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# Reed Switch Settlement System Instruction Manual

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Installation Manual

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## 1 INTRODUCTION

The RST Reed Switch settlement system is a simple, reliable system designed to monitor settlement or heave in rock, soil and different types of man made structures. The system consists of an access pipe, target magnets, probe and readout unit.

Magnetic targets are anchored to the ground around PVC, Inclinator Casing, or corrugated pipe. The anchors are not coupled to the access pipe, and are free to move with the soil. Magnets are available for attachment to inclinometer casing to monitor closure of casing telescopic sections.

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 anchor 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, Reed Switch Settlement Systems utilize 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.



Figure 1: Reed Switch Probe Overview

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## 2 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.

## 3 INSTALLATION

The following procedures is only one of different ways on how to install

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.
2. Make sure the water pipeline is pre-installed 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 to counter buoyancy when installation 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 a certain distance in order to maintain tension in the borehole.
8. Pull the center water pipeline out of the borehole.
9. Make sure the inclinometer casing bottom guide tip is attached to the 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 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 out up 3 meter 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.

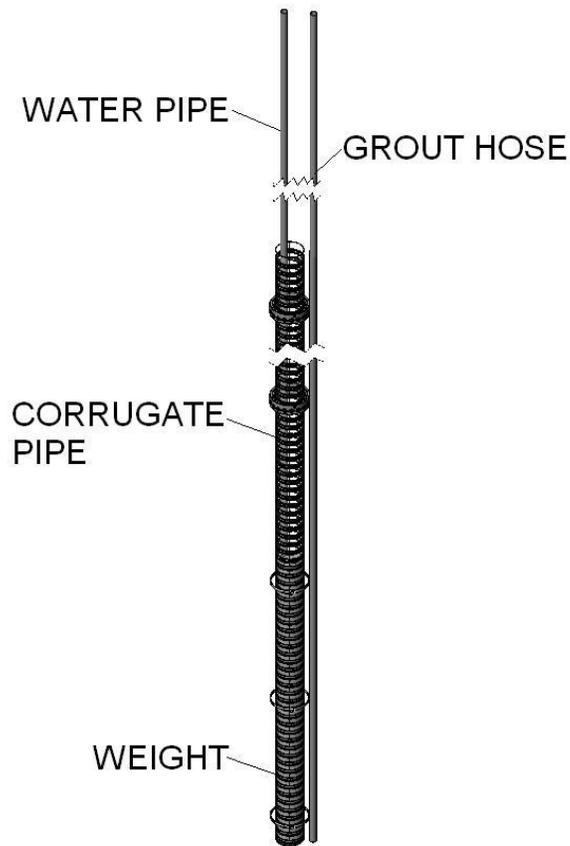


Figure 2: Corrugated Pipe, Water Pipe, & Grout Hose setup

## 4 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 3: Reed Switch Probe Controls

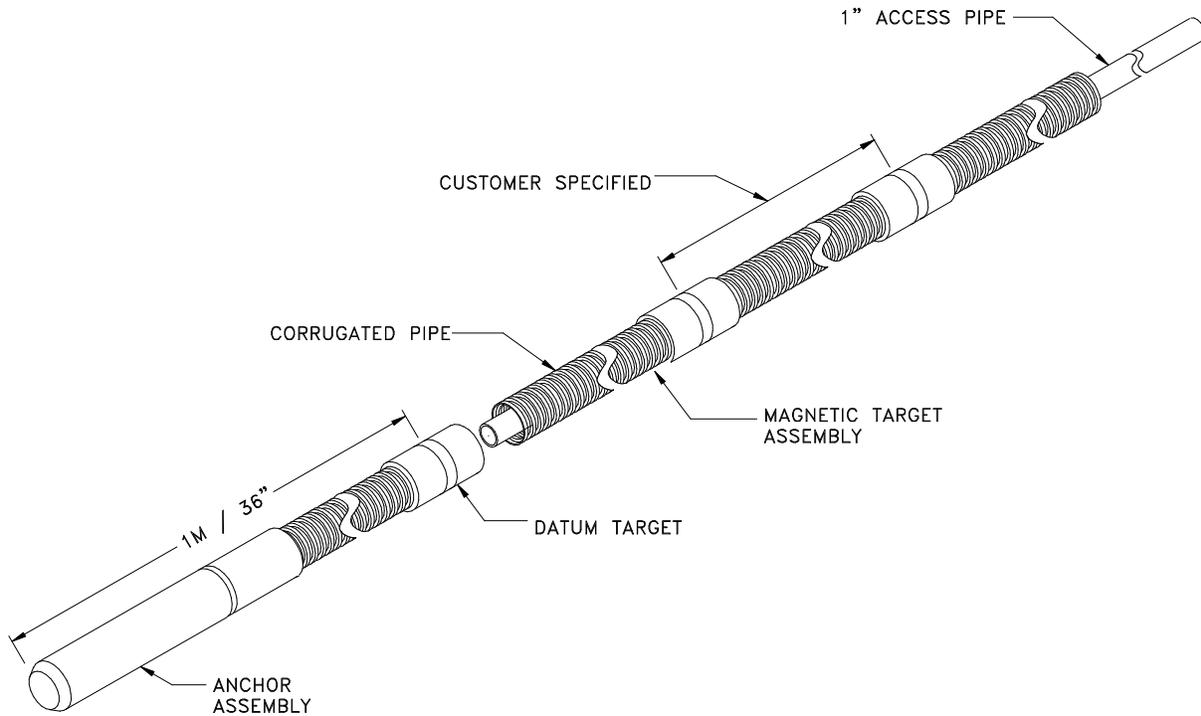
#### 4.1 Measuring Magnetic Rings Elevation

