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Instruction Manual
Model 1610
Geokon/Ealey Tape Extensometer

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1. INTRODUCTION

1.1 Theory of Operation

The Model 1610 Tape Extensometer is designed to measure changes in the distance separating two fixed points. Most often the points are located on opposite sides of an underground opening, such as a tunnel, and the measurement is usually of closure of the tunnel walls, (see Figure 1), or roof/floor convergence caused by pressure in the surrounding ground. The tape extensometer is particularly useful for the measurement of deformation of the shotcrete tunnel linings used as part of the "New Austrian Tunneling Method" (NATM). It also finds use in the measurement of closure between the walls of open cuts, in cut and cover operations and between the walls of deep foundation excavation. Other applications include structures, buildings and unstable slopes. By using the same fixed points to locate a leveling staff or EDM target, it is possible to incorporate tape extensometer data into a more comprehensive monitoring survey.

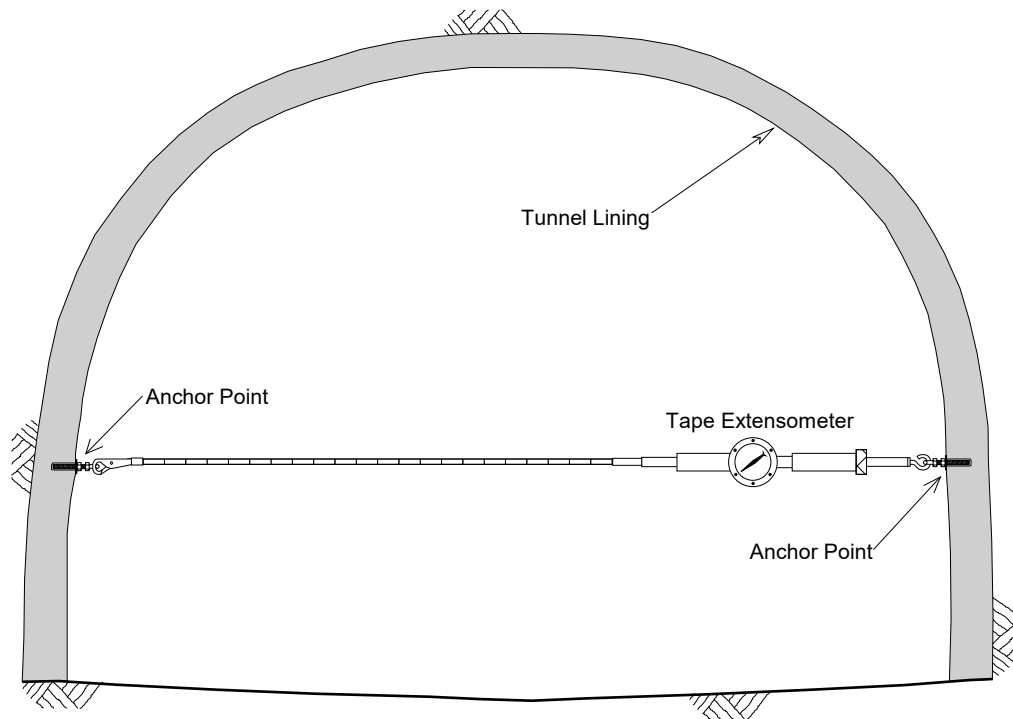


Figure 1 - Typical Installation

The Tape Extensometer has two purposes: to apply a consistent tension to a measuring tape, which has punched holes at regular intervals, and to provide an accurate reading of the distance from the punched hole being used to the eyebolt being measured.

1.2 Construction Details

Figure 2 shows details of the construction of the tape extensometer. The device consists essentially of a steel measuring tape in which holes have been punched at regular intervals. This tape can be stretched between two points located on opposite sides of the underground opening. There is a hook on the end of the tape and another on the back end of the tape extensometer. A locating pin attached to sliding bars is designed to engage one of the punched holes in the tape. The correct hole is that which permits the tape to be tensioned to its correct tension as indicated by system of colored indicator lights.

The tape extensometer can be shortened and the tape tensioned, by rotating a winding handle until the correct tension indicator light is illuminated. At this moment the digital indicator will give the correct reading.

