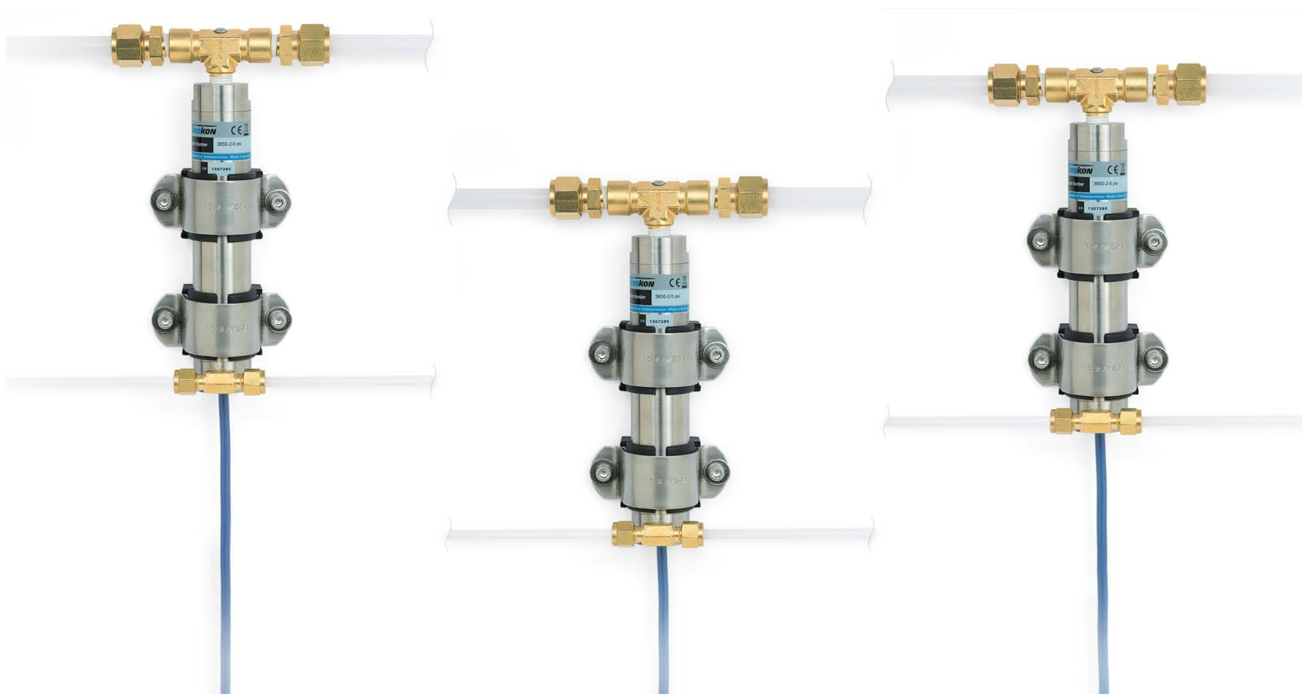
Model 3655

Semiconductor Multipoint Hydraulic Leveling System

Instruction Manual



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1. INTRODUCTION

The Model 3655 Multipoint Hydraulic Leveling System is a system, comprising a series of sensitive semiconductor pressure sensors connected together 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

1. Reservoir enclosure mounting feet and supplied hardware
2. Sensor mounting brackets and suppled hardware
3. 12.7 mm (1/2") diameter nylon liquid line tubing, enough to connect the sensors to the reservoir, plus a 1.2 m (4’) length used in the filling process.
4. 6.4 mm (1/4") diameter polyethylene vent line tubing, enough to connect the sensors to the reservoir, plus a 3.4 m (11’) length used in the filling process.
5. Bi-directional valve
6. Rubber tubing and Swagelok union for vacuum pump attachment
7. Small syringe for small adjustment in the level of fluid in the reservoir through the Swagelok in the cap
8. Large syringe for extracting air or liquid from the sensor through the seal screw hole
9. Jumper line for connecting the liquid reservoir to the desiccant chamber
10. Spare desiccant packs

