



# INSTRUCTION MANUAL

## MAGNETIC REED SWITCH PROBE EXTENSOMETER SYSTEM

### Model R-4

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This product should be installed and operated only by qualified personnel. Its misuse is potentially dangerous. The Company makes no warranty as to the information furnished in this manual and assumes no liability for damages resulting from the installation or use of this product. The information herein is subject to change without notification.

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## 1 APPLICATIONS

The model R-4 magnetic extensometer is designed for monitoring the vertical deformations of soil. Settlements or heaves can be followed during construction works such as mining or tunnelling operations, foundations, embankments or earth fills.

Measuring targets are constituted by magnetic anchors surrounding a telescopic vertical pipe, positioned at various depths. In operation, a reed switch probe inserted in the pipe allows the detection and the measurement of their locations, and then the calculation of their vertical movement along the time, as well as total settlement.

## 2 PRODUCT

### 2.1 GENERAL DESCRIPTION

The magnetic extensometer is comprised of the following:

- an access pipe, which can also be an inclinometer casing. The latter can be used to measure both vertical and horizontal movements.
- several telescoping sections used where the axial deformation of the pipe is expected to exceed 1%. They are fitted with flush joint slip or threaded couplings.
- one datum ring anchor which is installed in stable strata. It constitutes the reference elevation to which settlement of the magnetic targets is referenced to.
- several magnetic anchors. Different kinds exist: plate anchors designed to be embedded in a fill and leaf spring anchors (also called spider anchors) used in boreholes.
- an end cap that is glued at the end of the access pipe.
- a readout unit constituted by a probe and a measuring tape on a reel with built in buzzer and light.

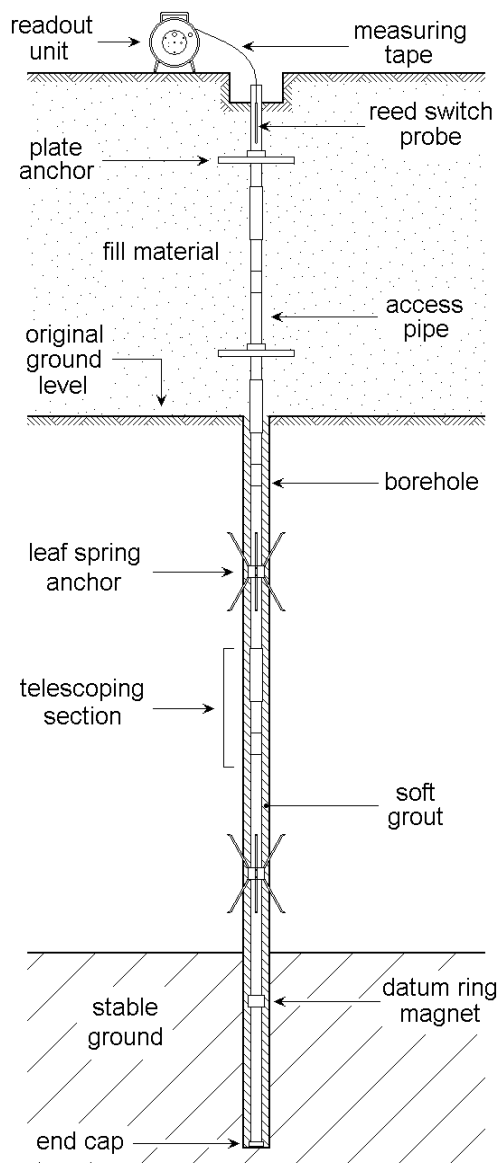


Figure 1: Model R-4 extensometer

## 2.2 OPERATION PRINCIPLE

Magnet anchors are located at different depths around an access pipe. They are not coupled with it and are free to move with the soil.

Readings are got using the probe inside the access pipe. When the probe enters the anchor magnetic field, a reed switch closes, activating the buzzer. The actual depth of the anchor is read from the measuring tape onto which the probe is connected.

Measuring also the depth of the datum ring leads to know the vertical displacement of anchors above.