The precision of the instrument will depend to a large degree on the skill of the operator in achieving a consistent and repeatable tape tension. Techniques are described later, (see Section 3.2), which will maximize the precision and accuracy.

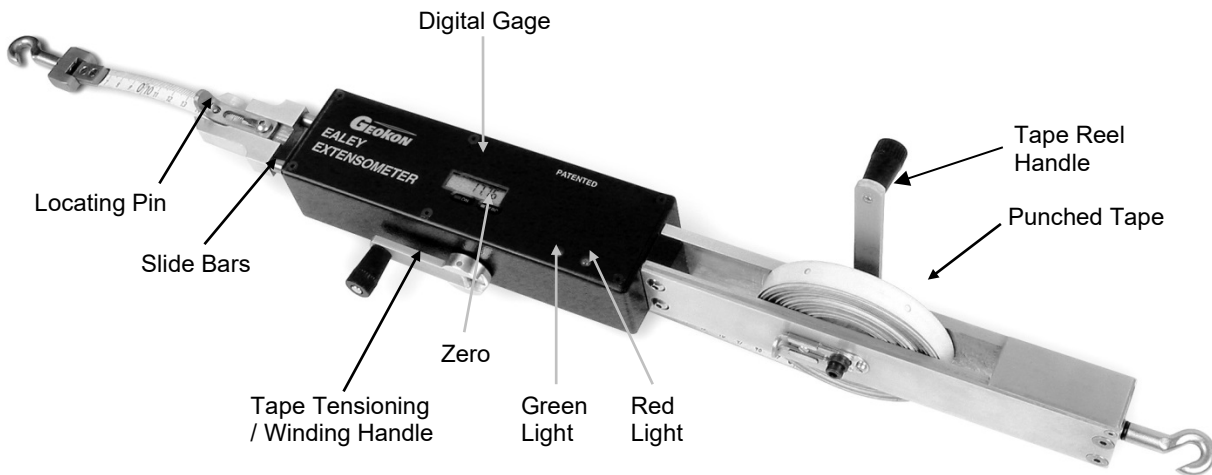


Figure 2 - Model 1610 Tape Extensometer

2. INSTALLATION

Anchor points are of three types as shown in Figure 3.

2.1 Groutable Anchors

An eyebolt is threaded into the end of a piece of $\frac{3}{4}$ " (#6) rebar and the rebar is grouted inside a short (9" or 250 mm) borehole, or cast inside the shotcrete lining (NATM).

2.2 Expanding Wedge Anchors

An alternative to grouting is to use a rockbolt type expansion shell anchor inside a $1\frac{3}{8}$ " diameter (35 mm) borehole. These anchors are recoverable.

2.3 Weldable Anchors

Occasionally anchors may be located on steel ground supports such as tunnel arches, steel tubing or on soldier piles. The eyebolt is attached to a small steel plate, which is then welded to the structure. (Alternately an eyebolt can be screwed directly into a $\frac{1}{4}$ -20 hole drilled and tapped in the steel member.)

