



RST INSTRUMENTS LTD.

MEMS Horizontal Inclinometer System

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MEMS Horizontal Inclinometer System

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Product: MEMS Horizontal Inclinometer System
Installation Manual

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1 GENERAL DESCRIPTION

The RST Micro Electro Mechanical Systems (MEMS) Horizontal Inclinometer System represents a breakthrough in inclinometer system technology, providing unprecedented accuracy, efficiency and ease of use. The system is comprised of a MEMS Horizontal Inclinometer Probe, Cable system, Reel with battery power, and a Windows Pocket PC™ that functions as a readout, analysis, and data storage device.

Wireless communication between the inclinometer control reel and the Pocket PC™ ensures ease of use and reliability, by removing two weaknesses inherent in conventional analog inclinometer systems. By removing the physical connection between the inclinometer control cable and the readout instrument there is no concern with fragile connectors, cable related failure and related reliability problems. The Achilles heel of any inclinometer control cable reel is the slip ring required to maintain electrical contact as the reel revolves. As the RST system is wireless from the control cable to the readout, a slip ring is not required, and there are no associated electrical continuity problems.

The RST MEMS Horizontal Inclinometer Probe incorporates cutting edge MEMS (Micro Electro Mechanical Systems) technology providing high precision and durability. A highly accurate survey of the inclinometer casing is used to establish the initial position of the casing. Any subsequent deviations in the casing from this initial value (i.e. baseline reading) represent changes occurring in the subsurface. The RST MEMS Horizontal Inclinometer System can accurately measure the rate, depth and magnitude of these deviations.

The RST MEMS Horizontal Inclinometer System is designed to provide complete profiles of differential settlements. Typical applications include monitoring settlement and heave in dams, landfills, embankments and under storage tanks.

The information included in this manual outlines the use and care of the RST MEMS Horizontal Inclinometer System. It provides descriptions of how to take readings and interpret the data. For more information on the installation of inclinometer casing, and other related issues, please contact RST Instruments Ltd.