## 3 INSTALLATION PROCEDURE

### 3.1 PRE-INSTALLATION ACCEPTANCE READING

A control reading should be taken as the probe is received to ensure it has not been damaged during shipment or handling on site.

Check good functioning of the probe by getting it closer to a magnetic anchor. The readout unit should buzz. Slip the probe into the anchor in the same way as if it were embedded in soil. The buzzer sounds when the probe gets closer to the central hole of the anchor, it stops when the probe is inside the hole and it sounds again when the probe gets out from the other side.

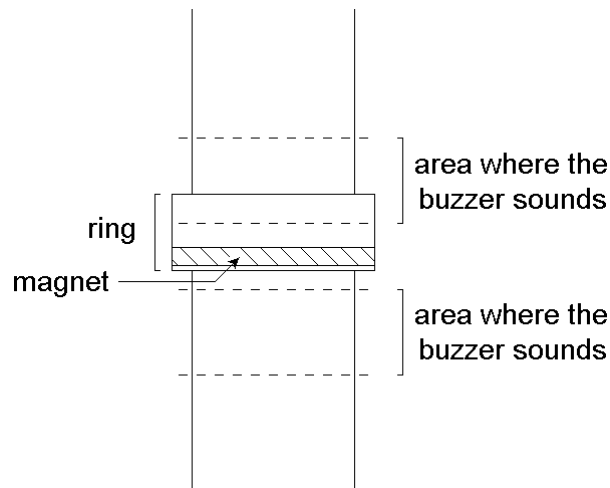


Figure 2: Sketch of sensitive areas

For details about how to take readings, please refer to next chapter (Reading procedure).

### 3.2 INSTALLATION IN AN EARTH FILL

The change in elevation of the plate anchors is referenced to either:

- the elevation of lowermost plate anchor when this anchor is placed on a stable substratum.
- the top of the access pipe in which case the elevation of the access tube must be accurately surveyed each time a series of measurements are made.
- the elevation of one datum ring magnet grouted in a borehole drilled into a stable stratum.

In case of datum ring use, follow instructions below for proceeding.

- Before drilling, be sure the drill rig is vertical. Use for example a plumb line. A tolerance of one or two degrees is acceptable.
- Drill a hole of about 40 mm larger than the diameter of the datum ring anchors. The future annular space (when the access pipe is in the hole) should allow passage of the grout tube. The borehole should be long enough to consider that the bottom is stable. Collecting samples can help to check the nature of the soil. Drill one meter below the elevation chosen for the location of the lowermost datum anchor.
- Glue an end cap onto the bottom of the lowermost access pipe.
- Install a datum ring magnet on the lowermost section. The datum ring should be a minimum of one meter above the bottom of the borehole. This accommodates the probe and leaves space for material that might accidentally be dropped in the access tube. Position the datum ring in place and tighten the setscrews firmly.
- Assemble sufficient access pipe so that, once installed, the assembly will exceed the borehole collar.
- Place this first assembled length with the datum ring in the borehole and grout the space around the access pipe. Once the grout has set, use the probe to determine the depth of the datum ring. Record the reading.

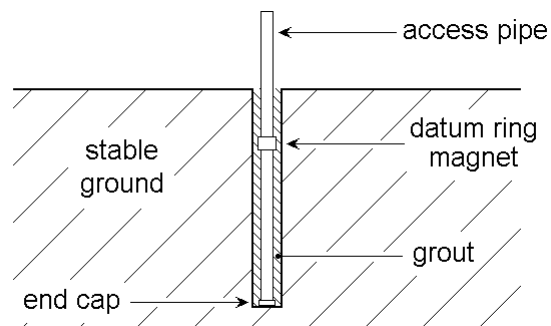
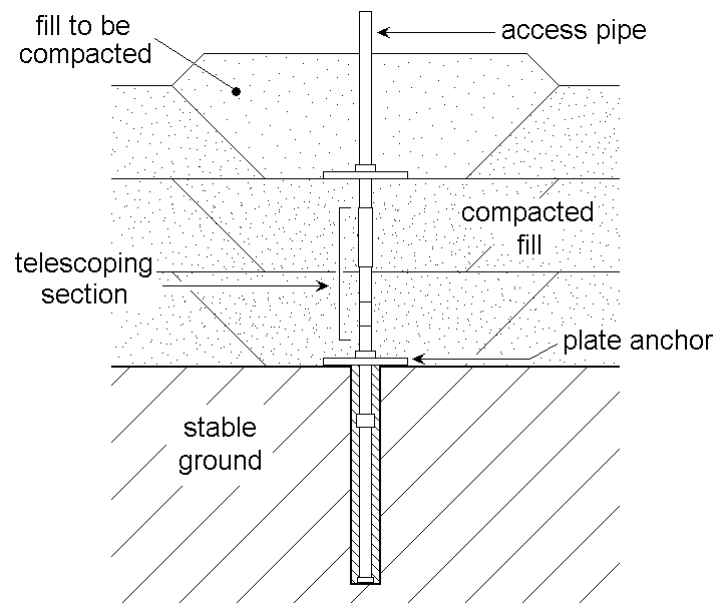