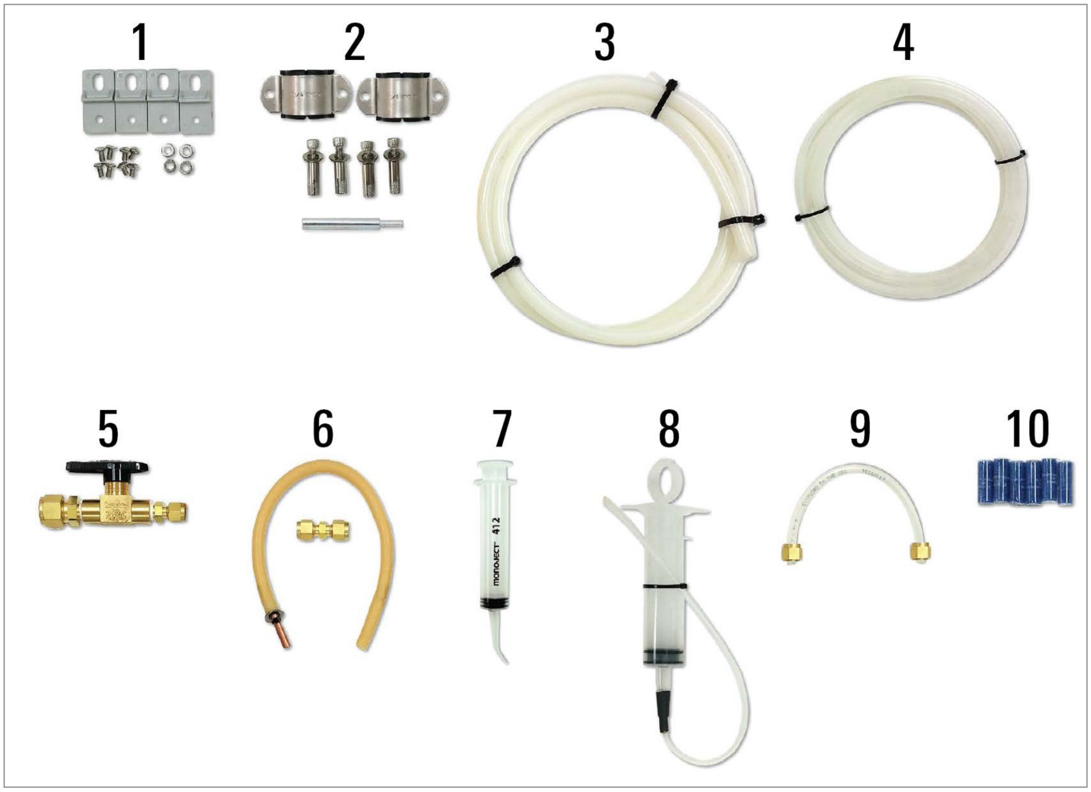

FIGURE 1: *Model 3655 Accessories*

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 sensors.

Attach the reservoir, using the provided mounting feet and hardware (Accessory 1), to a stable structure or one that can be easily level surveyed.

The sensors are then installed to the concrete or other surface using either drop-in anchors (see Section 2.2.1 and Figure 2), or customer supplied bolts/studs that are welded to or screwed into the steel or other material.

2.2.1 MOUNTING SENSORS TO CEMENT WITH THE PROVIDED DROP-IN ANCHORS

1. Use a leveling device to align the first mounting bracket (Accessory 2) 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 (0.5") holes approximately 37 mm (1.5") deep. Clean the holes thoroughly, blowing out with compressed air if possible.
3. Insert the drop-in anchors, threaded side up, into the holes. Insert the Model TLS-209 Setting Tool into the anchors and strike with a hammer until the lip of the anchor touches the lip of the setting tool.
4. Using the same process, install the second mounting bracket.
5. Attach the sensor to the wall using the mounting brackets and remaining hardware, as illustrated in Figure 2.

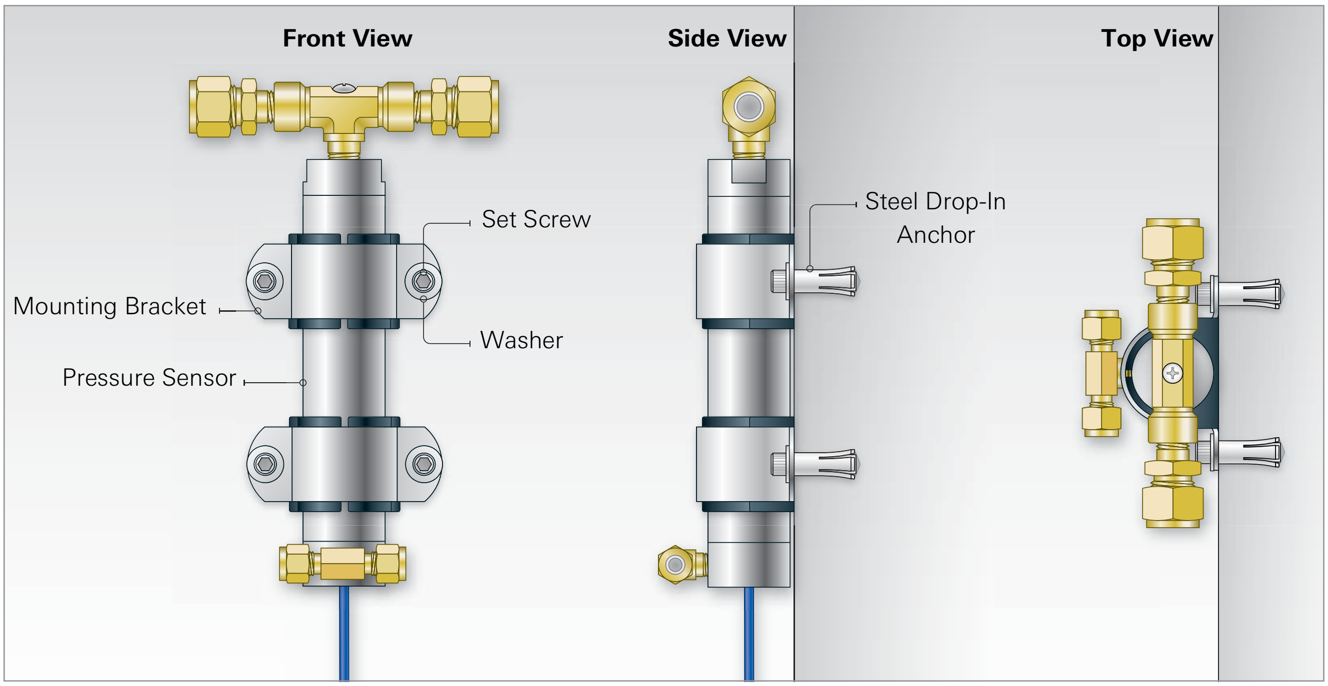

FIGURE 2: *Model 3655 Mounting Details*

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.

All tubing will be connected via the provided Swagelok fittings, refer to Appendix E for the Swagelok installation procedure.

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 (Accessory 3) 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"). One end of the liquid line will be terminated via a bidirectional valve at most remote sensor after the filling procedure is complete.

2.3.2 VENT LINE

The routing of the vent line (Accessory 4) 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, the line connects through all of the sensors of the system, and then terminates at a desiccant chamber located next to the reservoir.