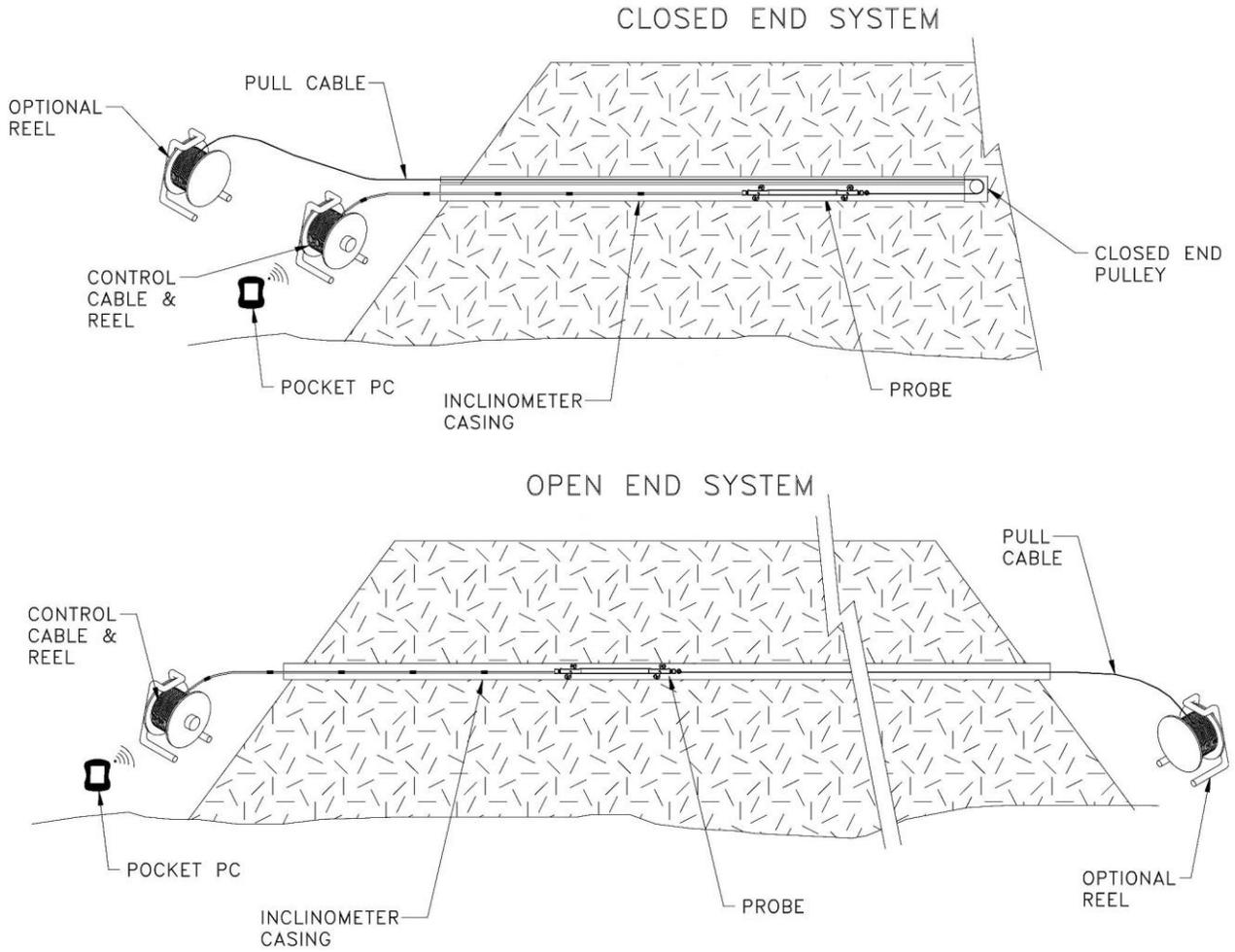


Figure 1 – Closed & Open End MEMS Horizontal Inclinometer System

2 INTRODUCTION

Please Note

This manual assumes the user has a working knowledge of how to use the RST Digital Inclinometer System. The function of the MEMS Horizontal Inclinometer Probe is very similar to the standard biaxial (vertical) probe. If not familiar with this system, please refer to the Digital Inclinometer System Instruction Manual (in addition to this manual).

An initial survey is required to obtain base line readings. Data from future surveys will be compared to the base line. From the collected data, a profile of the inclinometer casing indicating the magnitude of settlement or heave is produced. Each individual survey requires the probe to be drawn or pulled through the casing, then reversed and passed through the casing again (probe is reversed end for end – not rotated axially 180° as in a vertical inclinometer survey). Measurements are collected at 0.5m intervals with the metric probe or 2 ft. intervals with the imperial probe.

Data is retrieved directly on the iPAQ™ Pocket PC™ via a wireless link to the Digital Cable Reel. A profile can be generated on the inclinometer readout immediately following the survey. Alternatively, the data may be transferred to a computer and imported into MS Excel or other popular spreadsheet software. RST Inclinalysis™ software can also be used to quickly and efficiently reduce the data and produce plots.

3 UPON RECEIVING THE MEMS HORIZONTAL INCLINOMETER PROBE

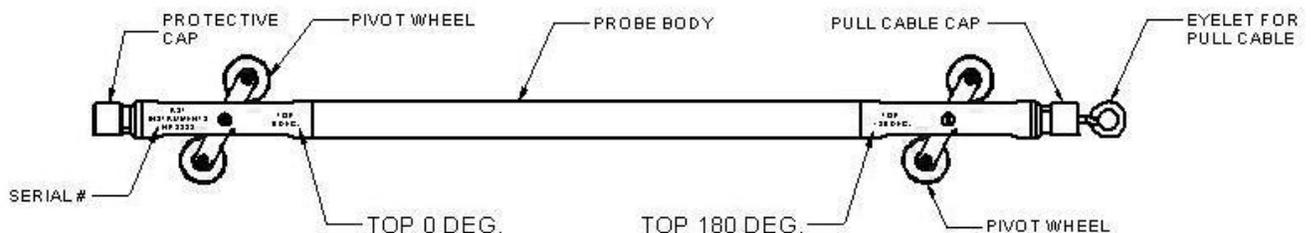


Figure 2 – MEMS Horizontal Inclinometer Probe Details

3.1 REQUIRED ITEMS

To map the profile of settlement or heave, the following items are required:

1. MEMS Horizontal Inclinometer Probe
2. Inclinometer Cable & Digital Reel (site specific length)
3. Pull cable
4. Inclinometer Readout (iPAQ Pocket PC)
5. Inclinometer casing

3.2 FUNCTIONALITY TEST

Before deploying the unit in the field, it is always a good idea to test the instrument and to verify that it is working correctly. This is also a chance to familiarize yourself with the RST Digital Inclinometer Program and its functionality.