To measure magnetic rings elevation in boreholes, standpipes or wells:

1. **Press the ON button to turn on the Reed Switch Probe.**
2. **Reed Switch Probe will initially beeps 3 times and a number of LEDs (depending on the battery level) will flashes 3 times to indicate the current battery status.** If there is only 1 or 2 LEDs flashing, the battery should be replaced soon.
3. **Reed Switch Probe will then turn into stand-by mode and the far left LED will keep flashing.** (The Reed Switch Probe will shut off automatically if there is no activity for 2 minutes.)
4. **Hold ON button to adjust sensitivity until desired level is achieved.**
5. **Lower the probe into borehole, standpipe, or well.**
6. **Once the probe comes in contact with magnetic field, the buzzer will beep and the LEDs will flash.** Toggle button to turn beeping on/off.
7. **Read the mark on the tape to determine the Anchor elevation.**

## 5 1.5" CORRUGATED SETTLEMENT SYSTEM

1. Connect magnetic target assembly to anchor and datum assembly.
2. Lower the assembly down the borehole.
3. Install 1" access pipe.
4. Grout the anchor in place.



Note: Anchor assembly comes with starter access pipe

Figure 4: Assembly of 1.5" Corrugated Settlement System

## 6 TARGETS

The targets include the datum target at the bottom of the borehole, spider targets at desired elevations of the borehole, and plate targets that are installed at desired elevations during the construction of fill or embankment to be monitored. Figure 5 shows a typical dam installation of a reed switch settlement system with the different types of targets.

