Model TES-AN-31EL
Electrolytic Level Tiltmeter

Model TES-AN-31EL-B
Electrolytic Level Horizontal Beam Sensor

with
Option R – Raw half bridge output
Option V – Voltage output
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1 Introduction

TRITECH Model TES-AN-31EL and TES-AN-31EL-B are tiltmeters for measuring very small tilts, of the order of half a degree, with a high resolution. It uses a ceramic encapsulated electrolytic bubble level sensor as its sensing element.

The TES-AN-31EL Tiltmeter is housed in an aluminum die cast enclosure and is generally used as a stand alone unit for measuring tilt. It is either attached directly to the structure whose tilt is to be monitored using suitable mounting brackets or fixed to vertical beams.

The TES-AN-31EL-B Beam Sensor is housed inside a 38 mm x 38 mm hollow aluminum structural section (beam) and is available in different lengths, generally between 1 to 3 metres. It is mostly used as a linear array of linked beams, fixed to anchors at specified lengths. The beam sensor is used to measure the differential vertical displacement between the two anchors at its ends. An array of linked beam sensors allow the vertical settlement profile along the array line to be determined.

NOTE: Effective from January 1, 2009, the electrolytic sensor is not mounted inside the TES-AN-31EL-B beam as stated in the above paragraph. The model TES-AN-31EL tiltmeter in its aluminum die cast enclosure is directly mounted on the beam. Please make a note of this in reading this manual as it is also applicable to beam sensors supplied before January 1, 2009.

Both the TES-AN-31EL and TES-AN-31EL-B sensors are available with either raw half bridge output (output option R) or voltage output (output option V). The raw half bridge output sensors are lower cost sensors but require a suitable datalogger that can accept half bridge sensors with ac excitation. TRITECH suggests the model CR10X datalogger from Campbell Scientific, U.S.A., for this application. The raw half bridge output option is more popularly used with beam sensors that are used in arrays as a number of sensors in close proximity allows easy use of a datalogger and associated wiring while reducing the cost per sensor.

The voltage output sensors can be read with any digital voltage measuring device like digital indicators or multimeters but do require an additional very low current dc power source. A 9 V dc battery is sufficient to power the tilt sensor. Most commercially available dataloggers generally have some provision for supplying the required power to the sensor. Although voltage output sensors are costlier their output can be read by low cost digital voltmeters.

The voltage output option is more popularly used with TES-AN-31EL which is mostly used as a stand alone tilt sensor and the sensors are generally spread over a fairly wide area.

1.1 Applications

The TES-AN-31EL Tiltmeters and TES-AN-31EL-B Beam Sensors are widely used in following applications:

- Monitoring vertical rotation of retaining walls.
- Monitoring inclination and rotation of dams, piers, piles and other structures.
- Monitoring settlement or heave in ground.
- Monitoring stability of structures in landslide areas.
- Monitoring tunnels for convergence and other movements.
- Monitoring safety of structures around zones of excavation or tunneling.
- Monitoring deflection in bridges and struts under different loading conditions.
1.2 Conventions used in this manual

**WARNING:** Warning messages calls attention to a procedure or practice, that if not properly followed could possibly cause personal injury.

**CAUTION:** Caution messages calls attention to a procedure or practice, that if not properly followed may result in loss of data or damage to equipment.

**NOTE:** Note contains important information and is set off from regular text to draw the users’ attention.

This users’ manual is intended to provide you with sufficient information for making optimum use of El tiltmeters and beam sensors in your applications.

To make this manual more useful we invite valuable comments and suggestions regarding any additions or enhancements. We also request you to please let us know of any errors that may be found while going through the manual.

1.3 How to use this manual

The manual is divided into a number of sections. Each section contains a specific type of information. The list given below tells you where to look for in this manual if you need some specific information.

*For understanding principle of electrolytic tilt / beam sensors: See § 2.1 ‘Principle of Operation’.*

*For installation of electrolytic tilt / beam sensors: See § 3 ‘Installation of Tilt and Beam Sensors’.*

*For essential tools and accessories: See § 3.2 ‘Tools and accessories required for installation’.*
2 The Electrolytic Tilt / Beam Sensor

2.1 Principle of Operation

The Tilt / Beam sensor uses a bubble level sensor just like those used in spirit levels except that in this case the spirit is replaced with an electrically conductive fluid known as electrolyte. In TES-AN-31EL and TES-AN-31EL-B, the glass vial of the spirit level is replaced with a more thermally stable and dimensionally accurate ceramic housing.

