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Instruction Manual

Model 4650

VW Settlement Sensor

(Doc Rev T, 04/30/19)

Warranty Statement

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

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EQUATIONS

1. GENERAL DESCRIPTION

The 4650 Settlement System is designed to measure the differential settlement between two points. A reservoir is located at a stable reference point and is connected to a sensor located at the settlement point by two liquid filled tubes. The sensor senses the pressure of liquid within the tube. This provides a measure of the height of the liquid column, which in turn gives a measurement of the elevation difference between the reservoir and the sensor.

Figure 1 shows a typical installation used to measure the settlement inside an embankment. The sensor is read by means of an electrical cable extending to the readout location. Readings may be taken using a readout box or datalogger.

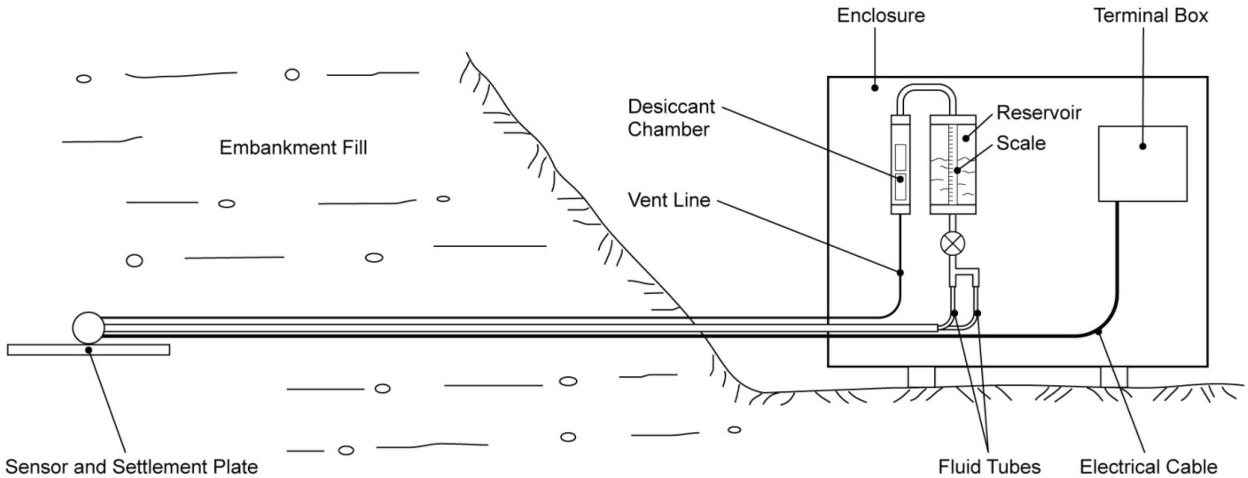

Figure 1 - Typical Installation of Vibration Wire Settlement System

The sensor (Figure 2) contains a thermistor for measurement of temperature as well as gas discharge tubes for protection against lightning damage. The cable contains a vent tube that connects the air inside the sensor to the space above the reservoir. This ensures that the sensor readings are unaffected by any changes in barometric pressure. A desiccant chamber located at the reservoir end of the vent line prevents moisture from migrating into the line.

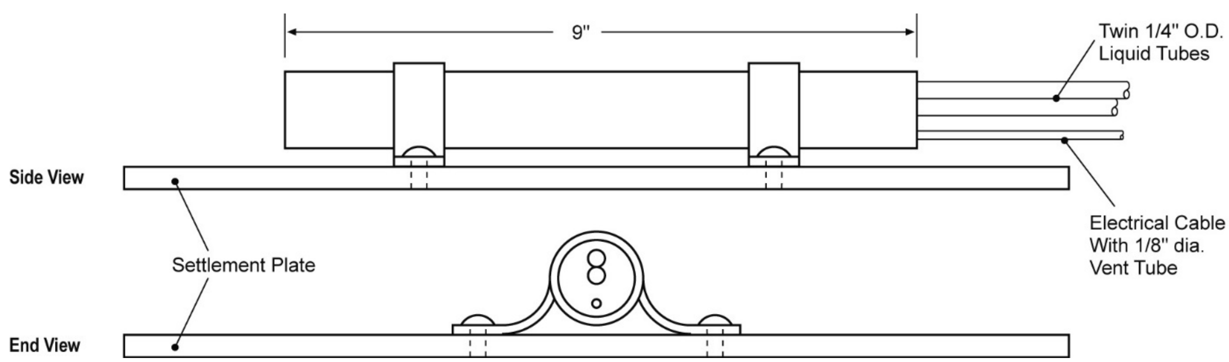

Figure 2 - Sensor Details

Figure 3 shows details of a typical reservoir system. Two liquid filled tubes are provided for each sensor and more than one sensor can be connected to a single reservoir. The use of two liquid filled tubes permits the tubing to be flushed periodically to remove any accumulation of air bubbles. With this type of liquid settlement sensor, it is vital that there be no air bubbles in the liquid line. The liquid used is typically a de-aired antifreeze mixture, which resists the growth of algae and is not susceptible to freezing.