Figure 3: Extensometer at this step of installation

Then, whatever the type of reference used (datum ring, anchor on substratum, top of access pipe), the procedure is the same:

- Determine by a survey the elevation of the borehole collar or the ground level.
- Place and compact the backfill material around the access pipe forming a small mound. The latter must be free of rock fragments and stones greater than 15 mm in order to avoid any damages to the tube. Use for example sand and gravel. Be sure to keep the top of the tube at least one meter higher than the surrounding backfill material. For installation in a rock fill, the access pipe can be protected from the surrounding material by a kind of gabion constituted by stones inside a wire mesh.
- Fix together the access pipe sections or use telescoping couplings to accommodate settlement or heave in excess of 1% of the access pipe length. Remember that in dams or embankments, local settlements are often greater than the average settlement based on all the height. Install the telescoping coupling fully or partially open as required. Use the semi-cylindrical jig provided with the telescoping sections to fix the opening to 15 cm. Any couplings used should not impede movement of the anchors. To minimize friction, the coupling can be coated with heavy grease a distance of 15 cm above each joint. Check the verticality of the assembly.
- Position the plate anchors on the access pipe at the required elevation. Place selected material and compact it to the surrounding material density.
- Continue adding access pipe and plate anchors as the fill progresses. Take readings of the plate anchor elevations as they are added. For details about how to take readings, please refer to next chapter.



**Figure 4: Example of extensometer at this step of installation**

- Cap and protect the protruding end of the access pipe between installation steps.

### 3.3 BOREHOLE INSTALLATION

#### 3.3.1 DESCRIPTION OF ANCHORS

Apart from datum rings, two types of anchors are available. Their use depends on the way the borehole is drilled and on the type of soil.

Classical anchors comprise six leaf springs fixed to a PVC body containing the magnets and are supplied with the blades collapsed. They are held by a wire loop which will be released by pulling on a retaining cord from the surface at the end of the installation. An additional tie-wrap is installed around the springs for security.