The ceramic electrolytic bubble level sensor has three terminals and behaves as a resistive half bridge circuit. The electrolytic bubble sensor has two end terminals and a middle terminal. Electrically it appears as a potentiometer with a fixed resistance between its end terminals and the middle terminal behaves as wiper in a potentiometer. When the bubble level tilts, the resistance between the middle and one of the end terminals goes up and between the middle and the other end terminal goes down. The effect reverses if the direction of tilt is reversed.

The change in the ratio of resistance between the middle terminal and the two end terminals can be measured using an electrical half bridge circuit. In a half bridge circuit the indicator / datalogger applies a voltage across the end terminals and measures the output voltage between the middle terminal and one of the end terminals.

Unfortunately, as the electrolyte used in the sensor deteriorates irreversibly if a dc voltage is applied across its terminals, a pure ac excitation voltage source is a must.

In tilt / beam sensors with raw output option the bubble level sensor terminals are directly available across the output terminals.

In tilt / beam sensors with voltage output option a signal conditioning card converts the half bridge bubble level sensor output to a proportional dc voltage with a nominal full scale value of ±1 V dc.

Tilt / beam sensors with a measurement range lower than 1° are very sensitive sensors and are easily influenced by even small vibrations that appear as noise on the output. These sensors should, as far as possible, be mounted at locations where expected vibration levels are quite low. To exploit the full sensitivity limit of these sensors some kind of averaging facility should be available in the readout unit or datalogger used for monitoring.

2.1.1 Temperature sensitivity of electrolytic bubble level sensors

Electrolytic bubble level sensors have a relatively higher drift in output with ambient temperature. The TES-AN-31EL / TES-AN-31EL-B tilt sensors should therefore be located in areas where the change in temperature is expected to be minimum. For example, the sensors should never be mounted at a place where they would be exposed to direct sunlight.

If required, the tilt sensors can be supplied with a thermistor temperature sensor which can be used to measure the sensor temperature. This temperature reading can be used to correlate the change in tilt with sensor temperature to detect change in tilt that can be attributed to change in sensor temperature.

In the voltage output sensors an integral temperature sensor in the signal conditioning circuit is used to reduce the temperature effect of the bubble level sensor. However, an additional thermistor for recording sensor temperature can be provided if required.

2.2 Sign convention for Tilt and Beam Sensors

The tilt and beam sensors basically measure rotation of the electrolytic level sensors. The electrolyte level sensor capsule is mounted on an aluminum block that can rotate about a screw at one end and has a taper at the other end lying between a pair of thumb nuts which are used to set the initial sensor zero. Considering the pivot screw as the fixed reference if the tapered end of the block rotates counter clockwise the rotation is considered positive. Similarly clockwise rotation is considered negative.
The voltage in case of voltage output sensors are also correspondingly positive for rotation in positive direction and negative for negative direction.

For beam sensors the rotation is converted to a gradient reading using the distance between the anchors at the two ends of the beam, also known as the gauge length. If L is the beam gauge length, and the angle of rotation is $\alpha$ the gradient would be $\tan(\alpha)$. The perpendicular displacement 'd' of one end of the beam considering the other end as fixed is given by

$$d = L \tan(\alpha)$$

For counter clockwise rotation of the beam the displacement is considered positive and for clockwise rotation the displacement is considered negative.

Vertical beam sensors consist of an TES-AN-31EL Tiltmeter mounted on a beam of suitable gauge length. The figure below shows the sign convention for vertical beam sensors.

