RST INSTRUMENTS LTD.

Corrugated Pipe with Magnetic Targets Inclinometer Settlement System Installation Manual

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1 INTRODUCTION

The Corrugated Pipe with Magnetic Targets Inclinometer Settlement System a simple, reliable system designed to monitor settlement or heave in rock, soil and different types of man made structures. The system consists of a one-piece corrugated pipe, corrugated pipe end cap weight, inclinometer casing, target magnets, probe and readout unit.

Corrugated pipe is installed around the outside of the inclinometer casing. Magnetic Targets are positioned around the corrugated pipe. The annular space between the borehole wall and the corrugated pipe is backfilled with soft grout, coupling the pipe to the surrounding ground, so that the corrugated pipe and rings move with settlement or heave.

The probe is a normally open, simple reed switch that closes upon entering the magnetic field of the target anchor. Operation is analogous to a water level meter in that when the switch closes the electrical circuit is completed, causing a buzzer/light in the readout to operate. A two-conductor tape serves to both lower the probe and connect the probe to the circuit board. The switch closes upon entering magnetic field, the signal amplified, and fed to the light/buzzer. Anchor elevation is then read directly from the tape.

The probe incorporates two reed switches to avoid difficulty in manufacturing a ring magnet with uniform polarity, preclude false closure when passing through the three magnetic fields of the magnet, and negate the end effects on the magnetic field when spring steel spider magnets are employed.

Magnets are arranged within the target to yield a uniform, axial magnetic field with a well-defined null zone. Ceramic magnets, rather than ferrous magnets, are used because of their consistent magnetic properties:

- There is no significant change in field strength with time.
- The magnets are unaffected by most groundwater regimes.
- There is no appreciable difference in field strength with temperature.
- Field strength is unaffected by impact.

Like an inclinometer installation, Corrugated Pipe with Magnetic Targets Inclinometer Settlement System utilizes the bottom of the borehole as a reference datum. Typically, the borehole is drilled to stable ground and a datum reference magnet installed. If site conditions preclude the use of the bottom of the borehole as a datum, optical survey methods must be used at the borehole collar.

Settlement or heave is determined by comparing subsequent readings to the initial datum readings.

2 INSTALLATION

The following procedure is a suggested installation method. Site conditions & equipment may dictate other installation methods.

1. Make sure the corrugated pipe end cap weight is securely attached to the bottom end of the corrugated pipe. The end cap weight is used to counter the buoyancy in a wet borehole during installation.
2. A PE water pipe is preinstalled the full length of the corrugated pipe. Make sure the water pipeline is pre-attached in the center of the corrugated pipe.
3. Attach a grout host along the outside the corrugated pipe with cable ties or wire.
4. Attach the center water pipeline to a water pump.
5. Turn on the water pump to fill the corrugated pipe with clean water to counter buoyancy during installation of the settlement system.
6. Lower the corrugated pipe into the borehole (inside the steel casing). The end cap weight and the water filled in the corrugated pipe should help to sink the corrugated pipe to the bottom of the borehole.
7. Pull the corrugated pipe up with wire-rope choker to maintain tension in the borehole. This will keep the corrugated pipe straight and allow a smooth installation of the inclinometer casing.
8. Pull the center water pipeline out of the borehole.
9. Make sure the inclinometer casing bottom guide tip is attached to the first (bottom) section of the inclinometer casing.
10. Lower the inclinometer casing into the borehole (inside the corrugated pipe). Hold the inclinometer casing at the top. Fill the inclinometer casing with water. This will help to counter buoyancy during installation.
11. Attach next section of the inclinometer casing.
12. Lower and attach sections until the inclinometer casing is at the bottom of the borehole.
13. Secure the corrugated pipe to the inclinometer casing at the top with cable ties or wire. Cut off wire-rope choker.
14. Pull the steel casing up 3 meter out of the borehole and backfill the borehole with grout. It is important to keep the space between the inclinometer casing and the corrugated pipe free of grout and other obstructions.
15. Repeat the previous step with an increment of 3 meter until the steel casing is pulled out of the borehole completely. This helps to bond the corrugated pipe to the borehole securely and cleanly.

3 REED SWITCH PROBE

RST Reed Switch Probes are designed to measure the elevations of ring magnets in determining settlement. The RST Reed Switch Probe employs a high accuracy, NBS traceable, Teflon or polyethylene coated, non-stretch, flat tape, permanently marked in 1/100 ft. and/or 1 mm graduations.