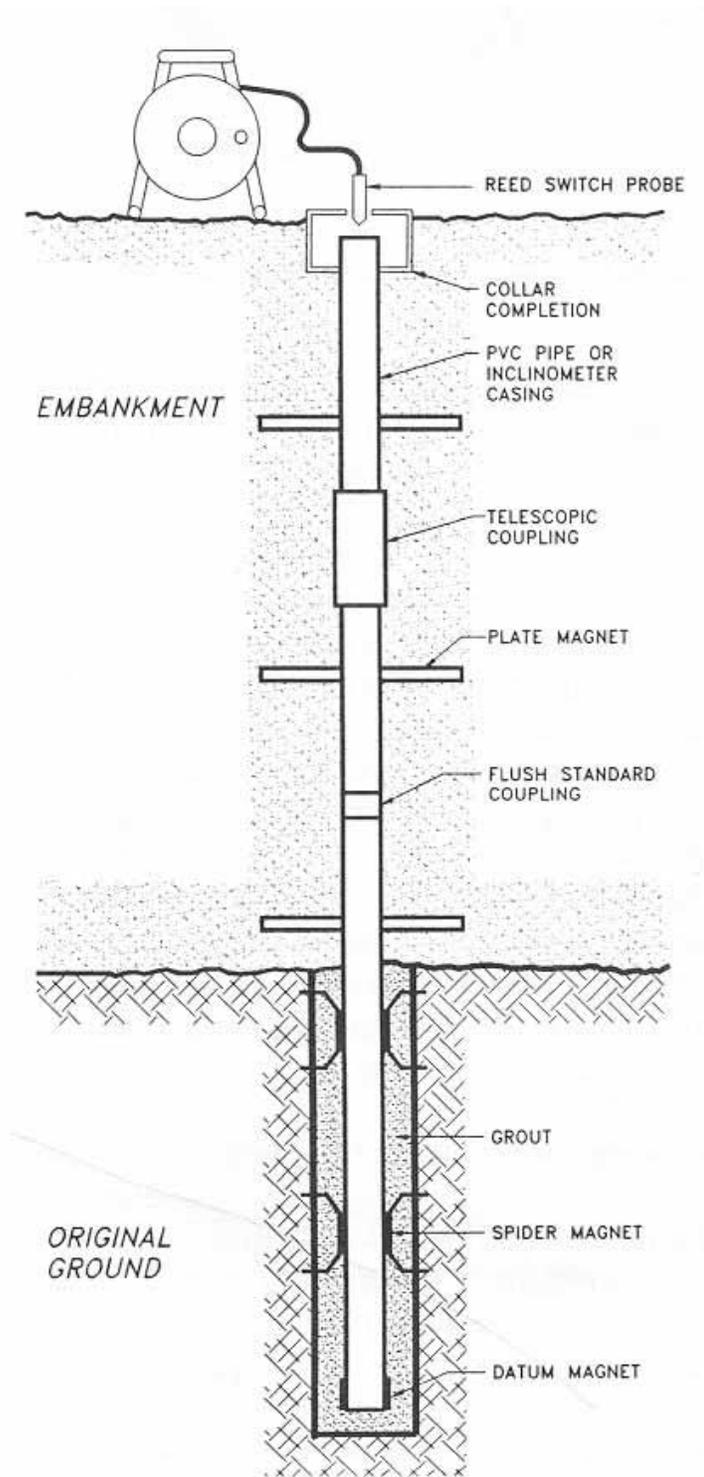


Figure 5: Cross-section of a Typical Reed Switch System

## 6.1 Datum Target

The datum target is simply a magnetic ring that is secured to the bottom of the access pipe. It serves as the reference point for the settlement system because the deep ground is generally very stable with respect to the construction zone. If there is no stable ground, then it is necessary to use surveying techniques to obtain a reference point at top of borehole.

## 6.2 Target Magnets

The targets are magnetic rings applicable to various settlement systems.



Figure 6: Components of a Target Magnet

Target magnets are installed as the settlement system is being installed into the borehole.

1. Install the appropriate amount of the settlement pipes until the position for the first target magnet has been reached.
2. Slide an assembled target magnet over and along the settlement pipes until the magnet reaches the appropriate location. **Secure target to corrugated, or standard casing material, as specifications designate.**

### 6.3 Spider Targets

The spider targets are magnetic rings with spring legs. Components of the system are shown in Figure 6.

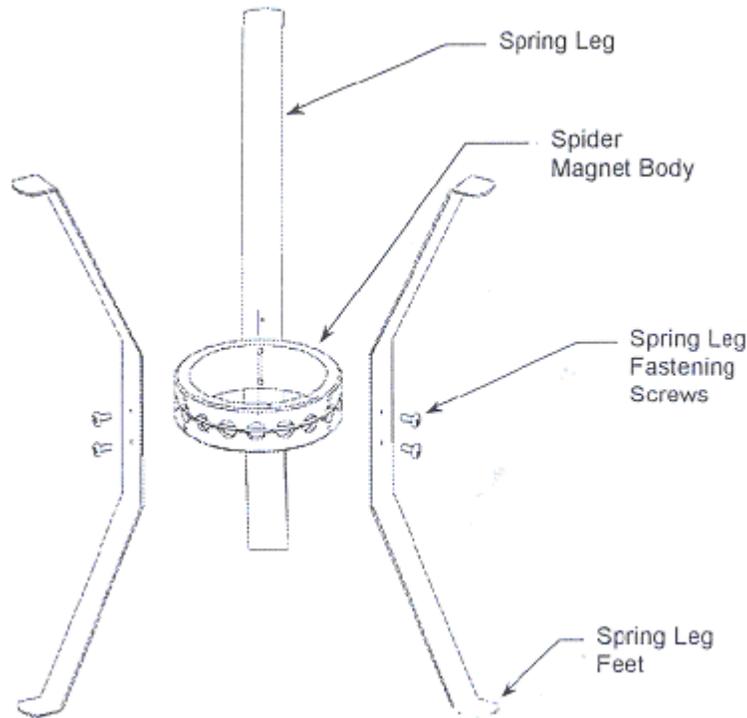


Figure 7: Components of a Spider Target

Spider magnets are installed as the settlement system is being installed into the borehole. Mechanical Release Spider magnets are installed onto the settlement system at site specific intervals.

