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Model 3650

Multipoint Settlement System

(Doc Rev Initial, 7/13)

Warranty Statement

Geokon, Inc. 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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Table of Contents

List of Figures

1. General Description

The Model 3650 Settlement System is a multipoint settlement system comprised of a series of sensitive pressure transducers connected together by a common 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. Pictures of the sensors and reservoir are shown in figures 1 and 2.

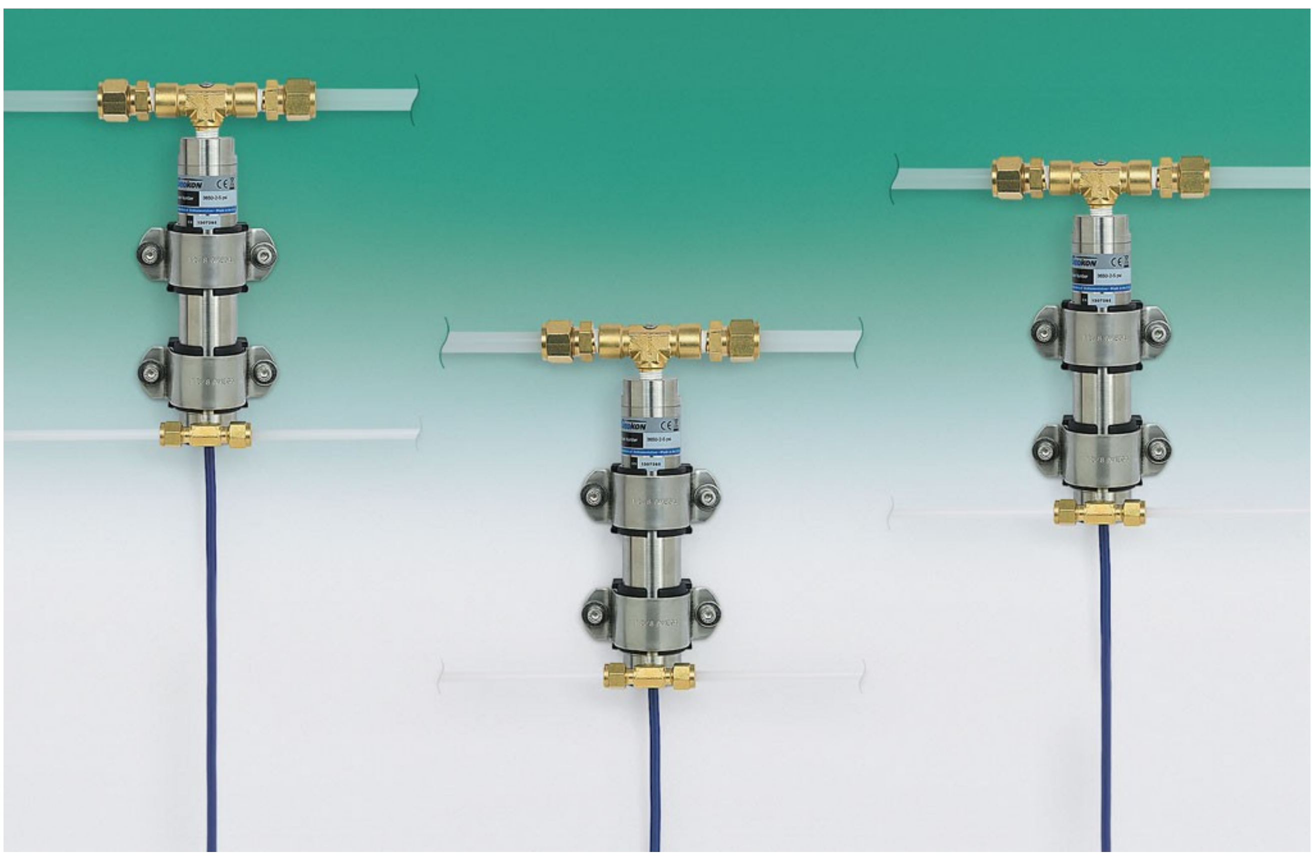

Figure 1 Model 3650 Settlement Sensors

Figure 2 Model 3650 Reservoir

2. Installation

2.1 Installing the sensor

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 sensors are installed by attaching the supplied bracket to the concrete or other surface using either the drop in style anchor or bolts or studs that are welded to or screwed into the steel or other material as shown in Figure 3.