### 2.3 Usage of Tilt and Beam Sensors

The TES-AN-31EL Tilt sensor is mostly used for stand alone applications where only the change in tilt or rotation of the structure is to be measured. The tilt sensor enclosure can be directly mounted on the structure by using two mounting screws or, more often, by using a suitable wall mounting bracket that allows some degree of rotational adjustment to orient the tilt sensor in a true horizontal position. The use of a wall mounting bracket allows easier drilling of mounting holes as very precise hole locations are not required.
The TES-AN-31EL Tilt sensor is also used with vertical beams of known lengths to determine the horizontal displacement of walls etc. In most cases a series of linked beams are fixed to the wall vertically using a series of anchors. The distance between the anchors is known as the gauge length. Two adjacent beams in the link share the same anchor.

Linked horizontal beams monitor vertical settlement or heave

The TES-AN-31EL-B Horizontal beam sensor is primarily used for obtaining the vertical displacement (i.e. settlement or heave) profile. A series of beam sensors are fixed to an array of anchors in a straight line in the desired direction along which vertical displacement profile is required. A stand alone horizontal beam sensor (i.e. when used singly) is equivalent to a simple tiltmeter and offers no additional advantage unless vertical displacement between two anchors at certain distance is required to be measured.

When beam sensors are used in an array, plotting the individual displacements against the gauge length of each beam yields the displacement profile as shown in accompanying figure. Gauge lengths in an array can be mixed, using shorter gauge lengths where higher resolution is required and longer gauge lengths where lower resolution is required or expected displacement values are very low. However, use of an uniform gauge length will give satisfactory results for most applications.
The sensor beam lengths in the figure is shown as L1, L2, ..., L7 and the corresponding displacement measured by each sensor is shown as d1, d2, ... d7. All beam lengths shown in the figure are equal. The sign of the displacement follows TRITECH convention for the EAN-30/31EL-B sensors. Displacement of sensors rotating anti-clockwise are shown with a positive sign and displacement of sensors rotating in the clockwise direction are shown with a negative sign.

On plotting the cumulative length vs. the cumulative displacement curve one gets the vertical displacement profile along the line of sensor string.

2.4 Sensor measurement range

Three different tilt measurement ranges are specified for the tilt / beams sensors.

1. Linear measurement range: This is the range within which the sensor output is linearly proportional to the measured tilt and linear gauge factors, as given in the calibration certificate, can be used. This range is nearly +/- 25% of the sensor's useable tilt measurement range.

2. Specified measurement range: This is the tilt measurement range over which the sensor's output meets its specified accuracy figure. It requires fifth order polynomial calculation of the sensor output to get the tilt value. This range is generally 70% of the sensor's useable tilt measurement range.

3. Useable measurement range: This is the range over which the sensor will provide a valid output that can be converted to get tilt figures. However, the measurement errors are greater than that specified for the sensor. This measurement range is used to classify the sensor and is used in the ordering code.

For example, if a $1^\circ$ tilt sensor is specified, the specified measurement range would be about 0.7$^\circ$ (around 12mm per metre) and the linear measurement range would be about 0.25$^\circ$ (around 4 mm per metre).

2.5 Calibration and gauge factors of tilt and beam sensors

The TES-AN-31EL / TES-AN-31EL-B tilt and beam sensors are supplied with individual test certificates. The test certificate provides a linear gauge factor that is applicable for only a limited fraction of the operating range of the sensor and is given in terms of gradient, i.e. mm per metre instead of degrees as this is the more common form for specifying small tilt values in the construction industry.

Within the range specified in the test certificate the tilt or gradient using linear gauge factors is given by

$$Y = mX + b$$

where $Y$ is the gradient in “mm per metre” and $X$ is the sensor output in CR-10X data units for raw half bridge output option and volts for voltage output option. The factors ‘$m’ and ‘b’ are provided in the test certificate.

As the tilt sensor output is fairly non-linear, for conversion of measured half bridge or voltage output to corresponding tilt in terms of gradient (i.e. mm per metre) the constants of a fifth order polynomial is provided in the test certificate.

The tilt or gradient using polynomial coefficients is given by:

$$Y = C_0 + C_1X + C_2X^2 + C_3X^3 + C_4X^4 + C_5X^5$$

Where, $Y$ is the tilt or gradient in “mm per metre”, $C_0$ through $C_5$ are the polynomial constants as given in the test certificate, and $X$ is the sensor output measured in terms of CR10X data units for raw half bridge output sensors and volts for voltage output sensors.