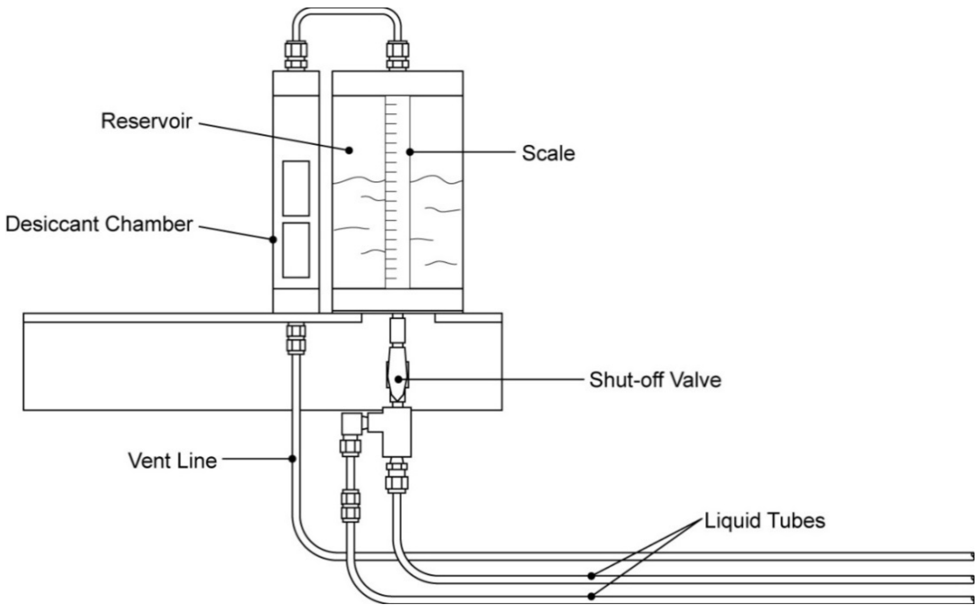

Figure 3 - Reservoir Details

2. INSTALLATION PROCEDURES

Most installations are in fills and embankments where the sensor and cables are buried. Elsewhere the cables and sensors may be attached directly to structures undergoing settlement of heave. The reservoir location must always be at a higher elevation then the sensor and higher than any part of the liquid filled connecting tube.

Prefilled systems are usually delivered with de-aired antifreeze solution already in the liquid lines. An extra length of small diameter tubing is connected to the outer ends of the liquid lines to allow the system to breath during transportation while simultaneously protecting the sensor from being overranged by temperature or pressure fluctuations and preventing the entry of air bubbles into the main liquid lines.

Alternatively, systems may be provided with the tubing empty for filling in the field.

2.1 Installing the Sensor

The sensor is usually attached to a settlement plate using the bracket(s) provided.

The settlement plate may be attached directly to a structure using bolts. In the case of installation in fills, a smooth, flat bottomed excavation should be made about 300 to 600 mm (12 to 24") deep. The sensor plate is placed on this flat surface and covered with fine material, similar to the fill, with all particles over 10 mm (0.4") in size removed. This material should be tamped down around the cell until the excavation is filled back to the original ground surface. The elevation of the settlement plate should be measured at the time of the installation using conventional level survey techniques. Check also that the sensor is still functioning after tamping.

2.2 Installing the Cables and Liquid Filled Tubes

Cables and tubing need to be placed in a trench approximately 300 to 600 mm (12 to 24") deep. The trench should not undulate, and individual cables and tubes should be laid side by side without touching or crossing each other. In no place should the tubing be higher than the reservoir location. Before backfilling the trench, examine the tubing for signs of air bubbles: If any are noted, the tubing will need to be flushed before initial readings are taken.

Compact the material in the trench around the cables. Do not allow large angular pieces of rock to rest directly on the cable. To prevent migration of water along the trench, bentonite plugs can be constructed at intervals.

Trenches in earth dam embankments should never penetrate entirely through the clay core. Compaction of the fill above the cables can proceed in a normal manner when the cover exceeds 600 mm (24") depth. Where cables are not buried, they should be adequately supported along their length to prevent undulations. They should also be protected from direct sunlight and insulated from rapid temperature fluctuations by encasing them in Styrofoam or urethane foam, etc.

2.3 Installing the Reservoir, Connecting the Sensor Tubes and Vent Tube

The reservoir should be installed on stable ground or at a location that can be level surveyed. The terminal housing should be affixed to stakes grouted firmly into the ground or preferably into a concrete pad poured at a location. The elevation of the reservoir pad should be surveyed and recorded at the time of installation. The reservoir should never be located where it is exposed to direct sunlight.

To fill the reservoir first make sure that the valve at the bottom is closed, then completely remove the vent line Swagelok fitting from the top and half-fill the reservoir with antifreeze solution (supplied) using the syringe supplied. To avoid foaming, poke the tube from the syringe to the bottom of the reservoir and keep it below the surface of the liquid while filling.

The sensor tubes are shipped full of de-aired antifreeze solution. One tube is capped and to the other tube is attached a long small diameter breather tube which is also full of antifreeze solution. The purpose of the breather tube is to prevent air from entering the sensor tube during shipment while at the same time allowing the barometric pressure to equalize inside and outside the sensor. It ensures that when the cap and the breather tube are removed from the ends of the sensor tubing air is not sucked into the tubing by a built-up negative pressure. When connecting the tubes from the sensor to the reservoir do not allow air to be trapped inside the tubing.