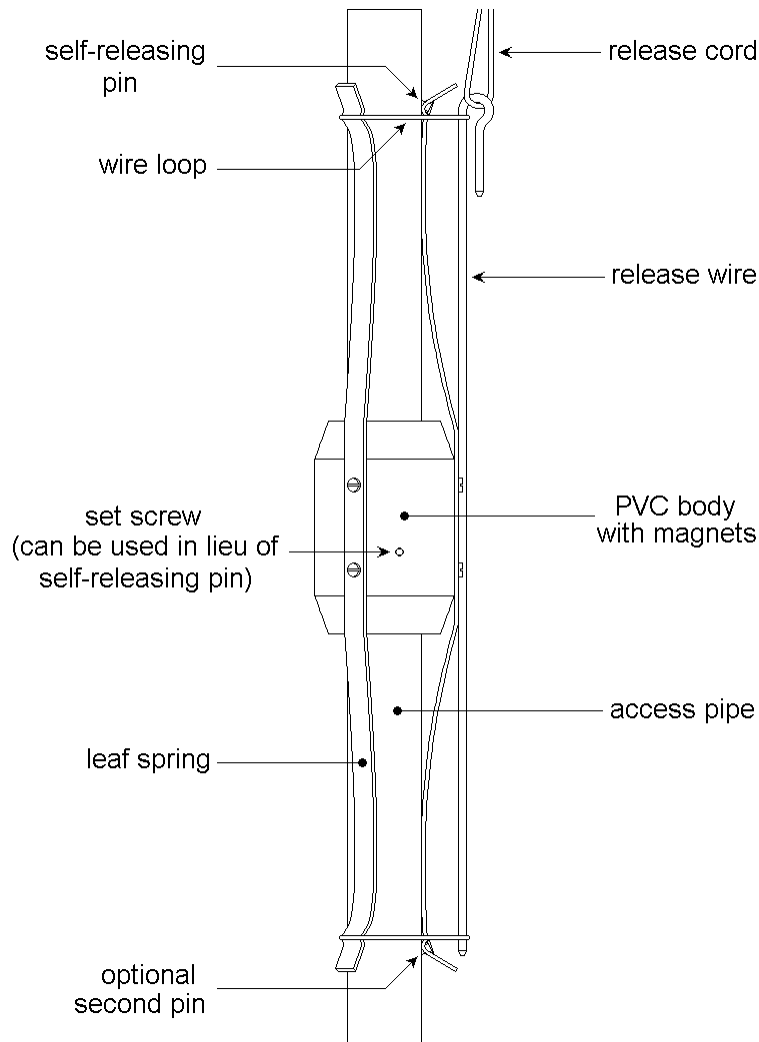


Figure 5: Leaf spring anchor, ready to be installed

The push-in anchors are used in shallow, cased boreholes. They have only three leaf springs already released.

**Be careful not to squeeze the legs of the push-in anchor to a diameter smaller than the access pipe diameter. The deformation of the legs may become permanent and the anchor may not fit any more into the borehole.**

Push-in anchors are installed from the surface, when the access pipe is already into the borehole. A special tool on a rod is used to push them down to their definitive locations. As they are slid along the access pipe, telescopic sections cannot be used. Therefore, push-in anchors are prohibited where settlement or heave exceeds 1% of the access pipe length. Furthermore, they are only used in cased boreholes. Contact Roctest – Telemac for more information.

### 3.3.2 INSTALLATION PROCEDURE

The change in elevation of the anchors is generally referenced to a datum ring magnet grouted in a borehole drilled into a stable stratum. If site conditions preclude the use of the bottom of the borehole as a datum, the elevation of the top of the access pipe or of the borehole collar must be accurately surveyed each time a series of measurements are made.

*Note: Nylon cords are required to complete the installation of leaf spring anchors.*

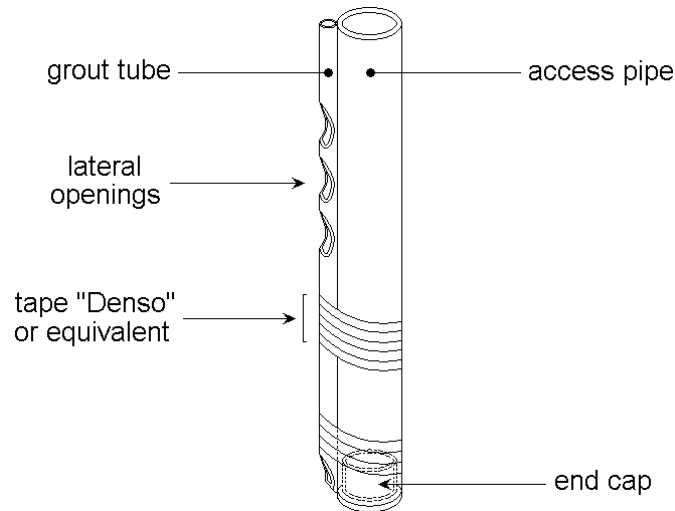
#### Borehole drilling:

- Before drilling, be sure the drill rig is vertical. Use for example a plumb line. A tolerance of one or two degrees is acceptable.
- Drill a hole of about 40 mm larger than the diameter of the datum ring anchor. The future annular space (when the access pipe is in the hole) should allow passage of the grout tube. The borehole should be clean, capable of retaining grout and have a uniform diameter. The hole should be long enough to consider that the bottom is stable. Collecting samples can help to check the nature of the soil. Drill one meter below the elevation chosen for the location of the lowermost datum anchor.