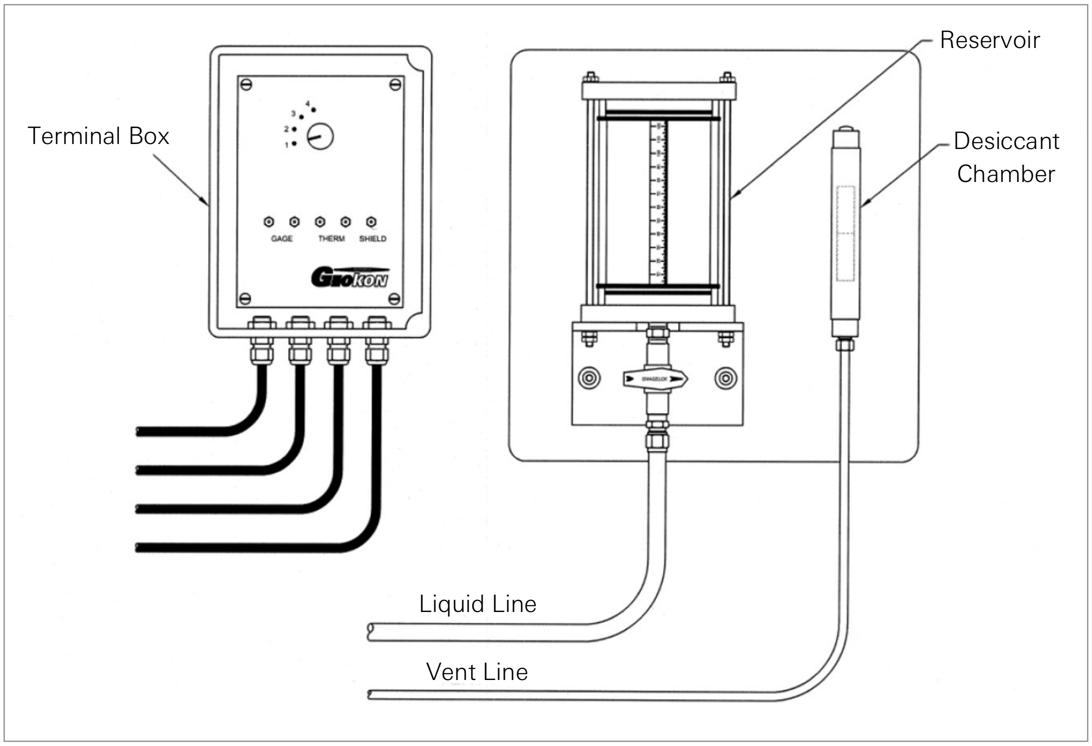

FIGURE 3: *Terminal Box, Reservoir, and Desiccant Chamber*

2.4 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.

2.4.1 FILLING FROM THE RESERVOIR

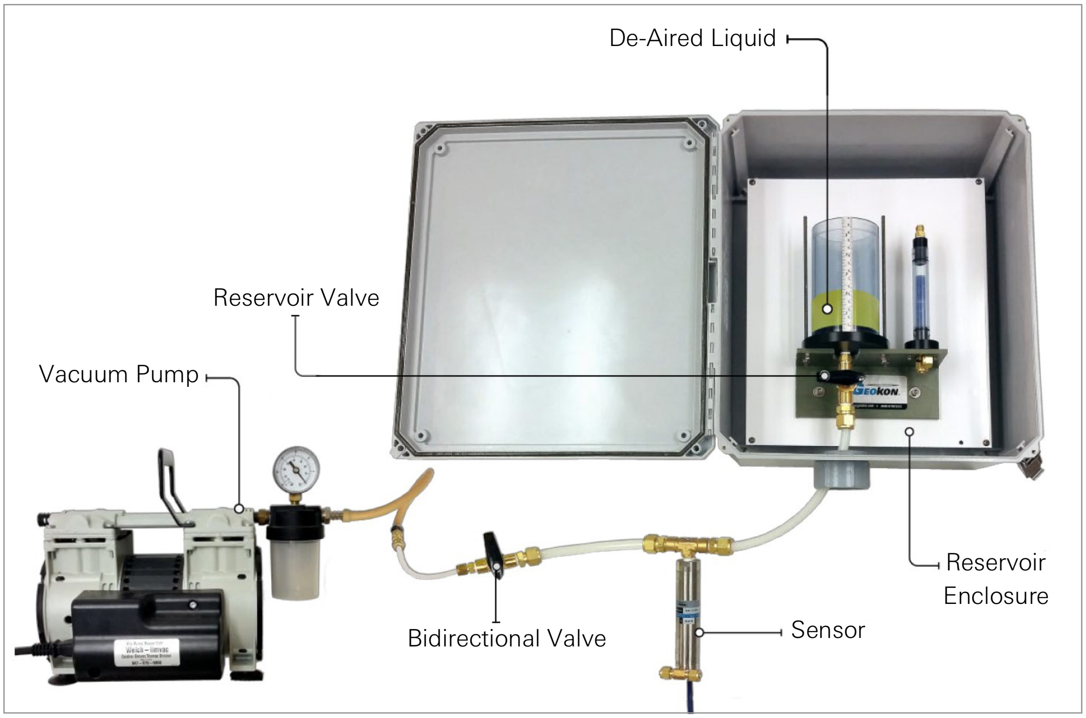

FIGURE 4: *Filling From the Reservoir*

1. Attach the provided 1.2 m (4’) length of 1/2" tubing (Accessory 3) to the last sensor in the string furthest from the reservoir. Install the provided bidirectional valve (Accessory 5) to the other end of the tubing.
2. Cut a length of 6.4 mm (1/4") tubing (Accessory 4), from the 3.4 m (11’) piece provided, long enough to reach the vacuum pump. Install the tubing onto the other end of the valve.
3. Connect the free end of tubing to a vacuum pump. A piece of rubber tube and a Swagelok union (Accessory 6) have been included which may aid in the connection to the pump.
4. Close the valve on the bottom of the reservoir. Open the bidirectional valve and turn the pump on to start evacuating the system.

Note: A general recommendation for the vacuum pressure level is below 10 Mbar when filling the 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.

5. When the vacuum has been established, remove the fittings from the reservoir top cap and remove the cap. Fill the reservoir with de-aired liquid. Avoid forming bubbles when pouring.
6. Open the valve at the base of the reservoir and allow the de-aired liquid to 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. Monitor the liquid as it nears the vacuum pump and close the bidirectional valve 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.