Samples of Raw Output and Voltage Output sensor Test Certificates are attached at the end of this manual. The calibration data shown in the test certificates is obtained by mounting the tilt or beam sensors on a precision 0.5 m long beam.
2.6 Specifications

Specifications for 1° sensor (standard)

- Useable measurement range: ± 1° (approx 18 mm per metre)
- Measurement range (for specified accuracy): ± 0.7° (approx 12 mm per metre) Using 5th order polynomial calculation
- Non-conformance error (poly fit): ± 0.3 mm per metre (standard) < ± 0.2 mm per metre (optionally available)
- Linear measurement range: ± 0.25° (approx 4 mm per metre) Using linear gauge factor
- Repeatability: ± 3 arc second

For Voltage output option only

- Output voltage: ± 1.5 V dc maximum
  (The output voltage is referenced to the O/P – terminal and not the P/S – terminal. When using a datalogger use a differential input.)
- Power supply voltage: 5.5 to 13 V dc

General Specifications

- Sensor type: Electrolytic level type, uniaxial
- Operating Temperature Range: -20°C to 55°C
- Mechanical zero adjustment range: approximately ± 4°
- Dimensions: See the ‘Dimensions’ section
- Output cable: 4-conductor shielded cable recommended. (6 conductor shielded cable is required for units with additional thermistor temperature sensor)
- Cable gland size for output cable: PG-7 (accommodates cable OD sizes from 2.5 to 6.5 mm).
- Temperature sensor (Optional, if ordered): R-T curve matched thermistor, 3 kohms at 25°C, provided between screw terminals marked T1 and T2. Dale type 1C3001-B3 or equivalent. (Themistor resistance vs. temperature table is provided at the end of this manual.)
3 Installation of Tilt and Beam Sensors

The horizontal beam sensor model TES-AN-31EL-B is supplied either as a bare sensor assembly for mounting inside a 38 x 38 mm hollow aluminum structural section (beam) of specified length or factory fitted inside a beam of specified length. Standard beam lengths are 1m, 2m and 3m but customer specified beam lengths between 0.5 m to 3m are also supplied.

The beam length in the specification refer to the gauge length of the beam in the mounted position. The actual length of the beam is about 36 mm longer than the specified size due to the mounting angles provided at the end of the beams.

The vertical beam sensors are made by clamping the standard tiltmeter on to the beams of specified length. The beams are same as for the horizontal beam sensors, except that the sensor compartment inside the beam is not required or provided.

3.1 Use of mounting kit

The tiltmeter and the beam sensors can be mounted directly to the anchors on wall or floor using the mounting angles or brackets supplied with the tiltmeter or beam sensors. However, if the structure is likely to deform in directions other than the rotational plane of the beams the use of components supplied with the optionally available mounting kit will give better result.

Mounting kits are available for mounting the tiltmeter and beam sensors on wall or floor but have to be ordered separately. Two mounting kits are required for mounting an individual beam sensor, but as invariably the beam sensors are mounted linked in series for profiling settlement, the number of mounting kits required is one more than the number of beams in a string. The mounting kit is common for wall, floor or series mounting.

Each mounting kit consists a set of groutable 148 mm long all threaded stud anchor, with an angle bracket and a set of nuts, spring washers, and plain washers. Another set of an all thread stud anchor of around 72 mm length and a set of nuts, plain washers, spring washers, disc spring washers, two single shouldered and one double shouldered nylon washer is also included. The nuts and washers are supplied assembled on the respective studs from which the correct position of these components during assembly can be noted.

3.2 Tools and accessories required for installation

The following tools and accessories are required for installation of beam sensors model TES-AN-31EL-B:

1. El-beam sensor mounting kits, one more than the number of beams to be mounted in series.
2. Two open ended spanners of 17mm size and one open ended spanner of 13mm size, or two adjustable wrenches.
3. One flat head screw driver with 4mm blade width.
4. Quick set epoxy grout for grouting the anchors in concrete.
5. Loctite 290 thread sealant or any other post assembly thread sealant.
6. Percussion or hammer drill with 12 mm drill bit.
7. Chalk line and coloured chalk.
8. Tape measure, longer than the maximum beam gauge length to be used.
9. Spirit level.
10. One of the following indicators for zero adjustment and monitoring:
    i) Tritech El-beam indicator model TES-DI-53 ELV (for raw output sensors only);
ii) 3 ½ digit, 2 V range, indicator or multimeter (for voltage output sensors only);

iii) CR-10X datalogger (suitable for both raw output or voltage output sensors).