#### Access pipe and anchors assembling:

- Glue an end cap onto the bottom of the lowermost access pipe.
- Install a datum ring magnet on the lowermost section. The datum ring should be a minimum of one meter above the bottom of the borehole. This accommodates the probe and leaves space for material that might accidentally be dropped in the access tube. Position the datum ring in place and tighten the setscrews firmly.
- Attach the grout tube to the base of the access pipe as shown below.





**Figure 6: Detail of the grout tube at the end of the access pipe**

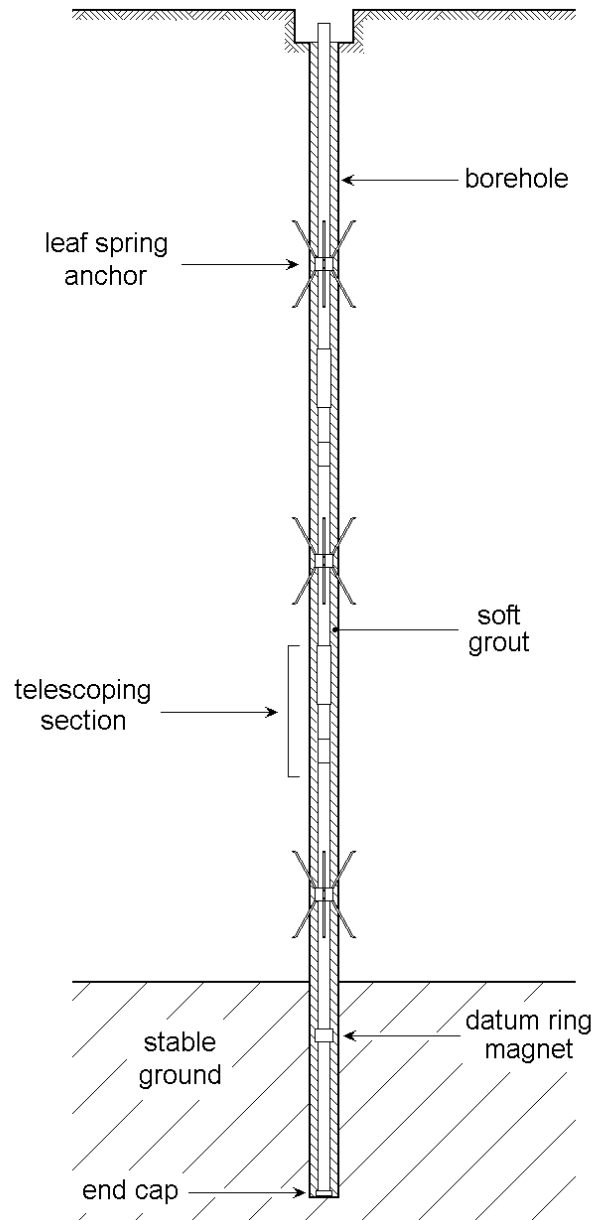
- In case of the six leaf spring anchors use, slide the first one on the access pipe to its definitive location. Mount it on the pipe using either a set screw or a locating pin. If the set screw is used, tighten each of the two set screws located on the PVC anchor body to prevent anchor from moving. In softer materials, it is better to use the locating pin assembly to hold the anchor in place. In that case, pull back slightly on the blade holding the pin to enable it to engage the pipe. Hold the anchor in place and mark the position where the locating hole has to be drilled. The hole position correspond to where the pin touches the access pipe. Then rotate the anchor to expose the hole location. Use a special drill bit with a collar to drill the hole. Avoid going through the pipe side. Slide the anchor back in position until the pin engages the access pipe hole.
- Coat the access tube with heavy grease to fill the annular space between the anchor body and the access tube. The heavy grease should extend 50 mm above and below each magnet location. To prevent the anchor from binding to the access pipe in compressible material, silicone grease can be applied 30 cm above and below the heavy grease.
- The tie wrap must be removed just before the insertion into the borehole.