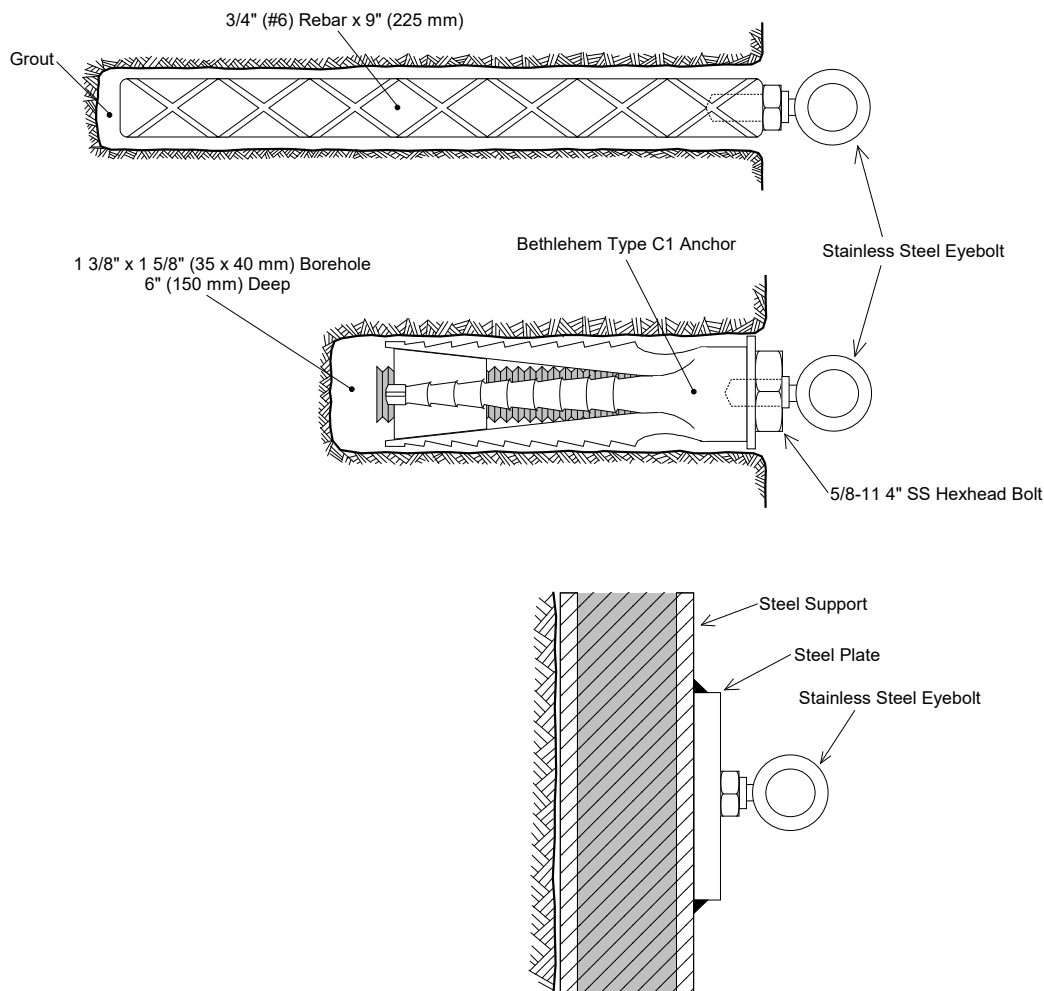


Figure 3 - Three Anchor Types

3. TAKING READINGS

3.1 Preliminary

Always make a careful note of the instrument and tape Serial Numbers when beginning a set of readings. Also note the temperature. Do not assume that the temperature underground will remain constant.

There is no on/off switch for the tension indicator lights; the tension device operates automatically. Ensure that the battery holder contains a charged 9-volt battery before commencing and that the digital gage is on. If the gage is off, **switch it on by moving the tape tensioning winding handle**. The gage will switch itself off after a period of inactivity.

To change the display units to either millimeters or inches remove the top cover plate and use the units selection button on the digital gage.

Before commencing, make sure that the display reads 0.00 mm, (0.000 inches), when the winding handle is turned fully clockwise until it will turn no more. It will come to a natural stop. **DO NOT FORCE THE WINDING HANDLE**. If the reading on the digital gage does not show 0.00 mm, or 0.000 inches, depress the zero button located just below the display window. Periodically check the zero reading from time to time, especially at the start of each set of measurements.

Turn the winding handle anticlockwise until the sliding bars are fully extended, the gage should read at least 55 mm, (2.200 inches).

(See Section 5 for recommended zero stability checking procedures.)

3.2 Tensioning the Tape

Correctly tensioning the tape requires a certain amount of skill. It is recommended that the operator practice the recommended technique until it can be performed rapidly and consistently. Refer to Section 5 for further details.

- 1) Hook the tape onto the first eyebolt and the instrument onto the second eyebolt.
- 2) Using the tape reel handle, reel in the tape so as to remove as much sag as possible then place the nearest punched hole over the locating pin and secure in place by sliding the slotted clip all the way over the tape and pin.
- 3) Turn the tape tensioning winding handle clockwise until one or both of the indicator lights comes on. Turn the winding handle back a small amount until both lights go off.
- 4) Turn the winding handle clockwise, in small increments, until only the green light is on when the instrument is at rest, untouched by the operator.
- 5) Place a finger under the tape, as shown in Figure 4, and **gently** lift the tape so as to relieve a small amount of tension on the tape – the green light should go off. **Gently** removing the finger should cause the green light to come on again. If the green light stays off, turn the winding handle clockwise a small amount until enough tension is being applied so that the green light goes on and off again with gentle placing and removing of the finger under the tape. The tape is now at the correct tension.