Installation is as follows:

1) With the reservoir valve closed, remove one of the caps from the fitting at the base of the reservoir, as well as the cap that does not have the breather tube from the end of the sensor tube.

2) Make sure that water is oozing out of the tube. (Elevate the breather tube if necessary.)
3) Open the reservoir valve slightly so that water dribbles out.

4) Connect the tube fitting to the mating reservoir fitting and tighten one turn only.

5) Remove the breather tube from the end of the other sensor tube. (Make sure that water is oozing out of the tube.)

6) Remove the second cap from the other fitting on the base of the reservoir.

7) Slightly open the reservoir valve.

8) While the water is dribbling out connect the second sensor tube fitting and tighten.

9) Remove the cap from the end of the vent line.

10) Make sure that the vent line to the sensor is not blocked. This can be checked using an aspirator bulb, (or simply by sucking), to draw a vacuum on the vent line while observing the sensor reading change on the GK-403, GK-404 or GK-405 readout box.

11) Attach the vent line to the vent line manifold using the Swagelok fittings. **Follow the instructions in Appendix D to ensure the Swagelok fittings are tightened properly!**

12) Add fresh desiccant to the desiccant chamber (or the vent line manifold).

13) Add more liquid to the reservoir to bring up to the half-full point. A few drops of light oil added through the top of the reservoir will prevent evaporation from the liquid surface.

14) Reconnect the vent line fitting to the top of the reservoir.

15) Connect the sensor cable to the terminal panel (if one exists) as follows: Black and Red wires to the gauge position, Green and White wires to the thermistor (temperature) position. Manual switch panels can be used in conjunction with GK-403, GK-404, or GK-405 readout boxes. Terminal strips are used in conjunction with dataloggers.

2.4 Initial Readings

Initial readings must be taken with great care; they are the base line readings to which all subsequent readings are compared. It is important that the liquid filled tubes be at a constant temperature. If the tubes are not completely buried the readings should be taken at a time when the temperature is relatively constant. The readings should never be taken when the tubes are exposed to direct sunlight. In addition, there should be no air bubbles in the liquid tubes. If air bubbles are detected the tubes should be flushed before the initial readings are taken. If there is any doubt, take readings, flush the tubing, and take readings again. Repeat if necessary until the readings are stable. (See Section 3 for readout instructions.) Always record the ambient temperature when taking readings.

Take careful measurement of the elevation of the liquid level inside the reservoir sight tube. Make a mark on the tube opposite the liquid level. This will serve as a quick visual check on any fluctuations and enable a quick means of measuring the magnitude of the change. For correction of subsequent calculations of settlement, see Section 4. (Reservoir level fluctuations may be due to temperature or pressure fluctuations or due to leakage.)

3. TAKING READINGS

When taking sensor readings also record the height of the fill above the sensor, the temperature, and any other physical phenomena or construction activity that might affect the readings.

3.1 GK-404 Readout Box

The Model GK-404 Vibrating Wire Readout is a portable, low-power, handheld unit that can run continuously for more than 20 hours on two AA batteries. It is designed for the readout of all Geokon vibrating wire gauges and transducers; and is capable of displaying the reading in either digits, frequency (Hz), period (μs), or microstrain (με). The GK-404 also displays the temperature of the transducer (embedded thermistor) with a resolution of 0.1 °C.

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

Figure 4 - Lemo Connector to GK-404

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

To turn the GK-404 on, press the "ON/OFF" button on the front panel of the unit. The initial startup screen will be displayed. After approximately one second, the GK-404 will start taking readings and display them based on the settings of the POS and MODE buttons. The unit display (from left to right) is as follows:

- The current Position: Set by the **POS** button, displayed as a letter A through F.
- The current Reading: Set by the **MODE** button, displayed as a numeric value followed by the unit of measure.
- Temperature reading of the attached gauge in degrees Celsius.

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

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, consult Section 11 for troubleshooting suggestions.
For further information, consult the GK-404 manual.

3.2 GK-405 Readout Box

The GK-405 Vibrating Wire Readout is made up of two components: The Readout Unit, consisting of a Windows Mobile handheld PC running the GK-405 Vibrating Wire Readout Application; and the GK-405 Remote Module, which is housed in a weatherproof enclosure and connects via a cable to the vibrating wire gauge to be measured. The two components communicate wirelessly. The Readout Unit can operate from the cradle of the Remote Module, or, if more convenient, can be removed and operated up to 20 meters (65 feet) from the Remote Module.

3.2.1 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.

3.2.2 Sensors with Bare Leads

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

3.2.3 Operating the GK-405

Press the button labeled “POWER ON”. A blue light will begin blinking, signifying that the Remote Module is waiting to connect to the handheld unit. Launch the GK-405 VWRA program by tapping on “Start” from the handheld PC’s main window, then “Programs” then the GK-405 VWRA icon. After a few seconds, the blue light on the Remote Module should stop flashing and remain lit. The Live Readings Window will be displayed on the handheld PC. Choose display mode “B”. Figure 5 shows a typical vibrating wire output in digits and thermistor output in degrees Celsius. If no reading displays or the reading is unstable, see Section 11 for troubleshooting suggestions. For further information, consult the GK-405 Instruction Manual.