**Pay attention, an accidental release of the legs could cause injury.**

Prepare release cord of sufficient length to extend between intended depth and surface. Allow a minimum of three meters of extra cord for surface handling. Attach the bottom of it to the release wire of the anchor. Label the top end of cord with anchor number or depth.

- Lower the assembly into the borehole. Make sure the pipe or the cord does not rotate.

- Fix the second length of access pipe directly into the first one or use telescoping couplings to accommodate settlement or heave in excess of 1% of the access pipe length. Remember that in dams or embankments, local settlements are often greater than the average settlement based on all the height. Install the telescoping coupling fully or partially open as required. Use the semi-cylindrical jig provided with the telescoping sections to fix the opening to 150mm. Any couplings used should not impede movement of the anchors. To minimize friction, the coupling can be coated with heavy grease a distance of 150mm above each telescoping joint. Check the verticality of the assembly.
- Repeat previous steps to install the other anchors and sufficient pipe sections. Once installed, the assembly should exceed the borehole collar.
- If push-in anchors are used, install them now. A special tool on a rod is used to push them down to their definitive location. When they exit the casing, the spring legs bite into the soil. The casing should be withdrawn without rotation. Casing withdrawal should not result in rotation or lifting of the anchors.
- If classical leaf spring anchors are used, take readings of their locations (including datum ring anchor). For details about how to take readings, please refer to next chapter. Then release each anchor springs by pulling on each draw cord. It will require about 4.5 kg of force to release one anchor.
- Grout the borehole. The grout to be injected is a homogenized mixture of cement and water made according to the usual grouting procedures. Hardness of grout and hardness of surrounding soil should be equivalent. To ensure compliance of the grout, it can be useful to cast test specimens to confirm its stiffness.
- Take a set of readings before the grout has set. Verify anchor position and that there is no grout in the access pipe. Record readings and the as-built location of the assembly including locations and elevations.



**Figure 7: Sketch of a borehole installation**

### 3.4 INITIAL READING

When the grout is set, an initial reading has to be taken and recorded. All subsequent readings are referenced to it. Therefore, measurements have to be the most accurate as possible. It is advisable to take several sets of readings from separate passes though the access pipe. Calculate for each measurement point the average of the readings.

If several probes have to be used during the project, take initial readings with all of them and compare data. Apply any offset to later readings.

For details about how to take readings, please refer to next chapter.

## 4 READING PROCEDURE

### 4.1 GENERALITIES

For minimizing errors, be sure that the same procedure is used by all technicians.

For large diameter access pipe, we recommend in order to get a better repeatability of readings the use of a probe centralizer which keeps the sensor centred on the access pipe axis.

*Note: The readout unit may support light rain, but is not waterproof. Keep it out of rain or wet mud.*

### 4.2 TAKING MEASUREMENTS

The readings consist in measuring the distance between each measurement point and the upper access tube edge.

The procedure to take the readings (including the initial one) is the following:

- Loosen the brake knob to allow the reel to turn freely.
- Lower the probe by the graduated electrical tape to the bottom of the access tube. Readings are always made from the bottom to the top of the access tube. Switch the readout unit on using the sensitivity button. Turn it at mid-position.
- Slowly raise the probe by the measuring tape. For each anchor, the buzzer sounds two times, indicating the magnetic field of the measurement point (the red light on the panel turns on as well). Record for each one the tape reading (use the top of the access pipe as reference):
  - $L_i$  as lower depth when the sound begins
  - $L_f$  as lower depth when the sound stops
  - $U_i$  as upper depth when the sound begins
  - $U_f$  as upper depth when the sound stops

### 4.3 QUICK VERIFICATION OF MEASUREMENTS

On site, even before converting raw readings into engineering values, several checks can be done to prevent a bad measurement.

