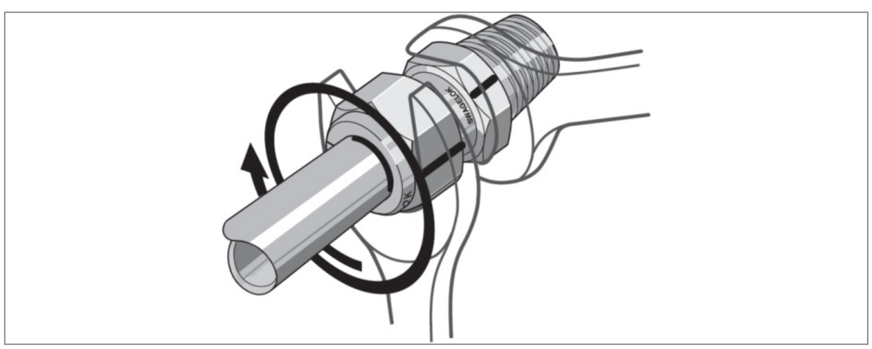

FIGURE 20: *Tighten Nut Slightly*

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