7. Remove the vacuum pump from the tubing.

2.4.2 FILLING FROM THE FAR END OF THE TUBING

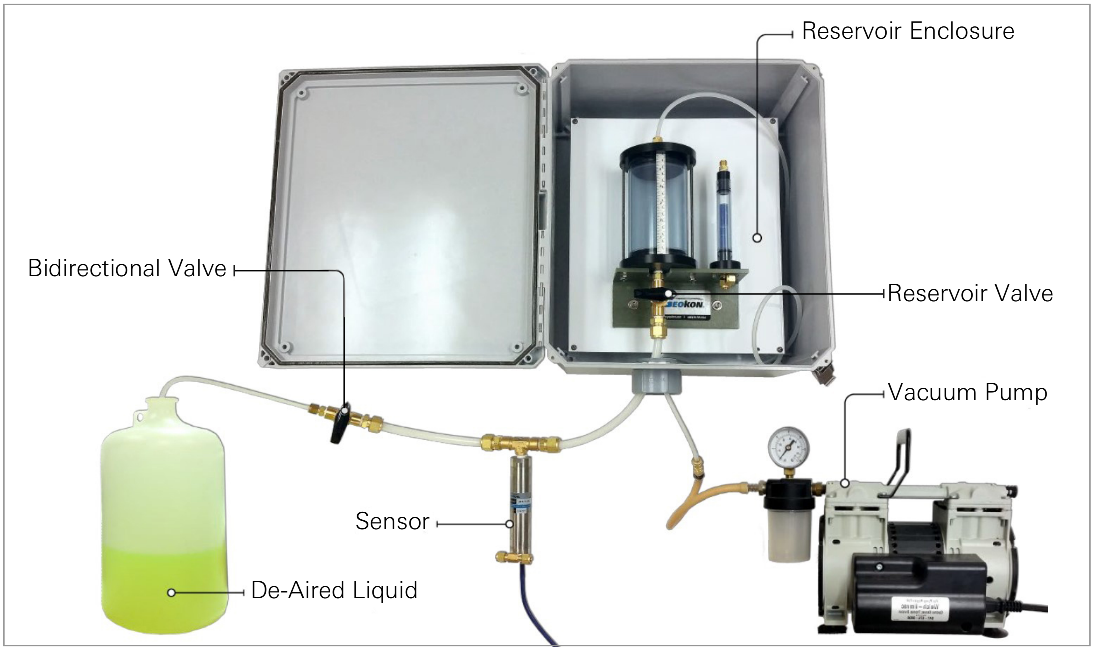

FIGURE 5: *Filling From the Far End of the Tubing*

1. Attach the provided 1.2 m (4’) length of 1/2" tubing (Accessory 3) to the last sensor in the string furthest from the reservoir. Install the provided bidirectional valve (Accessory 5) to the other end of the tubing.
2. Cut a length of 6.4 mm (1/4") tubing (Accessory 4), from the 3.4 m (11’) piece provided, long enough to reach into the bottom of the vessel containing de-aired fluid. Install tubing onto the other end of the valve.
3. Insert the free end of tubing into the vessel. Close the bidirectional valve.

Note: 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 when filling the system.

4. Cut a length of 6.4 mm (1/4") tubing (Accessory 4), from the 3.4 m (11’) piece provided, long enough to reach from the reservoir to a vacuum pump.Install tubing onto the top fitting on the reservoir.
5. Connect the free end of tubing to the vacuum pump. A piece of rubber tube and a Swagelok union (Accessory 6) have been included which may aid in the connection to the pump.
6. Open the valve on the bottom of the reservoir. Turn the pump on to start evacuating the system

Note: A general recommendation for the vacuum pressure level is below 10 Mbar when filling the 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.

7. When the vacuum has been established, open the bidirectional valve at fluid vessel and allow the de-aired liquid to fill the lines up to each sensor. Make sure the liquid level never falls below the end of the fill tube to prevent air from contaminating the tubing. Once fluid has filled the entire system and has entered the reservoir, close the bidirectional valve at the fluid vessel and turn off the pump.

Important! Make sure the liquid level never falls below the end of the fill tube where air could then be introduced into the system.

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

8. Remove the vacuum pump tubing from the reservoir.

2.5 REMOVING AIR AND ADJUSTING LIQUID LEVEL

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 and extract air or liquid from the sensor through the seal screw hole using the small syringe (Accessory 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.

FIGURE 6: *Seal Screw Removal (Left), Using Syringe for Air/Liquid Extraction (Right)*

The level of fluid in the reservoir will need to be adjusted approximately midway. To do this, remove the fittings from the reservoir top cap and remove the cap. Use the supplied large syringe (Accessory 8) to add or remove fluid, making sure to minimize air bubbles. Reinstall the reservoir cap.

2.6 INSTALL THE JUMPER LINE

Use the provided jumper line (Accessory 9) to connect the liquid reservoir to the desiccant chamber. Depending on site conditions, adding or removing the jumper may help to stabilize the sensor readings.

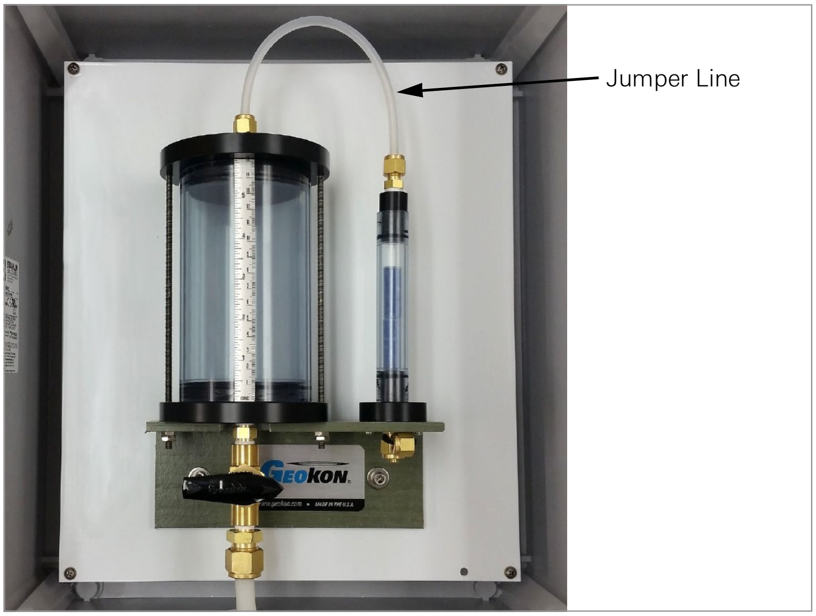

FIGURE 7: *Liquid Reservoir and Desiccant Chamber connected with Jumper*

2.7 ROUTING THE CABLES

Cables from each sensor can be routed to the readout location where they can be connected to a terminal box for manual readout (as shown in Figure 3), or to datalogger as shown in Figure 8.