- Connect the MEMS Horizontal Probe to the Reel via the end with the serial number (Top 0 DEG., Figure 2).
- Power on the Digital Reel and then turn on the iPAQ Pocket PC™.
- Launch the Digital Inclinometer program and wait for the unit to connect to the Reel (this may take a few moments). The status of the connection can be monitored at the bottom of the Main Menu screen. If you would like to verify that the wireless connection has been made, press the *Status* button. A screen will appear showing the connections (see Figure 3.).
- Under the *Calibration* tab, *Sensor Type* should read “MEMS” & *Probe Type* should read “Digital Horizontal” as in Figure 4.

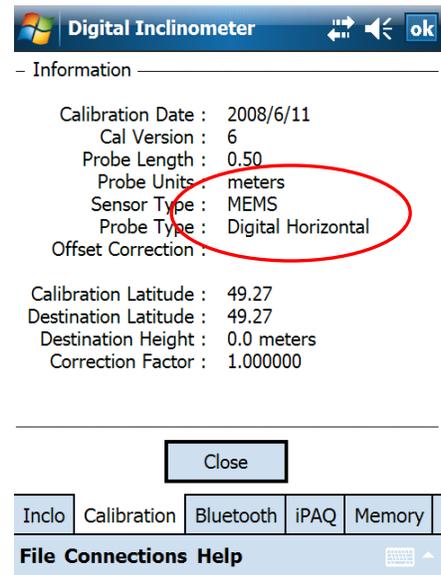
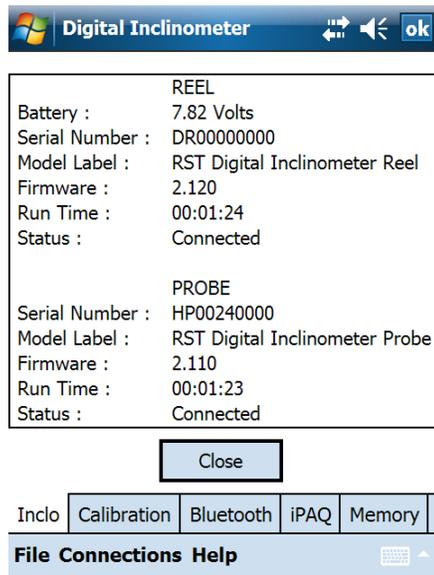


Figure 3 – Connection Info.

Figure 4 – Calibration Screen

- If any information is blank, then the connection was not successful. Refer to the *Digital Inclinometer System Manual* for more information. Press *OK* when complete.
- Create a site and borehole for the instrument. When complete, press the *Readings* button to display real-time readings from the probe. The readings screen should appear as follows:

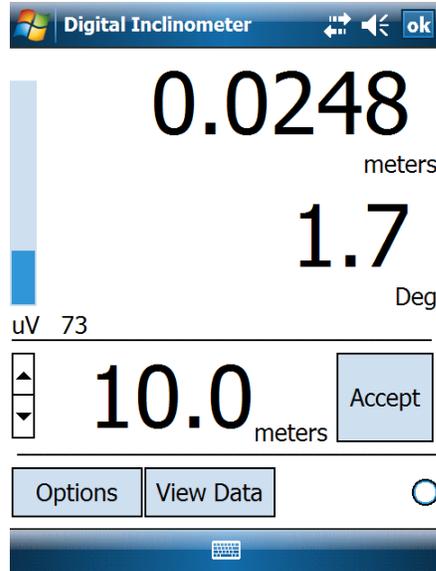


Figure 5 – Readings Screen

- Verify that the probe's signal increases or decreases as its angle with respect to the horizon. A positive deviation is given when the Top 0 DEG end is tilt above the TOP 180 DEG End (see figure 7). If the system is not functioning as expected, contact RST Instruments Ltd. for technical support.
- Verify that the probe's signal increases or decreases as its rotate with respect to the horizon axis. A positive deviation is given when the MEMS Horizontal Probe rotate clockwise along horizontal axis (See Figure 8). If the system is not functioning as expected, contact RST Instruments Ltd. for technical support.