3. Install the appropriate amount of the settlement pipes until the position for the first spider magnet has been reached.
4. Slide an assembled spider magnet (as shown in Figure 8) over and along the settlement pipes until the spider magnet reaches the appropriate location. **Ensure the spider magnet is orientated with the loop of the Release Pin closest to the mouth of the borehole** (so it can be pulled out of the spider magnet).

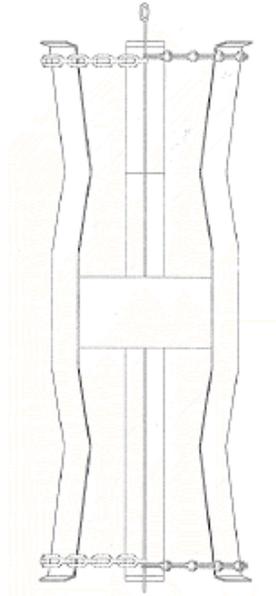


Figure 8: Compressed Spider Target

5. Secure the spider magnet in place. This can be achieved by taping it in place, or filing a small flat into the OD of the settlement system, large enough for the safety chain lock into. **(Spider Magnets for small diameter pipe have a tail on the lower chain for taping to the OD of the pipe).**

6. Secure a release line to the loop in the Release Pin (ensure there is sufficient length of release line so that then the spider magnet has reached its target depth, there is a comfortable length of release line protruding from the borehole).

**Note: maintain some slack in the release line(s), while lowering the settlement system into the borehole, to prevent a premature release of the spider magnet(s) legs and make sure the free end of the release line is secured, to prevent it from falling into the borehole.**

7. Continue installing the settlement pipes until the next spider magnet should be installed.

8. Repeat steps 2-5 for the remaining spider magnets.

9. When the installation of the settlement system is complete, release the spider magnets by pulling their respective line until no resistance is felt.

## 6.4 Plate Targets

Plate targets are installed during the construction of fill or embankment to be monitored. The plates, which have a magnetic ring in the center as shown in Figure 9 are simply placed at desired elevations. The plates may be made out of steel, PVC, or plywood, depending on the application.

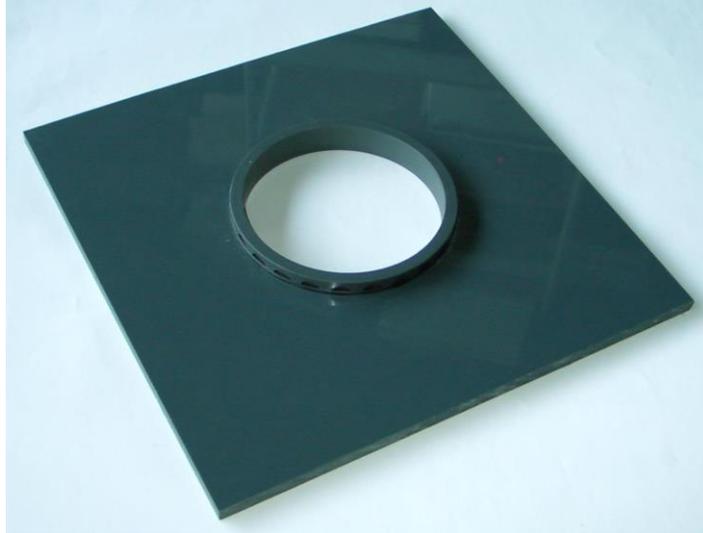


Figure 9: Plate Target

## 7 ACCESS PIPE

The access pipe may be PVC, inclinometer casing, and/or corrugated pipe. The inclinometer casing is mainly used when monitoring of both settlement and lateral deformation is required. The one-piece corrugated pipe is used when installing the settlement system in a wet borehole and where the borehole needs to be grouted. When vertical compression-settlement exceeds 1-2%, telescopic sections must be used to allow axial movement of the access pipe/casing while minimizing distortion due to vertical strain.

RST Inclinometer Casing is precision manufactured in 70mm (2.75") OD and 85mm (3.34") OD sizes. Two flush coupling methods are available to permit spider anchor installation in cased boreholes. The standard coupling method utilizes ABS cement and pop-rivets, with the RSAT Snap Seal Coupling System providing an O-ring sealed, self-coupling method.

## 8 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.

### 8.1 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).

## 8.2 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.

## 8.3 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 ( $\Delta d$ ).

**Table 3. Data Summary**

Target Magnet	January Initial Reading	February Reading	February $\Delta d$	March Reading	March $\Delta d$
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  $\Delta d$  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.

#### **8.4 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.