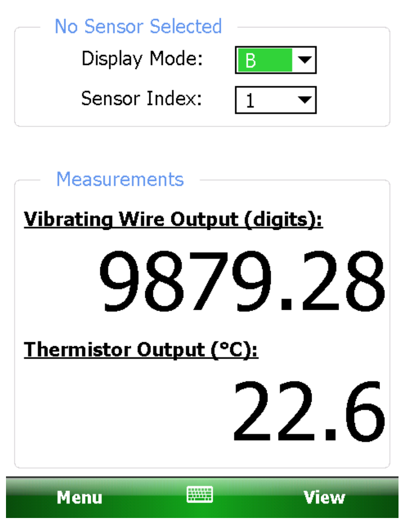

Figure 5 - Live Readings – Raw Readings

3.3 GK-403 Readout Box (Obsolete Model)

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

3.3.1 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.

3.3.2 Connecting Sensors with Bare Leads

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

3.3.3 Operating the GK-403

1) Turn the display selector to position "B".
2) Turn the unit on.
3) The readout will display the vibrating wire output in digits. The last digit may change one or two digits while reading.
4) The thermistor reading will be displayed above the gauge reading in degrees centigrade.
5) Press the "Store" button to record the value displayed.

If the no reading displays or the reading is unstable, see Section 11 for troubleshooting suggestions.

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

3.4 Measuring Temperatures

All vibrating wire transducers are equipped with a thermistor, which gives a varying resistance output as the temperature changes. The white and green leads of the instrument cable are normally connected to the internal thermistor.

The GK-403, GK-404, and GK-405 readout boxes will read the thermistor and display the temperature in degrees C.

To read temperatures using an ohmmeter: Connect an ohmmeter to the green and white thermistor leads coming from the transducer. (Since the resistance changes with temperature are large, the effect of cable resistance is usually insignificant. For long cables a correction can be applied, equal to approximately 48.5Ω per km (14.7Ω per 1000 ft.) 20 °C. Multiply these factors by two to account for both directions.) Look up the temperature for the measured resistance in Appendix B, Table 2.

4. DATA REDUCTION

4.1 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 4650 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;
E_0 is the sensor elevation at installation.
ΔE_{RES} is any change of the fluid level inside the reservoir sight glass.
(If the fluid level falls, ΔE_{RES} is negative. If the fluid level rises, ΔE_{RES} is positive.)
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 report supplied by the factory is shown in Figure 6.)

For Example:

If;
E_0 = 541.62 meters
R_0 = 9030 digits
R_1 = 8800 digits
G = -0.001765 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).

Then the new sensor elevation equals:
E = 541.62 – [(8800-9030) x -0.00175] + (–0.010)
E= 541.204 meters

In other words, there has been a settlement of 0.416 meters.

4.2 Correction for Settlement or Heave of the Reservoir Terminal

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

4.3 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 so that temperature effects tend to be insignificant. Systems exposed to the atmosphere and to sunlight may 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 elevation (E_T) corrected for temperature is given by:

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

Equation 2 - Elevation, corrected for temperature

Where;
T_0 is the initial temperature.
T_1 is the current temperature.
K is the temperature correction factor included on the calibration report.

Please note: The calibration report shown in Figure 6 was developed using a simple manometer and is good only over a range of three meters (ten feet) 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 calibration report shown in Figure 6.

2) Use the second calibration report, supplied with the equipment, which was developed by calibrating the pressure sensor over a wider range.

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

Settlement System Calibration Report

Model Number: 4650-1-70 kPa

Calibration Date: July 25, 2013

Serial Number: 1311893

Temperature: 21.3 °C

Transducer Range: 70 kPa

Calibration Instruction: CI-4600-4650

Cable: 3 m

Technician:

Tubing: 3 m

*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	9392.0	
1.0	9108.0	284.0
1.5	8824.0	284.0
2.0	8540.0	284.0
2.5	8256.0	284.0
3.0	7971.0	285.0

Calibration Factor G: -0.001760 m / digit

Calibration Factor G: -0.00577 ft. / digit

Thermal Factor K: 0.00378 m / °C

Thermal Factor K: 0.01241 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 6 - Typical Calibration Report

5. SPECIAL TOOLS AND APPARATUS REQUIRED FOR VARIOUS TEST PROCEDURES

- GK-403, GK-404, or GK-405 Readout Box
- Assorted wrenches
- Nitrogen supply cylinder with regulator valve
- Pressure tanks filled with de-aired liquid (50% antifreeze solution made with distilled water and containing dye)
- Vacuum pump and rubber connecting hoses with pinch clamps
- Motor generator (Gasoline powered)
- Auxiliary reservoir
- Miscellaneous connecting tubes and fitting

6. FLUSHING PROCEDURES

Periodic flushing of the liquid filled tubes may be required to remove air bubbles. A 300-meter (1,000 foot) length of tubing requires 2.5 liters (0.67 gallons) of liquid. Tubes should always be filled with de-aired liquid. Dye, added to the new flushing fluid, can be used to indicate when the flushing is complete.