4 OPERATING PROCEDURE

Caution

The MEMS Horizontal Inclinator Probe houses sensitive sensors and should be handled with care. Do not drop or impact the probe. Doing so will create a significant offset in the probe, permanently damaging the sensors or requiring the probe to be re-calibrated. RST highly recommends having the probe calibrated on an annual basis to ensure consistent and accurate results.

Note

Ensure the iPAQ battery is fully charged before attempting to take readings. Consult the Digital Inclinator Manual for further instructions on battery management. If the iPAQ Pocket PC™ battery becomes depleted, the Digital Inclinator program will be lost and will have to be restored from the iPAQ Backup location.

This procedure will work for both Close & Open Ends Horizontal Inclinator systems (Figure 1).

1. Run the Pull Cable through the installed inclinometer casing.
2. Remove the threaded dust caps from each end of the probe and store in a safe place.
3. Thread the Pull Cable Cap onto the connector at the Top 180 DEG end.
4. Connect the Pull Cable to the eye of the Pull Cable Cap.
5. Connect the Digital Inclinator cable to the Top 0 DEG end of the Inclinator Probe.
6. Insert the probe, Top 180 DEG end first, into the installed Inclinator Casing with the **wheels located in the bottom groove. Make sure the writings are not upside down.**
7. Pull the probe through the casing until it reaches the far end with the last possible inclinometer cable ferrule snug against the near end of the casing. Make note of how far the probe was inserted, as this will have to be setup on the Pocket PC™.
8. Power on the Digital Inclinator Reel and launch the Digital Inclinator Program on the Pocket PC™. Refer to the Digital Inclinator Manual for instructions of how to use the RST Digital Inclinator Program. A site and borehole needs to be created.
9. After creating a site and borehole, press the *Readings* button to perform a survey. The readings screen should appear as depicted in Figure 5.
10. With the inclinometer cable ferrule tight against the end of the casing and the Pull Cable taught, allow the probe to equalize and then take a reading (i.e. when the noise bar on the side of the unit is at a minimum). Press *Accept* to advance to the next interval.
11. Pull on the inclinometer cable until the next ferrule can be placed tight against the end of the casing.
12. Repeat steps 10-11 until the last ferrule reading has been logged.
13. The Digital Inclinator program will then prompt you to disconnect and rotate the probe. The following screen will appear:

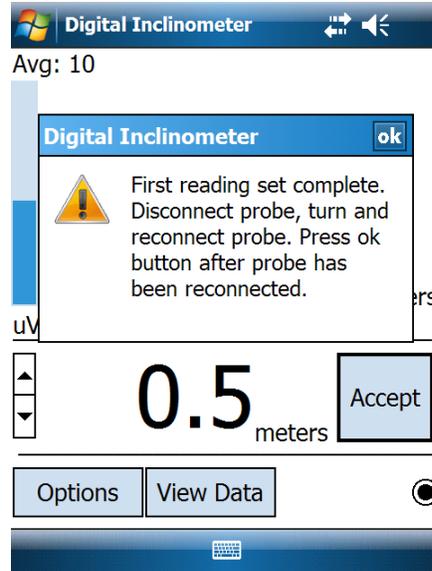


Figure 6 – Turn Probe Screen

WARNING: DO NOT press OK until you have turned the probe and reconnected it!