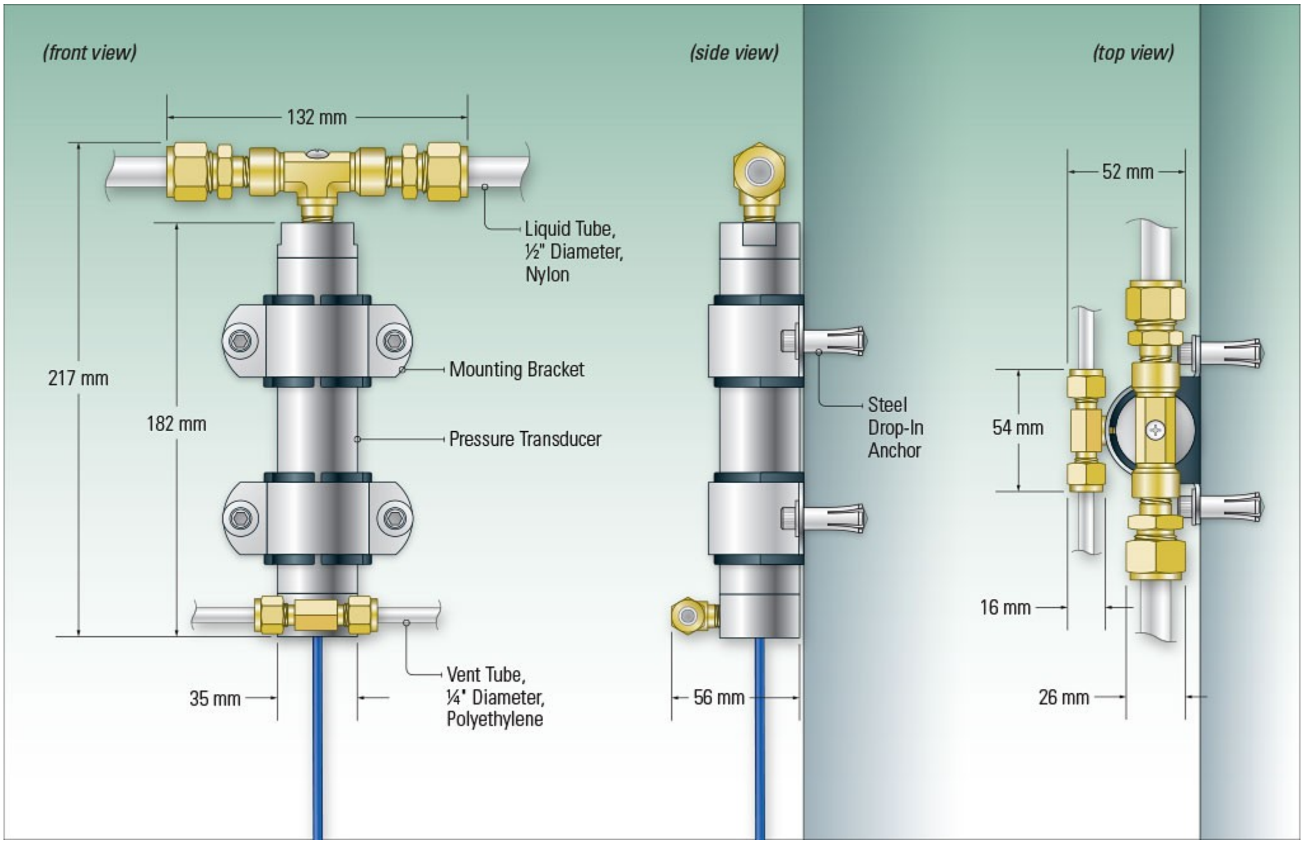

Figure 3 Model 3650 Mounting details

The sensor should be installed in the brackets with the liquid line (the larger one) on top and, preferably, in an area that can be shielded from direct sunlight. The Reservoir should be attached to a stable structure or one that can easily be level surveyed to. If possible it should also be protected from direct sunlight, which can cause evaporation and fluctuating temperatures will also change the specific gravity of the fluid which can be difficult to correct for.

2.2 Installing the tubing

The tubing should be installed after the sensors and reservoir have been fixed in position. The liquid tubing runs should be as straight as possible, without rises and dips and, if possible, in a general upward grade towards the reservoir. Siphons must be avoided at all cost. The vent line is much less critical but can be run in parallel to the liquid line for convenience. Tee connectors are supplied for both the liquid and air lines and the reservoirs are delivered with both tubing connectors and caps depending on whether or not the system is a series or "branch" system or a combination of the two.

3. Filling the System

Eliminating air from the system is very important.

The liquid used in the system must be one of a known specific gravity in order to convert the sensor gage factor, which is presented in kPa/mA to mm/mA. The conversion from kPa to mm of pure water is: 1 kPa = 102.2mm of water. If a mixture of water and anti-freeze, such as ethylene glycol, or propylene glycol, is used, the specific gravity of the fluid must be measured and the gage factor adjusted accordingly by dividing the 102.2 number by the specific gravity. If just pure water is used a very small amount of ethylene glycol anti-freeze, or copper sulphate can be added to prevent the growth of algae.