The best way to de-air a liquid is to use a Nold DeAerator (ask Geokon for more details). De-aired liquid is also available from Geokon in two gallon or five-gallon pressure tanks specially designed to prevent air from reaching the fluid. The liquid should also resist the growth of algae and should not be liable to freeze in cold climates. The growth of algae can be prevented by dissolving a crystal of copper sulfate in the liquid or by using commercial grade ethylene glycol solutions, which also prevent freezing. The use of distilled water, rather than tap water, is recommended. Figure 7 shows the apparatus recommended for flushing the tubes.

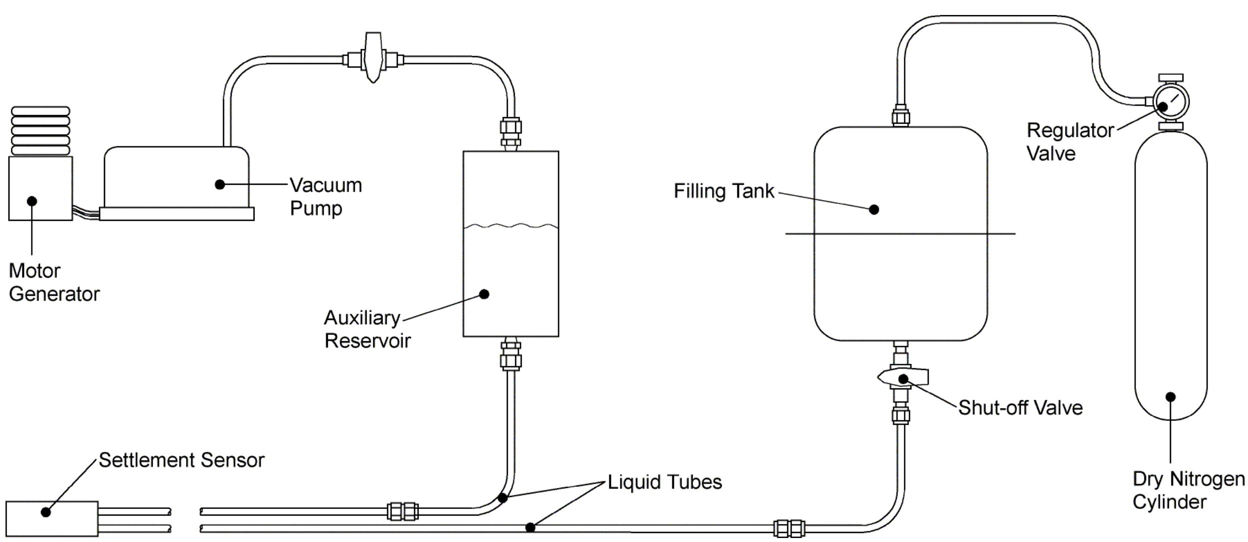

Figure 7 - Flushing Apparatus

Note that a bicycle pump can be used in place of the nitrogen cylinder.

1) Close the shut off valve at the base of the reservoir.

2) Disconnect one of the tubes and then reconnect it to the base of a filling tank that is filled with de-aired liquid.

3) The second tube is disconnected and attached to the base of an auxiliary reservoir. (For tubes longer than 200 meters (650 feet) it is recommended that a vacuum pump be attached to the top of the auxiliary reservoir. This will speed up the flushing process.)

4) Connect a nitrogen cylinder with regulator to the top of the filling tank.

5) Start the vacuum pump running then open the valve at the bottom of the pressure tank.

6) Adjust the nitrogen pressure until the settlement sensor reads at its maximum range value on the Readout Box. (See Section 3 for Readout instructions.) Be careful not to over range the sensor by more than 20%. **CAUTION! Do not allow the nitrogen pressure to exceed the pressure rating marked on the outside of the filling tank (usually 100 psi (700 kPa). Failure to observe this precaution could result in injury.**

7) Continue flushing until all the old liquid has been removed. (As flushing proceeds, the auxiliary reservoir may need to be emptied periodically.)

8) Store the flushed liquid in a container for later disposal. Do not allow any liquid to enter the vacuum pump as this could ruin it.

9) When flushing is complete, reconnect the fluid lines to the base of the reservoir. *Be careful not to introduce air bubbles during this process.*

7. PURGING THE VENT LINES

The vent line must always remain open because it connects the inside of the sensor to the space above the reservoir. Any blockage of the vent line due to pinching, dirt, or moisture will cause false readings that fluctuate and/or are sensitive to temperatures.

Blockages due to pinched tubes can be confirmed by applying a vacuum to the vent line and observing the reading on the sensor. If the sensor does not respond the tube is blocked by dirt or pinched, and this might be correctable if the blockage is accessible. Blockages due to moisture and condensation can be purged using a vacuum pump to evacuate the vent line. As the vacuum is applied watch for signs of water in the vent line. When the vacuum has stabilized, stop the pump, disconnect the vent line, and quickly reattach either a desiccant chamber containing fresh desiccant, or a cylinder of dry nitrogen. This ensures that the gas drawn back into the vent line is dry. Make sure the vent line connection is open between the desiccant chamber (or vent line manifold) and the top of the reservoir.

8. IN SITU CALIBRATION

A valuable feature of the Model 4650 settlement system is the ability to perform in situ calibrations. This is done by connecting an auxiliary reservoir to one of the fluid lines as shown in Figure 8.