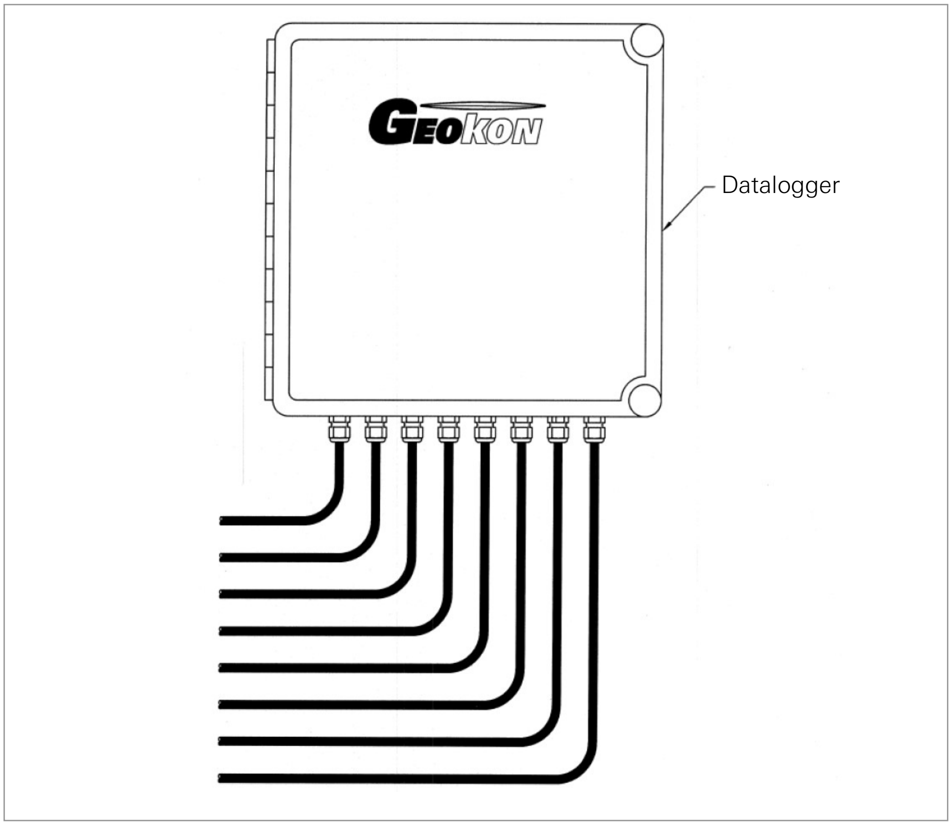

FIGURE 8: *Datalogger*

2.8 SPLICING AND JUNCTION BOXES

Cable splicing should be kept to a minimum since changes in cable resistance can cause changes in calibration if remote sensing techniques or 4-20 mA output are not in use.

The sensor is a semiconductor and, as such, has low-level output signals. **If cables are damaged or improperly spliced, the outputs can be seriously degraded. Therefore, it is absolutely necessary to provide a high degree of cable protection. If cables must be spliced, only recognized high quality techniques should be used.**

Cable used for making splices should be a high-quality twisted pair type, with 100% shielding and an integral shield drain wire. **When splicing, it is very important that the shield drain wires be spliced together.** Splice kits recommended by GEOKON incorporate casts that are placed around the splice and then filled with epoxy to waterproof the connections. When properly made, this type of splice is equal or superior to the cable in strength and electrical properties. Contact GEOKON for splicing materials and additional cable splicing instructions.

2.9 ELECTRICAL NOISE

Care should be exercised when installing sensor cables to keep them as far away as possible from sources of electrical interference such as power lines, generators, motors, transformers, arc welders, etc. Cables should never be buried or run with AC power lines. The sensor cables will pick up the 50 or 60 Hz (or other frequency) noise from the power cable and this will likely cause a problem obtaining a stable reading. Contact the factory concerning filtering options available for use with the GEOKON dataloggers and readouts should difficulties arise.

2.10 LIGHTNING PROTECTION

In exposed locations, it is vital that the sensor be protected against lightning strikes. Lightning protection measures available include:

- Placing a Lightning Arrestor Board (Model 4999-12L), in line with the cable, as close as possible to the installed sensor. These units utilize surge arrestors and transzorbs to protect the sensor. This is the recommended method of lightning protection.
- Terminal boxes available from GEOKON can be ordered with lightning protection built in. The terminal board used to make the sensor connections has provision for the installation of plasma surge arrestors. Lightning Arrestor Boards (Model 4999-12L) can also be incorporated into the terminal box. The terminal box must be connected to an earth ground for these levels of protection to be effective.
- If the sensors will be read manually with a portable readout (no terminal box), a simple way to help protect against lightning damage is to connect the cable leads to a good earth ground when not in use. This will help shunt transients induced in the cable to ground, away from the sensor.

3. TAKING READINGS

After the system is installed and filled, the sensor system zero reading 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 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.

The Model 3655 uses a semiconductor sensor with an output of either 0-5 Volts (Model 3655-2) or 4-20 mA (Model 3655-3). These sensors require an unregulated input of 24 VDC (9-33 VDC).