Filling the system is sometimes the most difficult job due to the problems associated with entrapped air bubbles and how to remove them. The ideal setup for filling this system is to connect a large filling supply with a shutoff valve to the system at the farthest point from the reservoir, then, using a vacuum pump (e.g a Mytivac vacuum pump, (available as an accessory), apply a slight vacuum (-0.25 to -O.5bar) to the liquid line at the reservoir end after first removing the tube from the reservoir. When the vacuum has been established the liquid is allowed to flow and will fill the lines up to each sensor. A small amount of air may be entrapped inside the sensor which can be bled off by removing the seal screw on the top of the tee fitting on the sensor by extracting air or liquid through the seal screw hole from the sensor using the syringe supplied. When all of the air has been removed from all sensors and lines, reconnect the liquid line to the

reservoir and fill the reservoir to the desired elevation. Any air in the reservoir connection can be prevented by allowing liquid to drain from the reservoir while the connection is being made. If no vacuum source is available the system can be filled from the reservoir and entrapped air can be removed from the system by "chasing" any bubbles to the sensor or nearest fitting and
slightly opening the connections to allow the air to escape. Be sure to keep an adequate amount of liquid in the reservoir when bleeding air from the system.

4. Taking Readings

Readout is accomplished by using a 12 or 24 volt power supply and a DVM set to amps, or by a datalogger, (e.g. Geokon Micro 10 datalogger).

The 4-20mA sensors are normally supplied with gage factors in kPa/mA and these are nearly identical from sensor to sensor. Each gage factor is then converted to mm/mA so that the readings, R, in milliamps, can be converted into the height of the fluid column between reservoir and sensor.
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. Data Reduction

5.1 Calculation of Sensor Elevation

Readings can be used to calculate the elevations of each sensor and to plot them on a graph versus time. For the standard 3650 settlement system using 4-20mA type sensors the readings will get larger as the sensors settle relative to the reservoir.

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

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

Where $\mathbf{E_0}$ is the sensor elevation at installation in meters

$\mathbf{\Delta E_{RES}}$ is any change of the fluid level inside the reservoir. If the fluid level falls, ΔE_{RES} is negative. If the fluid level rises, ΔE_{RES} is positive.

$\mathbf{R_0}$ is the initial sensor reading in mA

$\mathbf{R_1}$ is the subsequent sensor reading in mA

G is the calibration factor supplied with the sensor in kPa/mA.

0.1022 is the conversion factor m/kPa for pure water.

A **typical** calibration sheet as supplied by the factory, for a system using water as the liquid, is shown in figure 4 (on page 7).

Example:

$\mathbf{E_0}$ = 541.62 meters

$\mathbf{R_0}$ = 10.400mA

$\mathbf{R_1}$ = 13.601mA

G = 2.19kPa/mA

$\mathbf{\Delta E_{RES}}$ = –10mm (i.e. the level of water in the reservoir sight tube is 10mm lower than the level measured at the time of the initial reading).

So the new sensor elevation is

$$E = 541.62 - (13.601-10.400) \times 2.19 \times 0.1022 - (-0.010)$$

E= 540.89 meters

Or, in other words, there has been a settlement of 0.73 meters at this sensor relative to the reservoir location..

5.2 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.

5.3 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 temperature correction to the elevation, $\mathbf{E_{T,}}$ is given by:

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

Where $\mathbf{T_0}$ is the initial temperature and $\mathbf{T_1}$ is the current temperature, in ºC, and **K** is the temperature correction factor in meters/ºC that 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.

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Pressure Transducer Calibration Report

Model Number: 3650-2-5 PSI

Date of Calibration: March 29, 2013

Serial Number: 1307286

Temperature: 22.5

Pressure Range: 35 kPa

†Barometric Pressure: 996.1

Calibration Instruction: CI-VW Pressure Transducers

Technician: [signature]

Applied Pressure (kPa)	Gage Reading (mA) 1st Cycle	Gage Reading (mA) 2nd Cycle	Average Gage Reading	Change	Linearity (%FS)	Polynomial Fit (%FS)
0	3.998	3.998	3.998		-0.03	-0.02
7	7.210	7.211	7.211	3.21	0.05	0.05
14	10.399	10.398	10.399	3.19	-0.02	-0.03
21	13.602	13.599	13.601	3.20	0.00	-0.01
28	16.803	16.801	16.802	3.20	0.01	0.01
35	19.999	19.999	19.999	3.20	-0.01	0.00

Linear Gage Factor (G): **2.19** **(kPa/ mA)** **Regression Zero:** **4.003**

Polynomial Gage Factors: A: **9.02E-05** **B:** **2.19** **C:*** **-8.75**

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.

Figure 4 – A Typical Calibration Sheet