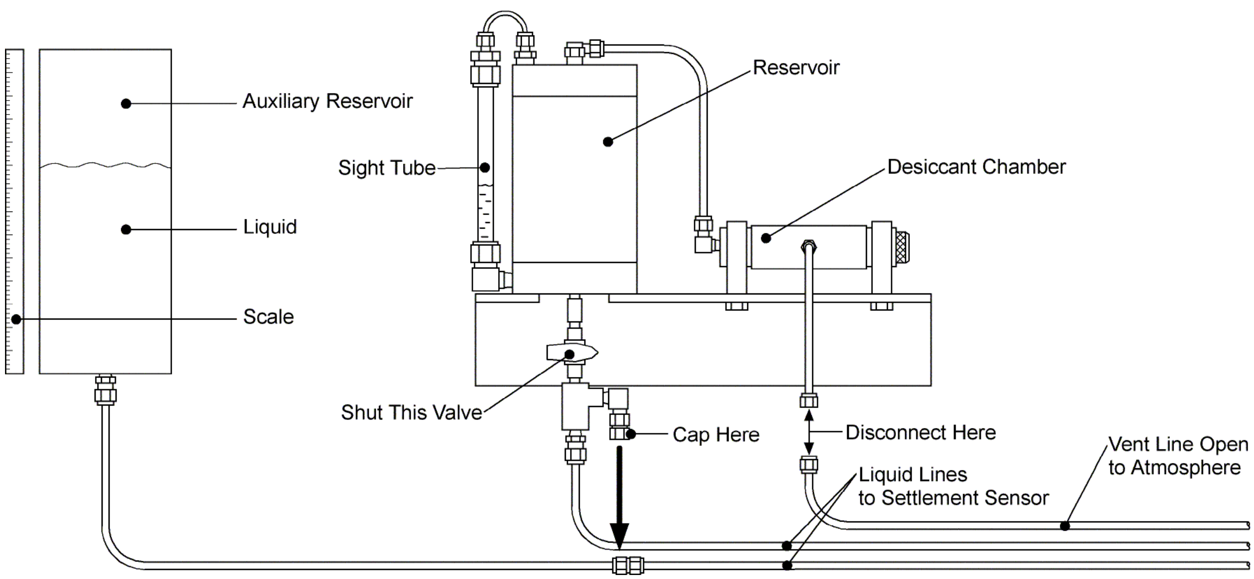

Figure 8 - In Situ Calibration Apparatus

First close off the valve at the bottom of the reservoir, half-fill the auxiliary reservoir with the same liquid used in the reservoir and connect it via a short length of tubing to one of the fluid lines, being careful not to introduce air into the lines. Cap off the open fitting on the reservoir connection and disconnect the vent line from the vent manifold. Raise and lower the auxiliary reservoir by measured amounts using a scale to measure the elevation of the water level.

Read the sensor using a GK-403, GK-404, or GK-405 readout box. (See Section 3 for readout instructions.) Record the readings after allowing sufficient time for the readings to stabilize (usually requires around one to five minutes although it will be noted that the sensor responds instantaneously to change of water elevation even where the liquid tubes are very long.) Record the sensor readings at five or more different elevations, then, from the data calculate the calibration factor and compare it with the factory generated value on the calibration report.

Remove the auxiliary reservoir and reconnect the fluid line to the base of the reservoir and the vent line to the desiccant chamber or vent line manifold. Reopen the valve at the base of the reservoir.

9. IN SITU ZERO CHECK

This procedure is not recommended as a regular procedure but only one to be undertaken if there is some serious doubt as to the zero stability of the sensor or to confirm a sudden or critical change in the amount of settlement which is causing concern.

Disconnect the vent line from the desiccant chamber. Close the valve at the bottom of the reservoir. Disconnect the liquid lines from the bottom of the reservoir connect one of them to a nitrogen cylinder. Turn on the nitrogen and adjust the pressure so that the sensor reading is at its maximum value. (Do not exceed 20% above this maximum range.) The other tube can be left open (with long lengths of tubing (>200 m) the process can be speed up by attaching a vacuum pump to the end of the other fluid line.) Once all the liquid has been purged from the lines, allow the nitrogen to flow for another 30 minutes. This will tend to dry out the inside of the tubing. Turn off the nitrogen and disconnect the ends of the tubing so that they are both open to atmosphere along with the open vent line. Wait until the sensor reading stabilizes and then record this zero reading. Compare this reading with the factory zero reading shown on the calibration chart.

Refill the liquid lines following the flushing procedures described in Section 6 with the following difference: If a vacuum pump is used, allow the vacuum pump to run for 30 minutes (or until the sensor reading has stabilized), before opening the valve at the bottom of the filling tank to allow liquid to enter the lines. This will greatly reduce the chances of air being trapped inside the tubing and sensor cavities.

10. MAINTENANCE

Every 3 months:

- Conduct a visual examination of the reservoir terminal housing. Check for leaks by observing the water level in the reservoir sight tube. Add additional fluid as necessary by removing the top connector of the Tygon sight tube. Alternatively, if the water level in the reservoir begins to rise this may be due to squeezing of the tubing by ground pressures. It is important not to let the fluid overflow from the reservoir into the vent line; this could adversely affect the readings. Drain off any excess fluid before it reaches the top of the reservoir. If regular maintenance is not possible then it is advisable to disconnect the tubing connecting the top of the reservoir to the desiccant chamber and leave them both open to the atmosphere.