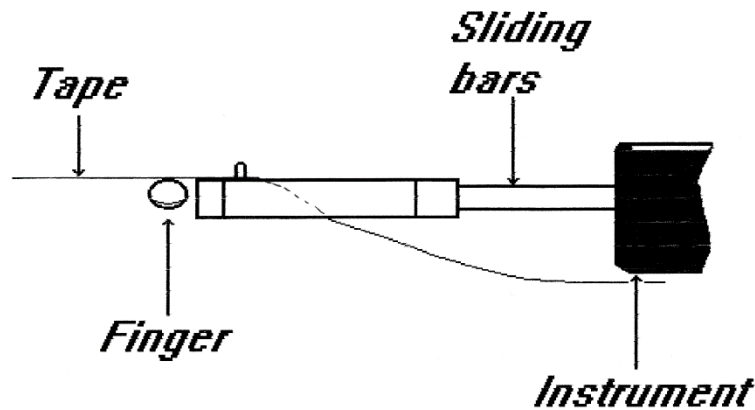


Figure 4 - Tensioning the Tape

- 6) If the red light comes on the tape is over-tensioned, so turn the winding handle anticlockwise and return to step 3.2.3. Alternatively, it may be that the finger pressure being applied to the tape is too great, or, being applied too roughly.
- 7) The red light is set to illuminate at between 0.2 to 0.3 mm after the green light. Over long distances (15 meters or more), tape flutter may cause the red light to come on too soon. If this is the case, return the instrument to the supplier for adjustment, specifying the conditions under which the instrument is required to operate.

3.3 Taking the Reading

Once satisfied that the correct tape tension has been applied, take the reading on the digital gage. It may be necessary to twist the instrument in order to read the gage and this may cause the red or the green light to come on. However, the reading on the digital gage will remain the same so long as the winding handle is not moved.

The travel of the digital gage is slightly larger than the pitch of the punched holes. As a result it may be possible to take readings on two adjacent punched holes. Thus it might happen that continued movements carry the readings beyond the range of the slide bars, before that happens take readings on both tape holes that are within range of the slide bars. For example, if the reading increases to a reading higher than 52 mm switch to the next tape hole and take a second reading of around 1 mm, (or vice versa if the reading decreases to below 1 mm), then continue to use this new tape hole in subsequent readings.

The total distance between the eyebolts is the sum of the distance along the tape indicated by the punched hole used, plus the digital gage reading, plus any correction that is required to account for temperature variations, as described in Section 4. (Note that the first hole in the tape starts at the same dimension as the nominal length of the instrument from the centerline of the pin to the centerline of the hook on the back of the tape extensometer. In the case of metric units this is 500 mm and, for the English units, 20 inches.).

After the reading has been taken, turn the winding handle clockwise, until the sliding bars are fully retracted, then remove the locating pin from the tape. The instrument is now ready for the next reading. For better accuracy it is recommended that all readings be repeated a number of times and the average taken.

4. TEMPERATURE CORRECTIONS

The Effect of temperature on the readings is shown in Table 1 for distance of from 3 to 16 meters and Temperature changes of up to 15 degrees Celsius

For increasing temperatures the corrections, in millimeters, should be added and for decreasing temperatures the corrections should be subtracted.

The following equation can be used for all distances, D, and Temperature, T.

$$\text{Correction } C = [0.0074 + 0.00028(D - 6)] \times D \times (T_1 - T_0)$$

Equation 1 - Temperature Correction

4.1 Metric Temperature Correction Example

A Metric type extensometer measuring over a distance of 10.45 meters shows an initial reading (R_0) at 20° C (T_0) such that the tape pin falls in the hole located at 10.45 meters while the reading on the digital gage is 32.34 mm or 0.03234 meters. The measurement is:

$$\begin{array}{r} 10.45 \\ + 0.03234 \\ \hline 10.48234 \text{ meters} \end{array}$$

A subsequent reading (R_1) taken at a temperature of 0° C (T_1) appears to be 10.49654 meters so the apparent displacement, $R_1 - R_0 = 0.01420$ meters or $+ 14.20$ mm.