14. Disconnect the inclinometer cable from the probe.
15. Remove the Eyebolt cap (with Pull Cable attached) and thread onto other end of the probe (Top 0 DEG end).
16. Turn (do not rotate) the probe 180 degrees and then connect the inclinometer cable to the TOP 180 DEG end of the probe. Re-insert the probe, TOP 0 DEG end first, into the casing with the **wheels located in the bottom groove. Make sure the writings are not upside down.**
17. Press OK and Repeat steps 6-12 (take a second set of readings). During the second pass, the instrument checksum will be displayed on the readings screen. The checksum can be used to gauge the quality of the reading (identify if a location error has been made). Please refer to the Digital Inclinometer system manual for further information on checksums.
18. Disconnect the Inclinometer Cable and Pull Cable and replace Protective Caps.
19. Upon returning to the office, clean the probe and wheel assemblies if needed.
20. Create and ActiveSync connection with your desktop PC and copy the data to a safe location. Please refer to the Digital Inclinometer System for more information.

5 REDUCTION OF DATA

5.1 READING

The readings taken represent the vertical displacement, defined by $(\frac{1}{2}m) * (\text{SIN}(a))$, where “a” is the angle between the horizon and the longitudinal axis of the probe. A positive reading from Top 0 DEG end indicates settlement and a negative reading indicates heave. The opposite applies if the Inclinometer Cable is connected to the opposite side (Top 180 DEG end). For instance, Figure 7 below is showing settlement.

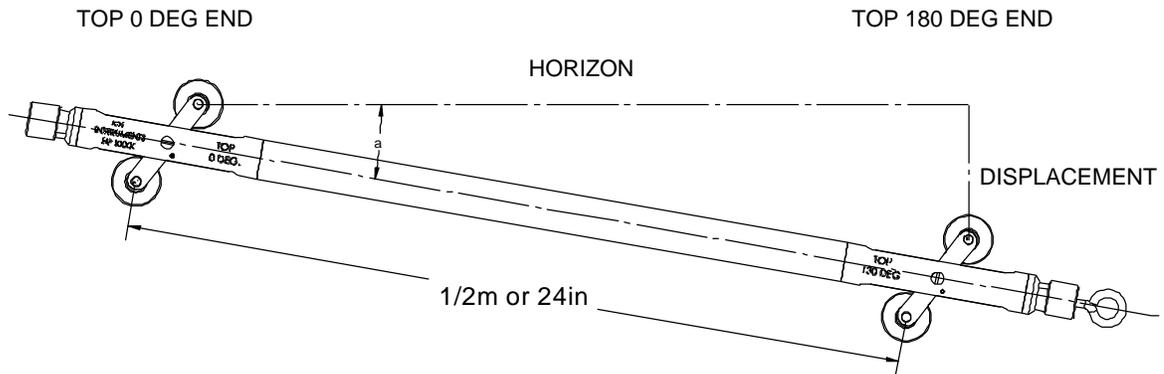


Figure 7 – Vertical Displacement

Refer to the *Digital Inclinometer System Manual* for instructions on reducing the data in the field. Data can be plotted on the Pocket PC™ and errors discovered.

Data reduction can be performed in several ways including:

1. Plot the data in the field on the Pocket PC™ using the RST Digital Inclinometer Software.
2. Use RST Inclinalysis™ software on your desktop or laptop PC.
3. Import the *.csv files directly into Microsoft Excel™.

5.2 SIGN CONVENTIONS

The MEMS Horizontal Inclinometer Probe houses two MEMS accelerometers, which measure tilt in horizontal axis and the rotation along horizontal axis (see figure 7 & 8). Proper installation of the inclinometer casing attempts to align one set of grooves in line with the vertical plane of expected movement.

When an inclinometer casing is surveyed for the first time (i.e. baseline readings), it is necessary to insert the TOP 180 DEG end of the MEMS Horizontal Probe first into the inclinometer casing so that each time a survey is repeated, the probe will always have the same orientation in the casing.

In practice, it is often difficult to achieve exact orientation of grooves relative to some predetermined direction. The groove closest to the anticipated movement direction is usually chosen as the main reference direction. It is recommended that this direction (A+) be marked on the casing itself to ensure surveys are performed in the same manner each time.

The azimuth of this groove direction can be measured in a clockwise direction from the main reference direction (A+). All subsequent measured inclinometer movements would be referred to this direction.