Readings are taken with an ohmmeter and VDC regulated power supply, use the applicable wiring chart in Appendix C.

Warning! Incorrect connection may cause permanent and irreparable damage to the sensor.

3.1 COMPATIBLE READOUTS AND DATALOGGERS

GEOKON can provide several datalogger options. Devices compatible with this product are listed below. For further details and instruction consult the corresponding Manual(s) at geokon.com/Dataloggers.

Dataloggers

DATALOGGERS:

- **8600 Series**

  The MICRO-6000 Datalogger is designed to support the reading of a large number of GEOKON instruments for various unattended data collection applications through the use of GEOKON Model 8032 Multiplexers. Weatherproof packaging allows the unit to be installed in field environments where inhospitable conditions prevail. The Nema 4X enclosure also has a provision for locking to limit access to responsible field personnel.

Model 4999 Manual

3.2 MODEL 4999 TERMINAL BOXES

Terminal boxes with sealed cable entries are available from GEOKON. These allow many sensors to be terminated at one location with complete protection of the lead wires. The interior panel of the terminal box can have built-in jacks or a single connection with a rotary position selector switch.

For further details and instruction consult the Model 4999 Instruction Manual.

3.3 MEASURING TEMPERATURES

Each sensor is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Appendix C shows which cable conductors are connected to the thermistor. Connect an ohmmeter to the thermistor leads coming from the sensor. 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.

Look up the temperature for the measured resistance in Appendix B.

4. DATA REDUCTION

4.1 SENSOR ELEVATION CALCULATION

Readings can be used to calculate the elevation of the sensor and to plot them on a graph versus time. For all types of sensors, the readings will get larger as the sensors settle relative to the reservoir.

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

$$E = E_0 - (R_1 - R_0)G \times 0.1022 + \Delta E_{RES}$$

EQUATION 1: *Elevation*

Where:
E_0 = The sensor elevation at installation in meters.
R_1 = The current readings in digits.
R_0 = The initial reading in digits.
G = The calibration factor, supplied with the sensor.
0.1022 = The conversion factor which converts kPa into meters of pure water.
ΔE_{RES} = Any change of the fluid level inside the reservoir, converted into meters. If the fluid level falls, ΔE_{RES} is negative. If the fluid level rises, ΔE_{RES} is positive.

FOR EXAMPLE:

The installed sensor elevation is 541.62 meters. The initial reading (R_0) of the sensor is 10.400 mA. The current reading (R_1) is 13.601 mA. The gauge factor (G) is 2.507 kPa/mA. The level of water in the reservoir sight tube is 10 mm **lower** (-10 mm, or -0.010 m)(ΔE_{RES}) than the level measured at the time of the initial reading. The elevation calculation is:

$$E = E_0 - (R_1 - R_0)G \times 0.1022 + \Delta E_{RES}$$

$$E = 541.62 - (13.601 - 10.400)2.507 \times 0.1022 + (-0.010)$$

$$E = 540.8 \text{ meters}$$

The installed sensor elevation and calculated elevation are subtracted, giving a total settlement of 0.82 meters at this sensor relative to the reservoir location.

4.2 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.

4.3 TEMPERATURE CORRECTION

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 combined with Equation 1 is:

$$E_{corrected} = E_0 - [(R_1 - R_0)G \times 0.1022 + (T_1 - T_0)K] + \Delta E_{RES}$$

EQUATION 2: *Elevation with Temperature Correction*

Where:
T_1 = The current temperature in °C.
T_0 = The initial temperature in °C.
K = The temperature correction factor in meters/°C. This factor can 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 slope of the line from a plot of temperature v mA.

5. TROUBLESHOOTING

Technical Support

Maintenance is confined to replacing desiccant capsules (Accessory 10) in the desiccant chamber. Desiccant capsules are dark blue when active and pink when inactive. Maintenance and troubleshooting of the sensor is confined to periodic checks of cable connections and maintenance of terminals. Once installed, the sensor is usually inaccessible and remedial action is limited.

Should difficulties arise, consult the following list of problems and possible solutions. For additional troubleshooting and support visit geokon.com/Technical-Support.

SYMPTOM: SENSOR READINGS ARE UNSTABLE

☐ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, transformers, arc welders and antennas. Make sure the shield drain wire is connected to ground.

☐ Does the readout or datalogger work with another sensor? If not the readout or datalogger may have a low battery or be malfunctioning. Consult the appropriate readout manual for charging or troubleshooting.

☐ The sensor may have been damaged by over-ranging or shock. Inspect the diaphragm and housing for damage.

SYMPTOM: SENSOR FAILS TO GIVE A READING

☐ Is the cable cut or crushed? This can be checked with an ohmmeter. This can be checked with an ohmmeter. If the resistance reads infinite or very high (megohms), a cut wire must be suspected. If the resistance reads very low (<100Ω), a short in the cable is likely.

☐ Does the readout or datalogger work with another sensor? If not the readout or datalogger may have a low battery or be malfunctioning. Consult the appropriate readout manual for charging or troubleshooting.

SYMPTOM: THERMISTOR RESISTANCE IS TOO HIGH

☐ Check for an open circuit. Check all connections, terminals, and plugs. If a cut is in the cable, splice according to instructions in Section 2.8.

SYMPTOM: THERMISTOR RESISTANCE IS TOO LOW

☐ Check for an open circuit. Check all connections, terminals, and plugs. If a cut is in the cable, splice according to instructions in Section 2.8.

☐ Water may have penetrated the interior of the sensor. There is no remedial action.