The model 4001 reed switch probe is fully featured with a stainless steel probe, light, buzzer, test switch and on/off sensitivity control. The moisture resistant electronics and standard 9-volt battery are housed in the reel hub. To replace the battery gently pull and twist the reel hub to remove. The hub assembly simply snaps into the cavity.

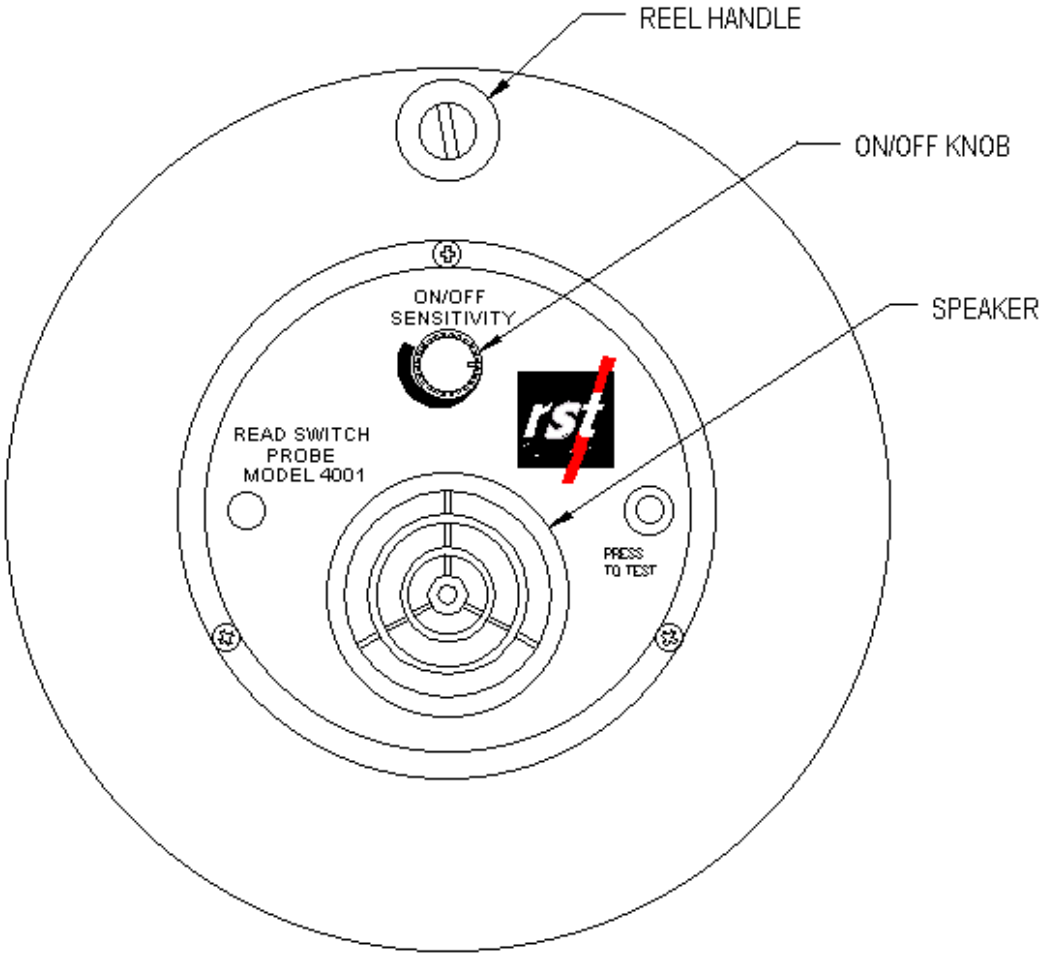

Figure 1: Reed Switch Probe Controls

4 TARGETS

4.1 Target Magnets

The targets are magnetic rings applicable to various settlement systems.

Figure 2: Components of a Target Magnet

The Target Magnetics are pre-installed to the corrugated pipe at a specific interval. However, they can be adjusted to custom intervals on field. Simply loosen the set screws on the Target Magnetics, move to desired location, and tighten the set screws. The deepest Target Magnetic ring should be at least 300mm (12 inches) from bottom of the corrugated pipe to allow the reed switch probe to pass the magnetic field.