The RST MEMS Horizontal Inclinometer System uses the industry standard sign convention, where tilt in the direction of the Top 0 DEG end results in a positive deviation and tilt in the direction of the Top 180 DEG end results in a negative deviation (see Figure 7).

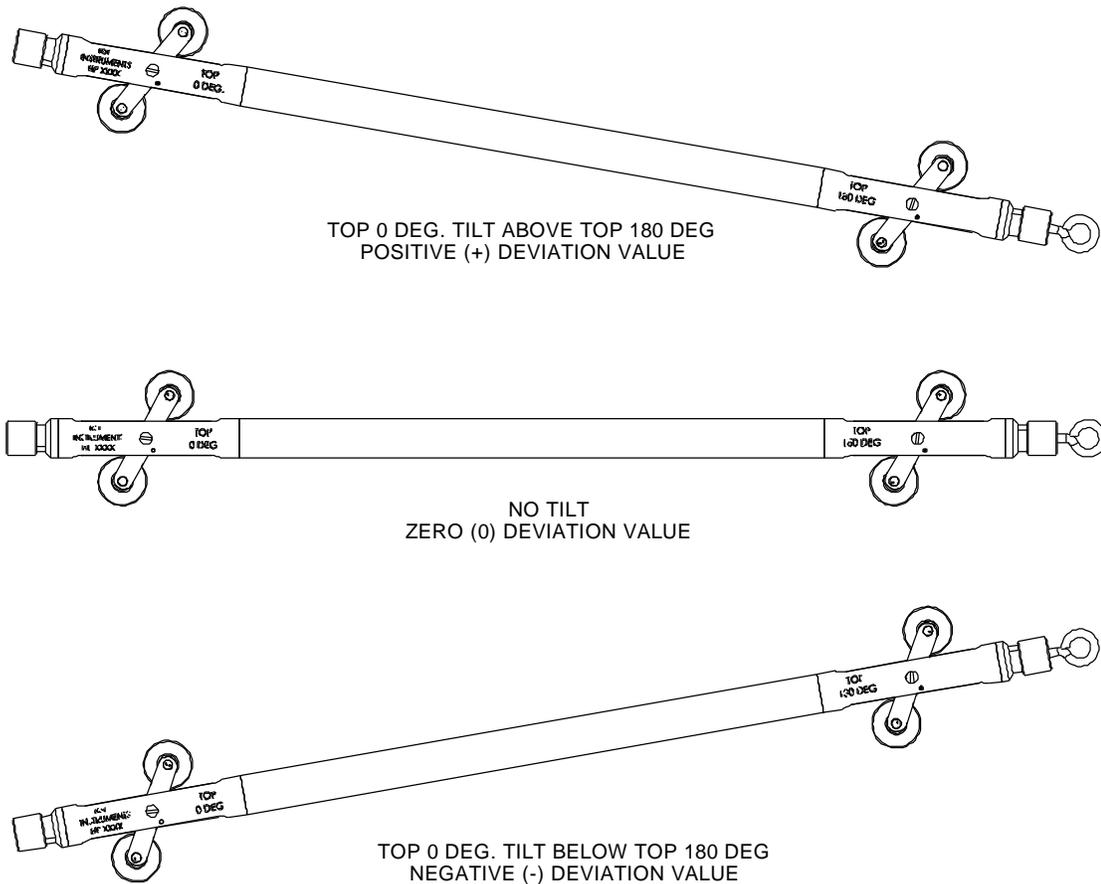


Figure 8 – Tilt Sign Convention

Rotation clockwise along horizontal axis (when the TOP 0 DEG end is toward you) results in a positive deviation and rotation counterclockwise along horizontal axis (when the TOP 0 DEG end is toward you) results in a negative deviation (see Figure 8).