APPENDIX A. SPECIFICATIONS

A.1 MODEL 3655 SPECIFICATIONS

Model	**3655-2**	**3655-3**
Output	0-5 VDC	4-20 mA
Supply Voltage	24 VDC (9-33 VDC)	
Pressure Range	Vacuum to 350 mbar (5 psi)	
Over Pressure	2 x Full Scale (F.S.)	
Performance		
Long Term Stability	0.1% F.S./year	
Accuracy	≤ 1.5 psi Range: ±0.25% F.S. > 1.5 psi to ≤ 5 psi Range: ±0.1% F.S.	
Compensated Temperatures	0° to 70 °C (32° to 160 °F)	
Operating Temperatures	-20 to 80 °C (-4 to 176 °F)	
Mechanical Configuration		
Wetted Parts	316L Stainless Steel & Brass	
Electrical Connection	see ordering chart	
Vibration	10 g, 4 to 2000 Hz	
Liquid Tubing	2.7 mm (1/2") Nylon	
Vent Tubing	6.4 (1/4") Polyethylene	
Cable	04-375V9: 4 twisted pairs, Violet PVC Jacket, 9.53 mm Ø	02-250V6: 2 twisted pairs, Blue PVC Jacket, 6.35 mm Ø

TABLE 1: *Model 3655 Multipoint Hydraulic Leveling System Specifications*

A.2 THERMISTOR

See Appendix B for more information.

Range: -80 to +150 °C

Accuracy: ±0.5 °C

A.3 SENSOR DIMENSIONS

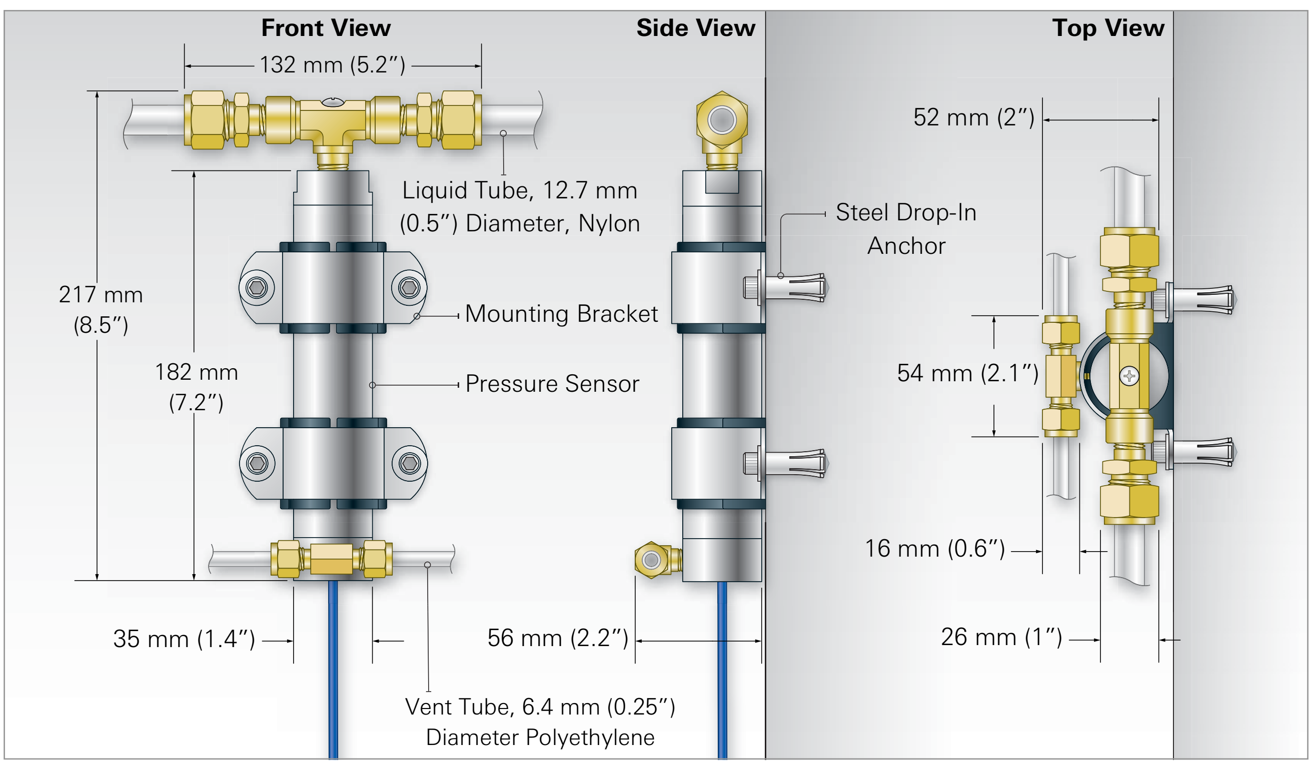

FIGURE 9: *Model 3655 Sensor Dimensions*

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

B.1 3KΩ THERMISTOR RESISTANCE

Thermistor Types include YSI 44005, Dale #1C3001–B3, Alpha #13A3001–B3, and 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 2: *3KΩ Thermistor Resistance*

APPENDIX C. WIRING CHARTS

Warning! Incorrect connection may cause permanent and irreparable damage to the sensor.

C.1 0-5 VOLT DIRECT CURRENT OUTPUT SENSORS

Multimeter set to read in Volts (V) DC and power supply set at 24 VDC (9-33 VDC).

GEOKON **Cable #04-375V9 (Violet)**	**Multimeter Connection**	**Power Supply Connection**	**Function/Description**
Red	N/C	Red (+)	Power +
Red's Black	N/C	Black (-)	Power -
White	Red (+)	N/C	Signal +
White's Black	Black (-)	N/C	Signal -
Blue	N/C	N/C	Thermistor
Blue's Black	N/C	N/C	Thermistor
Shield	N/C	N/C	Ground

TABLE 3: *0-5 Volt Direct Current Output Sensors*

C.2 4-20 MILLIAMP OUTPUT SENSORS

Multimeter set to read in milliamps (mA) DC and power supply set at 24 VDC (9-33 VDC).

Connect the black (-) leads of the multimeter and power supply together.