The required correction for temperature is:

$$[0.0074 + (0.00028 \times (10.45 - 6))] \times 10.45 \times (0 - 20) = - 1.807 \text{ mm}$$

$$\text{So the true displacement is: } \Delta D_{\text{true}} = + 14.20 - 1.81 = 12.39 \text{ mm}$$

Table 1 shows the Correction Factor by Function of Distance and Temperature. The correction is positive for increasing temperatures.

		Distance In Meters													
		3	4	5	6	7	8	9	10	11	12	13	14	15	16
Change in Temperature (Celsius)	15	0.450	0.495	0.556	0.661	0.796	0.945	1.095	1.245	1.441	1.622	1.805	2.012	2.220	2.460
	14	0.420	0.462	0.520	0.615	0.741	0.885	1.023	1.165	1.345	1.515	1.682	1.875	2.075	2.295
	13	0.395	0.430	0.483	0.575	0.690	0.820	0.950	1.076	1.249	1.405	1.559	1.742	1.925	2.132
	12	0.360	0.395	0.445	0.525	0.636	0.755	0.875	0.995	1.150	1.295	1.440	1.610	1.775	1.966
	11	0.331	0.365	0.408	0.485	0.585	0.695	0.805	0.914	1.055	1.189	1.321	1.475	1.627	1.805
	10	0.301	0.330	0.370	0.442	0.530	0.631	0.732	0.833	0.965	1.082	1.201	1.342	1.481	1.642
	9	0.270	0.296	0.335	0.397	0.475	0.565	0.655	0.745	0.865	0.974	1.081	1.205	1.333	1.475
	8	0.240	0.265	0.295	0.353	0.424	0.504	0.585	0.665	0.768	0.865	0.961	1.072	1.185	1.311
	7	0.210	0.231	0.260	0.309	0.372	0.441	0.510	0.581	0.672	0.755	0.841	0.939	1.035	1.148
	6	0.181	0.198	0.222	0.265	0.318	0.379	0.439	0.498	0.575	0.648	0.721	0.805	0.889	0.985
	5	0.150	0.165	0.185	0.220	0.265	0.315	0.365	0.415	0.480	0.542	0.605	0.671	0.740	0.821
	4	0.120	0.133	0.148	0.175	0.212	0.252	0.292	0.330	0.385	0.432	0.480	0.535	0.592	0.655
	3	0.090	0.100	0.111	0.132	0.160	0.189	0.219	0.250	0.288	0.325	0.360	0.405	0.445	0.491
	2	0.060	0.065	0.075	0.088	0.105	0.125	0.145	0.165	0.193	0.215	0.240	0.251	0.295	0.325
	1	0.030	0.033	0.037	0.045	0.055	0.064	0.073	0.083	0.095	0.109	0.119	0.128	0.148	0.164

Table 1 Temperature Corrections in Millimeters

5. ZERO STABILITY CONTROL

Always set up two test point eyebolts mounted on a stable structure whose dimensions do not change. This can be between two walls of a stable underground opening or between opposite sides of a steel framework kept in a stable temperature environment. Use these test points at regular time intervals, preferably at the start of each measurement survey, to ensure that the self-length of the tape extensometer does not change with time. It is important that zero readings be accurate so repeat the reading a number of times, (five or more), until the accuracy of the recorded value is beyond doubt.

The zero stability control points will also be useful for practicing the measurement technique described in Section 3.2.

Note: It is important that the test point eyebolts be stable, that is, firmly fixed and immovable. Eyebolts attached to objects, which can move even slightly will make it impossible to perform the measurement technique as described in Section 3.2.

It is good practice to extend the monitoring survey to a point outside the area likely to be affected by movements. In this way there will be seen to be confirmation that the tape extensometer records no movement in those areas where no movement is expected. This will go a long way to improving confidence in the readings taken from the active area.

Any gradual or sudden change in the zero reading will indicate the need for servicing and recalibrating the instrument. (See Section 7.)