5 ACCESS PIPE

The access pipes include the corrugated pipe and the inclinometer casing. The one-piece corrugated pipe is used in a wet borehole to protect the inclinometer casing and to ensure the inclinometer casing is free of grout when bonding the corrugated pipe to the borehole. The inclinometer casing is used to monitor both settlement and lateral deformation.

RST Inclinometer Casing is precision manufactured in 70mm (2.75") OD and 85mm (3.34") OD sizes. The RST Glue & Snap casing utilizes ABS cement, with the RST Snap Seal Coupling System providing an O-ring sealed, self-coupling method.

6 TYPICAL APPLICATIONS

The typical applications include:

- dam settlement monitoring
- construction control of embankments and tills
- preload consolidation monitoring
- subsidence monitoring

However, the system may be used wherever it is desirable to measure the displacement along a pipe.

7 CALCULATION OF SETTLEMENT

The settlement is basically the difference between the current position of the target (with respect to the datum or another fixed reference point) and the initial position of the target.

7.1 Initial Readings

Accuracy of the entire system relies heavily on the initial readings taken after installation. These readings should be taken with great care. It is strongly recommended that a minimum of three individual sets of readings be taken from three separate passes through the access pipe. The initial reference reading is thus an average of the readings for each target magnet. Subsequent readings are determined as a difference between the current and initial readings (i.e. the positions of target magnets). A positive value would indicate settlement and a negative value would indicate heave (or whichever sign convention is preferred).

7.2 Taking Readings

1) Switch probe power on by turning the on/off knob.
2) Lower the probe to bottom of access pipe.
3) Raise the probe until the buzzer sounds. The position of the target (its depth) is found by reading directly off the measuring tape. Measurements are usually taken at the collar of the access pipe.
4) Record the depth of the target magnet on field data sheet. Raise the probe up to next target and repeat the above procedure for each target in the monitoring system. The depth for each target should always be determined by the first sound of the buzzer.

7.3 Data Reduction

If a datum magnet is installed in stable soil or rock at the base of the borehole, changes in the target magnet positions are referenced to this datum. Suppose a settlement system consists of 6 target magnets and a datum magnet, which are read on a monthly basis from January to March (see Table 1). Depths are measured by reading the tape directly, where it meets the collar of the access pipe.

Table 1. Field Data Referenced to the Top of the Pipe

Target Magnet	January (initial readings)	February	March
1	5.45	5.42	5.38
2	10.47	10.44	10.40
3	15.48	15.43	15.38
4	20.49	20.45	20.39
5	25.51	25.47	25.40
6	30.53	30.47	30.40
Datum Magnet	35.54	35.46	35.39

Settlement / heave is determined by taking the difference between the datum magnet (assumed to be stable) and the target magnet. For target 1, the datum-referenced reading is equal to:

35.54 - 5.45 = 30.09

Therefore, this target magnet is located 30.09 ft above the datum magnet. Table 2 lists the readings referenced to the datum magnet for each of the targets over the given monitoring period.

Table 2. Field Data Referenced to Datum Magnet

Target Magnet	January (initial readings)	February	March
1	30.09	30.04	30.01
2	25.07	25.02	24.99
3	20.06	20.03	20.01
4	15.05	15.01	15
5	10.03	9.99	9.99
6	5.01	4.99	4.99

A summary of the data is given in table 3, which includes the initial readings, the measured readings and the change in target positions (Δd).

Table 3. Data Summary

Target Magnet	January Initial Reading	February Reading	February Δd	March Reading	March Δd
1	30.09	30.04	0.05	30.01	0.08
2	25.07	25.03	0.04	24.99	0.08
3	20.06	20.03	0.03	20.01	0.05
4	15.05	15.01	0.04	15	0.05
5	10.03	9.99	0.04	9.99	0.04
6	5.01	4.99	0.02	4.99	0.02

The Δd values given in the above table represent the difference between the initial and current position of the target magnets. In this case, positive values indicate settlement, and negative values indicate heave in the soil or structure being monitored.

The above example of settlement is related to a case where the access pipe is anchored in stable ground.

If the bottom of access pipe is not anchored in stable ground, a datum target cannot be used as a reference point. The settlement should therefore be calculated with reference to the collar of the pipe, which has to be surveyed before each set of readings is taken.

7.4 Frequency of Readings

Frequencies of measurements are completely site-specific and should be determined by the project engineer, taking into account the relevant project information.