- Replace the desiccant capsules in the vent line manifold or desiccant chamber. Desiccant capsules are dark blue when active and pink when inactive.

Every 12 months:

- Flush the liquid tubes with fresh de-aired liquid.

- Check the in situ calibration as described in Section 8.

11. TROUBLE SHOOTING

Faulty readings may show up as unstable, fluctuating readings, sudden large changes of readings or readings of 9999 on dataloggers, unrelated to physical phenomena. The first task should be to see if the fault lies with the readout device. If a datalogger is in use, try reading the sensors with a portable GK-403, GK-404, or GK-405 Readout box.

11.1 Unstable Readings

Unstable readings with dataloggers may be caused by electrical noise from nearby power lines or electrical equipment. Remove such equipment, if possible, or read the sensors when the power is switched off.

Fluctuating readings may also be the result of air bubbles in the liquid lines or of plugged vent lines. Follow the procedures outlined in Section 6 and Section 7.

11.2 Reading of 9999

These will show up on dataloggers if the reading is overrange. This can happen if the electrical leads are shorted or open. Check the resistance between the black and red conductors. The resistance should be 180 ohms ±10 ohms plus five ohms for every 100 meters (328 feet) of lead wire. If the resistance is substantially different from these values check for loose connections in the terminal box and for visible signs of cable damage.

11.3 Sudden or Large Changes in Readings

Large or sudden changes in readings may be caused by leakage of liquid from the liquid lines. Check the reservoir sight tube. If leakage is detected and there is more than one sensor connected to the reservoir turn off each sensor valve at the base of the reservoir one by one until the leaking sensor is found. If preferred this sensor can be left isolated from the system so that it will not to disrupt the others.

APPENDIX A. SPECIFICATIONS

A.1 Model 4650 VW Settlement Sensor

Standard Ranges[1]	7, 17 m
Resolution	0.025% F.S.
Sensor Accuracy[2]	±0.1% F.S.
Temperature Range[1]	-20 °C to +80 °C (-4 °F to +176 °F)
Length x Diameter	Reservoir: 152 x 51 mm (6 x 2") Sensor: 191 x 35 mm (7.5" x 1.4")
Frequency Range	1400-3500 Hz
Electrical cable:	Model 02-335VT8, two shielded pairs, 22-gauge, 9.525 mm (3/8") diameter polyurethane jacket with ground wire and integral 3.175 mm (1/8") diameter polyethylene vent tube. Resistance 5.25 ohm/100 m (14.7 ohms/1000 ft.)
Liquid tubes:	Twin type 11 nylon tubes 6.35 mm (1/4") O.D. covered with one-millimeter polyethylene jacket.
Liquid:	A de-aired 55/45 solution of distilled water mixed with commercial grade propylene glycol. Specific gravity =1.041. Freezing point is –30 °C (-22 °F).
Desiccant Capsules:	Geokon Model 4500-8

Table 1 - Specifications

[1] Other ranges available on request
[2] Laboratory accuracy. Total system accuracy is subject to site-specific variables.

A.2 Thermistor (see Appendix B also)

Range: -80 to +150 °C (-112 to +302 °F)
Accuracy: ±0.5 °C (0.9 °F)

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

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

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

Equation 3 - Resistance to Temperature

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

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

Table 2 - Thermistor Resistance versus Temperature

APPENDIX C. SPLICING 4650 SETTLEMENT SENSOR TUBING AND CABLE

C.1 Replacing a Transducer

The most critical aspect of this operation is making sure that no air is allowed to get into the liquid lines.

The first step is to remove the faulty sensor by cutting both the liquid line and the cable from the faulty sensor using the procedures below.

C.1.1 Liquid Line

Extreme care must be exercised during this operation. The first step is to carefully strip a section of the outer (yellow) jacket off the tubing bundle to in preparation for splicing to the new sensor. This is a somewhat delicate operation as the jacket is tightly wrapped around the inner tubes. Practice the operation first on a waste piece of tubing bundle.

The new sensor should have the union already attached and ready to accept the tubing. Check to see that the sections of exposed tubing (including the part that must be prepared for the connection) will be short enough to fit into the splicing kit, and the outer jacket will be in the epoxy when finished

Be sure that the reservoir water level is maintained during the splicing operation and that the balance tube is disconnected from the top of the reservoir.

1) Cut one of the tubes about 50 mm (2") beyond the yellow jacket and immediately block the end so that no fluid can flow.

2) Place the correct nut and ferrule pack over the end of this tube, and then block the flow.

3) Next, remove the cap from one of the lines on the replacement sensor and make sure the fluid is right at the top of the exposed tube. If the fluid is not there, top this up with the small syringe provided with the sensors.

4) Attach the previously cut tube with the nut and ferrule to the Swagelok union with fluid flowing from the reservoir to avoid any air being trapped in the joint. (See Appendix D for Swagelok instructions.)