6. MAINTENANCE

6.1 Care of the Tape/Changing tapes

Care should be taken to keep the tape clean. *Avoid dragging the tape along the ground at all times!* The tape should be treated with the same care as any precision surveying tape. **The greatest danger is kinking the tape** and extreme care should be taken to prevent traffic from damaging the tape while in use. When reeling in the tape pass it through an oily rag to remove dirt and moisture and apply a thin film of oil. Broken tapes can be replaced easily with new tapes.

To remove an old tape simply grip the old tape and turn the tape handle in the opposite way to the reeling in direction, Keep turning and the tape reel spindle will come loose and can be pulled out of the tape reel. Then the new tape can be positioned over the tape reel with the looped inner end of the tape held in the notch. Then the reel is positioned back into the tape extensometer and the tape reel spindle pushed through the reel and threaded back into place in the tape extensometer body. There have been instances where moving traffic has blundered into the tape while readings are being taken resulting in a torn tape. A couple of bright orange sticky notes at mid-span might go some way to prevent this happening.

6.2 Care of the Instrument

The instruments working life will be extended if care is taken to keep the instrument clean. Whenever the instrument has been exposed to dirt or moisture clean it with a soft cloth at the end of the day, paying particular attention to the sliding bars

Store the instrument with the sliding bars retracted so that the gage reads between three and five millimeters.

6.3 Care of the Batteries

6.3.1 The 9-volt Battery

The 9-volt battery powers the indicator lights. It can be removed if the instrument is to be stored for any length of time. The 9-volt battery holder is located on the rear face of the casing. The 9-volt battery should be replaced at least once every year or sooner if the indicator lights start to fade. **Failure to replace the battery after it has gone flat will prevent the tape tension lights from coming on which may lead to tape damage if the tape is over-tensioned.**

6.3.2 The Digital Gage Battery

A coin type battery, Model LR44, powers the digital gage. In order to preserve the life of the battery it automatically switches itself off after about five minute of idleness. Note that if the battery switches itself off between readings the zero setting will **not** be lost when the battery switches itself back on. A low battery indication is given when the display begins to flash on and off. To change the battery it is necessary to remove the face plate and remove five cap screws that hold the digital indicator in place,

Note that removing the battery will cause the gage to automatically reset to millimeters. If this happens with an English unit, depress the button on the digital gage to switch to English units. Reattach the indicator and replace the cover.

7. SERVICING

It is recommended that the instrument be returned to the supplier at least once per year, for service and calibration. The instrument may be returned for a calibration check and the issue of a new calibration certificate at any time.

APPENDIX A. SPECIFICATIONS

Available Ranges¹:	15 m, 20 m, 30 m, (50 ft., 66 ft, 100 ft).
System Accuracy²:	±0.1 mm, (±0.004 in).
Repeatability³:	±0.1 mm, (±0.004 in).
Tension on the Tape	10 kgf (22 lbs.)
Overall Length	520 mm. (20.5 inches).
Case Dimensions	500 × 350 × 125 mm, (20 × 14 × 5 in).
Weight (with case):	2 kg., (4.4 lbs.).
Indicator and Digital Gage Battery	9-volt Coin Type LR44

Table 2 - Model 1610 Specifications

Notes:

¹ Other ranges available.

² Accuracy of the digital gage equal to the resolution (± 1 graduation) = 0.01 mm

³ Repeatability is the system accuracy to be expected under normal conditions and takes into account trained operator error, friction in the system, temperature variations and placement errors. The repeatability is affected by the environmental conditions under which the readings are taken and may be significantly worse than as shown.

APPENDIX B. THE USE OF THE HOOK MANIPULATOR

The Model 1610-10 Hook Manipulator Starter Kit is a simple, portable, and effective system that allows a person of average height to reach the roof of a 4 m tunnel. Extension rods are available for higher locations.



Figure 5 – Hook Manipulator in Use

To reach an overhead eye bolt complete the following steps:

1. Fit the tape extensometer hook through the hole in the end of the hook manipulator. Secure in place with set screw using the provided Allen wrench.
2. With magnet engaged on the end of the hook manipulator, raise the tape and hook onto the eye bolt.
3. Pull the hook manipulator away to disengage the magnet.
4. After taking readings, re-engage the hook manipulator to the magnet and remove tape extensometer from the eye bolt.



Figure 6 – Hook Manipulator to Tape Extensometer Connection