GEOKON **Cable #02-250V6 (Blue)**	**Multimeter Connection**	**Power Supply Connection**	**Function/Description**
Red	N/C	Red (+)	Power +
Black	Red (+)	N/C	Power -
White	N/C	N/C	Thermistor
Green	N/C	N/C	Thermistor
Shield	N/C	N/C	Ground

TABLE 4: *4-20 Milliamp Output Sensors*

APPENDIX D. TYPICAL CALIBRATION REPORT

GEOKON

Pressure Transducer Calibration Report

This Calibration has been Verified/ Validated as of: August 28, 2020

Model Number: 3655-2-10 kPa

Date of Calibration: August 18, 2020

Serial Number: 2034562

Temperature: 22.43 °C

Pressure Range: 10 kPa

Technician:

Calibration Instruction: CI-Pressure Transducers 7 kPa~3.5 MPa

Applied Pressure (kPa)	Gauge Reading (Volts) 1st Cycle	Gauge Reading (Volts) 2nd Cycle	Average Gauge Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0	0.006	0.006	0.006		0.03	0.00
2	0.972	0.972	0.972	0.97	0.00	0.00
4	1.938	1.938	1.938	0.97	-0.04	-0.02
6	2.907	2.907	2.907	0.97	-0.01	0.01
8	3.876	3.875	3.876	0.97	0.00	0.01
10	4.844	4.844	4.844	0.97	0.02	-0.01

Linear Gauge Factor (G): 2.0668 (kPa / Volt) **Regression Zero: 0.0045**

Polynomial Gauge Factors: A: -8.87E-04 B: 2.0711 C: -0.012

Calculated Pressures: **Linear, $P = G(R_1 - R_0)$**

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

Factory Zero Reading: Input Voltage: 24 VDC

Wiring Code: See manual for further information.

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: *Model 3655-2 Typical Calibration Report*

GEOKON

Pressure Transducer Calibration Report

This Calibration has been Verified/ Validated as of: October 16, 2019

Model Number:	3655-3-10 kPa	Date of Calibration:	October 10, 2019
Serial Number:	1941435	Temperature:	22.6 °C
Pressure Range:	10 kPa	Technician:	

Calibration Instruction: CI-VW Pressure Transducers 7 kPa~3 MPa

Applied Pressure (kPa)	Gauge Reading (mA) 1st Cycle	Gauge Reading (mA) 2nd Cycle	Average Gauge Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0.0	4.022	4.019	4.021		0.03	0.02
2.0	7.107	7.110	7.109	3.09	-0.02	-0.02
4.0	10.204	10.205	10.205	3.10	-0.03	-0.02
6.0	13.306	13.305	13.306	3.10	0.00	0.01
8.0	16.406	16.405	16.406	3.10	0.02	0.03
10.0	19.497	19.498	19.498	3.09	0.00	-0.02

Linear Gauge Factor (G): **0.6459** **(kPa/ mA)** **Regression Zero:** **4.016**

Polynomial Gauge Factors: A: **-4.33E-05** **B:** **0.6469** **C:*** **-2.60**

Calculated Pressures: **Linear,** $P = G(R_1 - R_0)$

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

Input Voltage: 24 VDC

Wiring Code: See manual for further information.

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 11: *Model 3655-3 Typical Calibration Report*

APPENDIX E. SWAGELOK TUBE FITTING INSTRUCTIONS

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

E.1 INSTALLATION

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

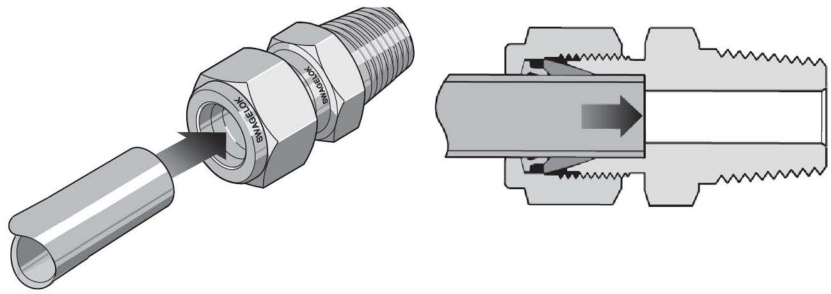

FIGURE 12: *Tube Insertion*

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.

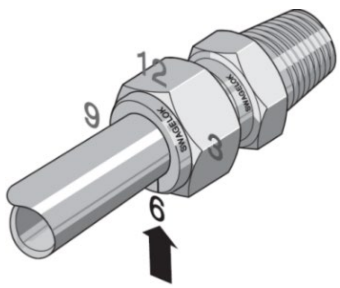

FIGURE 13: *Make a Mark at Six O'clock*

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-inch, 1/8-inch, 3/16-inch, 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.

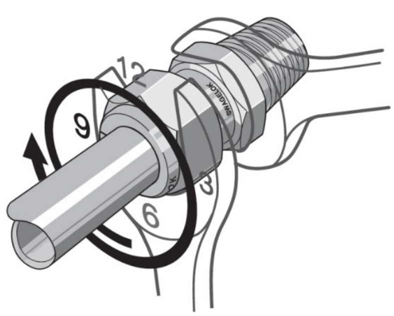

FIGURE 14: *Tighten One and One-Quarter Turns*

E.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 15: *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 pre-swaged ferrules into the fitting until the front ferrule seats against the fitting body.

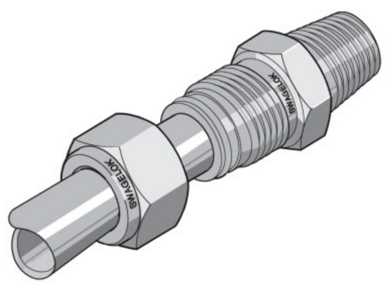

FIGURE 16: *Ferrules Seated Against Fitting Body*

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.

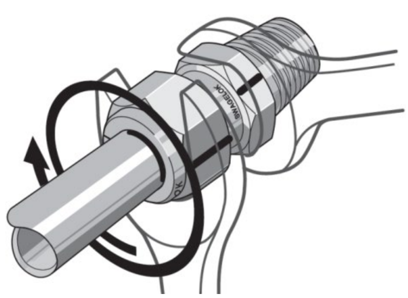

FIGURE 17: *Tighten Nut Slightly*

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