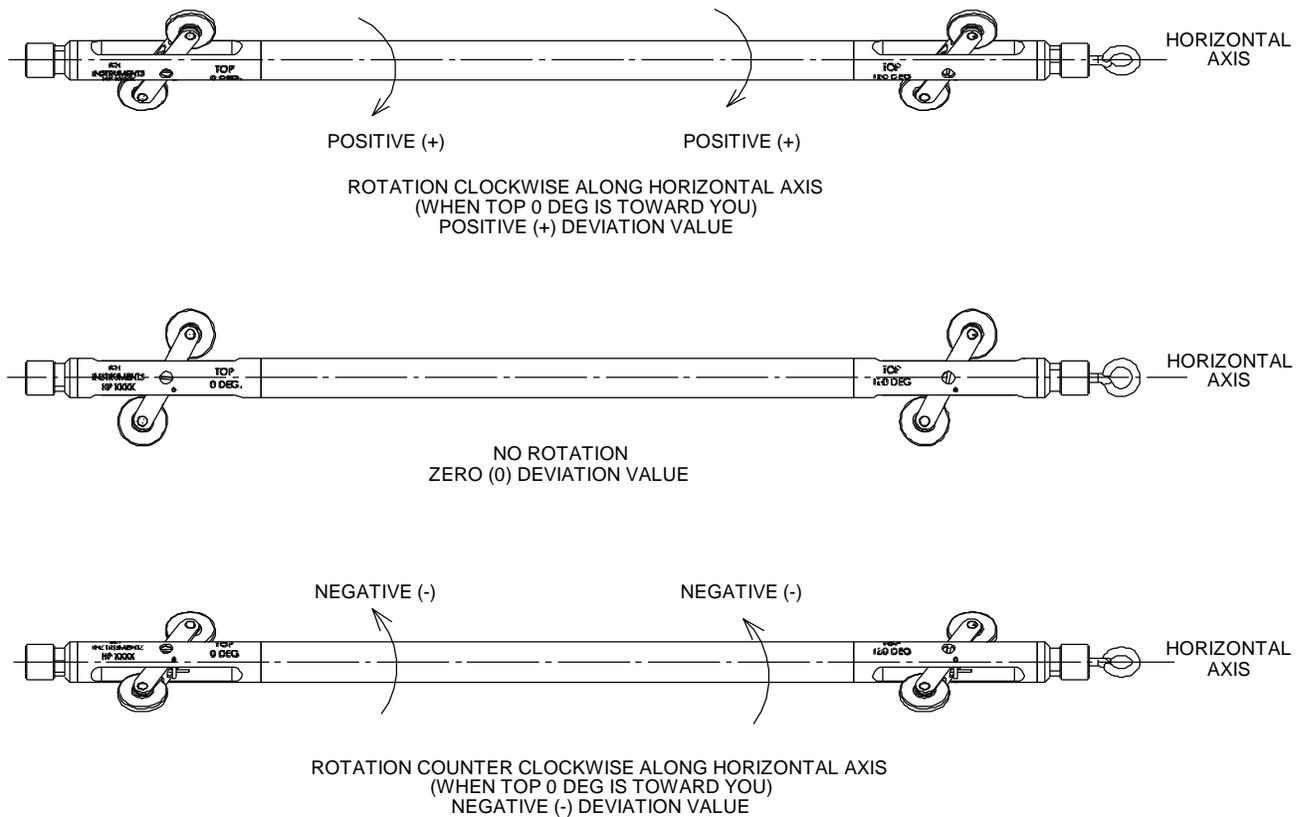


Figure 9 – Rotation Sign Convention

6 CARE AND MAINTENANCE

6.1 PROBE & REEL CONNECTORS

Proper care and maintenance of the MEMS Horizontal Inclinometer Probe and reel connectors will ensure trouble-free operation of the MEMS Horizontal Digital Inclinometer System. The following guidelines should be strictly adhered to. Failure to adhere to these guidelines can result in premature connector wear, and ultimately connector failure.

- Ensure the keyway is aligned before threading the connector together.
- Never over-tighten the bulkhead connectors when mounting. Snug (hand-tight) is more than sufficient.
- Only twist the brass coupling on the connector, do not twist the signal cable itself.
- Avoid sharp bends at the cable entry to the connector.
- Clean the plugs and receptacles with a mild soap and fresh water on a regular basis. Do not allow the connectors to get excessively dirty.