- Compare readings to previous ones. Are they in the same range? Are they changing slowly or abruptly? Consider external factors that can affect the measurements like construction activities, excavations or fills...

- In any case, it is advised to take several readings to confirm the measurement. Then, repeatability can be appreciated and dummy readings erased.

#### 4.4 DATA RECORDING SHEET EXAMPLE

Please refer to appendix 1 at the end of the instruction manual.

## 5 CONVERSION OF READINGS

The conversion consists in:

- calculating the average depths of the beginning and end of the buzzer sounds ( $L_i$ ,  $L_f$ ,  $U_i$ ,  $U_f$ ) for each measurement point, including the datum anchor.
- (assuming that the bottom of the borehole is not moving,) “inverting” the reference so that readings are distances between the anchor and the datum ring rather than distances between the anchor and the top of the access pipe.

Subsequently, the settlement is calculated by assessing the change in distance between the measurement point and datum anchor, from the initial measurement to the final measurement.

Example: (readings in meters)

Anchor number	Initial reading	Position	Actual reading		Movement
			Raw value	Average	
Datum	12.95	$L_i$	13.06	12.97	0.02
		$L_f$	12.96		
		$U_i$	12.95		
		$U_f$	12.89		
1	11.02	$L_i$	11.18	11.10	0.06
		$L_f$	11.10		
		$U_i$	11.09		
		$U_f$	11.03		
2	8.94	$L_i$	9.14	9.05	0.09
		$L_f$	9.05		
		$U_i$	9.04		
		$U_f$	8.98		
3	6.83	$L_i$	7.19	7.11	0.16
		$L_f$	7.11		
		$U_i$	7.10		
		$U_f$	7.04		

During initial readings, the depths of each anchor point were measured compared to the top of the access pipe. For example, the datum depth was 12.95m and anchor 1 was at 11.02m.

The actual reading of the datum depth is 12.97m. Its “movement” is then 0.02m. As the datum ring is not supposed to move, its “movement” is due to a movement of the top of the access pipe and has to be subtracted from all other anchors readings.

For example, movement of anchor 2 is:

$$9.05 - 8.94 - 0.02 = 0.09\text{m}$$

A positive movement indicates settlement and a negative movement indicates heave.

## 6 MAINTENANCE

To test battery conditions, turn on the sensitivity button to the maximum clockwise position and push the black button labelled "BATTERY TEST" on the control panel. If the battery level is correct, when the button is pushed, the buzzer sounds and the red indicator light on the panel turns on.

If the readout battery has to be changed, remove the three large slotted head screws located on the control panel. Slowly lift the control panel using caution not to pull any wiring located behind the panel. The battery holder is located on the back side of the control panel. Replace battery with a 9 volt alkaline battery. Be sure the battery connector is securely in place, and the battery is in its holder. Replace control panel.

If it is necessary to clean the measuring tape, use a soft cloth and clean water. Rinse off any mud or sand before wiping the cable. The use of chemical cleaners or solvent is not recommended. Excessive cleaning or use of other cleaning methods may damage the plastic protection and the cable markings.

## 7 TROUBLESHOOTING

Keeping the readout unit with its probe clean and dry as well as a secure storage decreases its chance to fail.

### 7.1 UNSTABLE READING

- Check the battery of the readout unit.
- Reduce the sensitivity of the probe.
- Check if the same troubles occur with another magnetic anchor (for example, one not yet installed). If so, the readout unit may be suspected and the factory should be consulted.
- Check if the same troubles occur with another readout unit. If not, check the battery level. The probe may have been partially damaged also.
- Check the integrity of the measuring tape. Sides of it enclose conductor wires.
- The probe may have been damaged by shocks.

### 7.2 NO READING

- Check the battery of the readout unit.
- Increase the sensitivity of the probe.
- Check if the same troubles occur with another magnetic anchor (for example, one not

yet installed). If so, the readout unit may be suspected and the factory should be consulted.

- Check if the same troubles occur with another readout unit. If not, check the battery level. The probe may have been damaged also.

- Check the integrity of the measuring tape. Sides of it enclose conductor wires. Cuts or shorts are located, the factory should be consulted.