5) The next operation is to repeat steps one through four with the other tube — with one exception — before making the connection with the tube and the union, keep the tube with the nut and ferrule blocked while removing the cap from the union and letting a small amount of liquid flow from the union. Next, block that flow and let a little flow from the tube to be attached. Attach the tube, allowing a little fluid to flow while making the connection. Tighten the Swagelok per the instructions in Appendix D.

C.1.2 Splicing the Cable

1) Cut the cable from the faulty sensor and strip the jacket back approximately 50 to 75 millimeters (two to three inches).

2) The cable has four conductors and a drain wire (bare), as well as a barometer equalization tube. The wire insulation should be stripped about 13 mm (1/2") in preparation for crimping together with the wires from the new sensor.

3) Strip the new sensor wires back the same way.

4) Crimp the wires together using the special crimper and test each connection for strength.

5) Using the supplied union, splice the vent tube. **Follow the instructions in Appendix D to ensure the Swagelok fittings are tightened properly!**

6) Take readings at the readout station to make sure the sensor and its thermistor are reading properly.

7) Place the cable in its epoxy splice kit and make the splice.

8) Do the same for the tubing assembly.

C.2 Adding an Extension to a Sensor Assembly

The first step in this operation is to connect the supplied section of tubing to the reservoir. This should be done with the liquid flowing from the reservoir in the same way that the operation is done when connecting a sensor.

After connecting the extension to the reservoir, the splice to the existing tubing bundle and cable should be made as in the connection for a replacement sensor. Be sure to remove the equalization line from the reservoir during this operation and always keep liquid in the reservoir.

Remember that for both operations the prime concern is preventing air getting into the liquid lines and making sure that all electrical connections are good before finishing the splices.

The splices should be allowed a couple of hours to cure before placing fill and compacting over them.

APPENDIX D. SWAGELOK TUBE FITTING INSTRUCTIONS

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

D.1 Installation

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

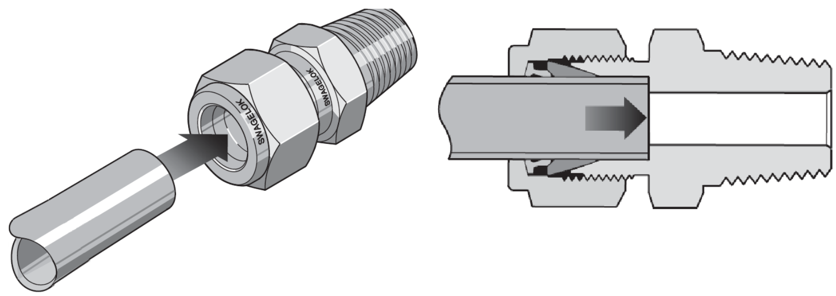

Figure 9 - Tube Insertion

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.

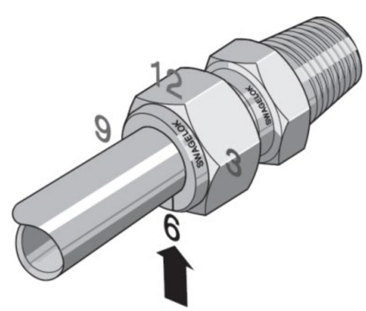

Figure 10 - Make a Mark at Six O'clock

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.)

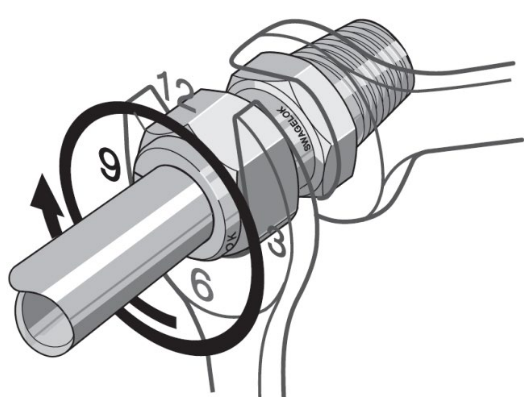

Figure 11 - Tighten One and One-Quarter Turns

D.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.*

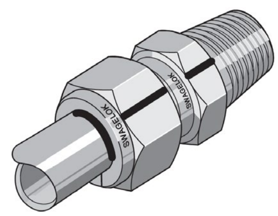

Figure 12 - Marks for Reassembly

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.

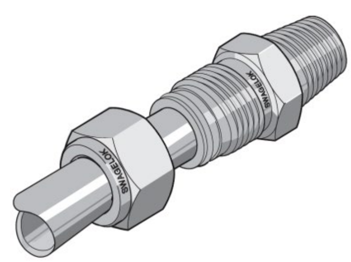

Figure 13 - Ferrules Seated Against Fitting Body

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.

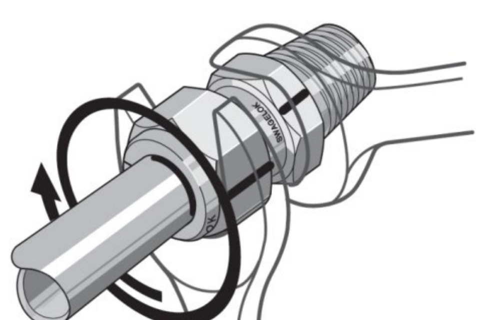

Figure 14 - Tighten Nut Slightly