- Rinse out with alcohol, allowing the connector to air dry. Replace dust caps, once the connector is dry.
- On a regular basis, lubricate the mating surfaces with the **supplied silicone spray**. The supplied product is *3M Silicone Spray part # 6204678-4930-3*. **DO NOT GREASE and avoid the use of any solvent based lubricants.**
- Amount of silicone spray used should be based on the frequency of use of the probe. One light spray to cover all contacts is enough after cleaning of the connector. Ensure the connector is clean and dry before applying the silicone spray.
- Elastomers contained in the connector can be seriously degraded if exposed to solvent, direct sunlight or high ozone levels for extended periods of time. Always replace dust caps once the connector is clean and dry.
- Always keep the dust caps clean and free of any foreign materials. Do not place the dust caps where they have the potential to become contaminated.
- Always use the dust caps and keep the connectors clean to prevent damage in storage and when in use.

Warning

In no case should solvent-based lubricants (such as WD-40) be used as a lubricant on the connectors. These products will damage the elastomers in the connectors resulting in loss of communication with the digital probe. **ONLY use the supplied silicon lubricant or RST approved equivalent.** If ever in doubt or any questions arise, do not hesitate to contact RST Instruments for further information.

6.2 INCLINOMETER PROBE

The MEMS Horizontal Inclinometer Probe consists of high-grade stainless steel components and is completely sealed. After the survey is complete, wipe all moisture off the probe and replace the protective caps over the connectors. If required, rinse the probe in clean water and dry. If the probe is exceptionally dirty, use a mild soap and fresh water to clean. *Never use solvents to clean the probe and connectors.*

Always store the probe in its original case whenever it is not in use. The high precision accelerometers in the probe can be damaged if the probe is subjected to excessive shock or vibration. Keep both the probe and its case clean and dry. If the probe is not cleaned and dried in the field be sure to clean and dry it (including the case) upon return to the office. It is good practice not to leave corrosive solutions (i.e. salt water) on the probe, connectors and cable, be sure to clean the parts if these conditions exist.

The probe wheels are made with high-grade hardened and heat-treated stainless steel. These are the most robust on the market and are extremely durable. The wheels contain sealed bearings which require no maintenance except keeping them clean and dry.

6.3 REEL AND CABLE

If required, wipe the cable with a clean rag to dry it off. The cable has a durable polyethylene jacket, simply use water and a mild soap to clean it off if necessary.

6.4 READOUT UNIT

To keep the Pocket PC™ in good condition and working properly, please adhere to the following guidelines:

- Never remove the Pocket PC from its supplied rugged case. There should be no reason to remove it except if there is an inherent physical problem with the Pocket PC itself. Communication and charging can be done exclusively through the external plugs on the rugged case.
- Keep the Pocket PC™ away from excessive moisture and extreme temperatures. Do not expose the Pocket PC™ to liquids or precipitation. Provided all the plugs are closed, the supplied *Rugged*

Case meets the IP54 standard for water and dust resistance, as well as being impact-resistant if dropped up to four feet from the ground. The plug covers are made of special material which allows the wireless features of the unit to function even when they are closed.

- Do not place anything on top of the Pocket PC™ to prevent damage to the screen.
- Clean the unit by wiping the screen and the exterior with a soft, damp cloth moistened only with water.
- Avoid exposing the Pocket PC™ to direct sunlight or strong ultraviolet light for extended periods of time. Also avoid scratching the surface of the screen and banging it against hard objects.
- Only use the Pocket PC™ stylus to prevent scratching the screen. The supplied rugged case incorporates a screen protector on the inside to allow use of the touch screen and buttons while maintaining water and dust resistance.

For further reference please see the supplied manufacturer's manuals for the Pocket PC™.

6.5 CALIBRATION

RST strongly recommends that the probe be sent in for calibration annually. Due to the high precision nature of the sensors and the sensitivity of the probe, calibration must be done to ensure quality results and continued performance of the probe. Heavy use in adverse conditions may require calibrations to be done more often.

Calibration should also be performed if the probe has been dropped or become damaged in any way. If checksums become significant and they are not due to errors in probe positioning or noise, the probe likely needs to be re-calibrated.

Calibration should also be performed after any wheel assembly replacement.