- The probe may have been damaged by shocks or water may have penetrated inside it. There is no remedial action.

## 8 MISCELLANEOUS

### 8.1 TAPE ELONGATION

Please note that measurements of settlements or heaves using the model R-4 extensometer are always referenced to the first initial readings. Therefore, if the same equipment is used during the project, there is no need to calculate the elongation of the tape for the different measuring points. Anyway, if that information is needed, details are given below.

The measuring tape is stretched due to the weight of the probe and the centralizer and to its own weight.

Use the following relation to calculate the elongation of the tape:

$$e = k \cdot L^2$$

where  $e$  = elongation of the tape in millimetres

$k$  = coefficient of elongation in mm/m<sup>2</sup>

$L$  = length of the tape in meters

Values of coefficient  $k$  depend on the type of tape:

- with yellow model tape,  $k = 0.0008$  mm/m<sup>2</sup>
- with white model tape,  $k = 0.0015$  mm/m<sup>2</sup>

*Note: The coefficient  $k$  has been measured in the worse conditions, i.e. with a 6.6 cm diameter centralizer fitted on the probe.*

Example: (using a yellow tape and a 6.6 cm diameter centralizer)

With  $L = 200$  m,

We get:  $e = 0.0008 \times 200^2 = 32$  mm

## 8.2 ENVIRONMENTAL FACTORS

Since the purpose of the extensometer installation is to monitor site conditions, factors which may affect these conditions should always be observed and recorded. Seemingly minor effects may have a real influence on the behaviour of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to: blasting, rainfall, tidal levels, excavation and fill levels and sequences, traffic, temperature and barometric changes, changes in personnel, nearby construction activities, seasonal changes, etc.

## 8.3 CONVERSION FACTORS

	To Convert From	To	Multiply By
LENGTH	Microns	Inches	3.94E-05
	Millimetres	Inches	0.0394
	Meters	Feet	3.2808
AREA	Square millimetres	Square inches	0.0016
	Square meters	Square feet	10.7643
VOLUME	Cubic centimetres	Cubic inches	0.06101
	Cubic meters	Cubic feet	35.3357
	Litres	U.S. gallon	0.26420
	Litres	Can-Br gallon	0.21997
MASS	Kilograms	Pounds	2.20459
	Kilograms	Short tons	0.00110
	Kilograms	Long tons	0.00098
FORCE	Newtons	Pounds-force	0.22482
	Newtons	Kilograms-force	0.10197
	Newtons	Kips	0.00023
PRESSURE AND STRESS	Kilopascals	Psi	0.14503
	Bars	Psi	14.4928
	Inches head of water*	Psi	0.03606
	Inches head of Hg	Psi	0.49116
	Pascal	Newton / square meter	1
	Kilopascals	Atmospheres	0.00987
	Kilopascals	Bars	0.01
Kilopascals	Meters head of water*	0.10197	
TEMPERATURE	Temp. in °F = (1.8 x Temp. in °C) + 32 Temp. in °C = (Temp. in °F - 32) / 1.8		

\* at 4 °C

E6TabConv-990505

Table 1: Conversion factors



# Appendix 1

Example of extensometer data sheet

EXTENSOMETER DATA SHEET	
Site name:	Installation date:
Location:	Date of initial reading:
Extensometer name:	Top level:
Probe manufacturer:	Date-time of readings:
Probe serial number:	Readings units:
Operator:	Fill level:

Anchor number	Initial reading	Position	Actual reading		Movement
			Raw value	Average	
Datum		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
1		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
2		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
3		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
4		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
5		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
6		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			

U<sub>i</sub>: upper depth when sound begins  
 U<sub>r</sub>: upper depth when sound stops

Anchor number	Initial reading	Position	Actual reading		Movement
			Raw value	Average	
7		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
8		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
9		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
10		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
11		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
12		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			
13		L <sub>i</sub>			
		L <sub>r</sub>			
		U <sub>i</sub>			
		U <sub>r</sub>			

L<sub>i</sub>: lower depth when sound begins  
 L<sub>r</sub>: lower depth when sound stops