3.3 Installation of Horizontal Beam Sensor

3.3.1 Mounting the sensor assembly inside the beam

The TES-AN-31EL-B, El-beam sensor is generally supplied mounted inside a beam of customer specified length. However, on specific customer request the sensor and the beams may be supplied separately. In such cases the sensor has to be mounted inside the beam before the beams are fixed.

1. The sensor compartment cover is fixed with two screws to beam. Remove the screws and the compartment cover.

2. The sensor assembly is provided with two mounting screws at the back of the assembly. Remove the two mounting screws and place the sensor assembly inside the sensor compartment in the beam. Align the mounting holes on the beam with the mounting holes on the sensor assembly and fix the two mounting screws from the back of the beam.

3. Fix the sensor compartment cover back.

3.3.2 Installing the anchors

Horizontal beam sensors are used to find the relative vertical displacement of the two anchors at its ends. The distance between the two anchors is known as the gauge length of the beam sensor. The beam sensors are generally supplied in standard gauge lengths of 1, 2 or 3 m, but other customer specified lengths are also available.

The beam sensors are generally used in a string with two beam sensors sharing a common anchor for fixing.

1. Using a chalk-line and suitable coloured chalk mark a straight line along which the beam sensors would be fixed. For wall mounting use a spirit level and a beam to ensure that the line is as horizontal as possible. For floor mounting the line should be aligned along the direction in which the vertical settlement profile is desired.

2. With a tape measure, on the above line, mark off distances corresponding to the gauge length of the beams to be fixed. It may be noted that the beams are slightly longer than their gauge length. If required, beams of different gauge lengths may be used in the same string. Each mark corresponds to an anchor position.

3. Drill 12mm diameter anchor holes to a depth of about 100 mm at the marked position. Ensure that the holes are as perpendicular to the wall or floor surface as possible.

4. Clear the hole of debris by blowing air or brushing.

5. Fix the longer (150 mm) anchors of the mounting kits with suitable epoxy grout in these holes such that around 50mm length of anchors project out of the surface after fixing. Follow epoxy manufacturer’s recommendation for fixing the anchors.

6. Allow the grout to set for the recommended time before handling.

7. Measure and record the exact centre distances between each anchor in the string. Hint: As the anchor centres may be difficult to locate, measure the distance between the left side of each anchor.
3.3.3 Fixing the beams

The El-beams are provided with two mounting angles on each side. The beams can be fixed to the anchors directly using these mounting angles. However, if the string of beams are subject to any torsional movement the separately available beam mounting kits provide more flexibility and are strongly recommended.

The figure below also shows the correct position of each component of the kit while mounting the beams.

1. Fasten angle brackets to the already grouted 148 mm anchors. Check the relative position of the nuts, washers and angle brackets from the drawing.
2. Fix the 72 mm stud anchors on the angle brackets fixed to the grouted anchors.
3. Slightly loosen the mounting angle at both sides of each beam by loosening the hex nut holding it to the beam.
4. Fix the beams on the 72 mm stud anchors as shown in drawing. Use the double shouldered nylon washer between the mounting angles of two adjacent beams.
5. Lightly tighten the nuts so that the spring washers are slightly compressed.
6. Tighten the bolt head holding the mounting angles to the beam ends.
7. Put a drop of Loctite 290 (post assembly thread locking compound) at the accessible junction of each nut on the studs to lock them in place.

Figure below shows how to mount the TES-AN-31EL-B horizontal beam sensor on wall using the standard mounting kit.
3.4 Installation of Tiltmeter

The TES-AN-31EL Tiltmeter is used to measure simple rotation of structures in a single plane known as plane of rotation. The plane of rotation is a plane parallel to the back side (surface) of the tiltmeter.

Depending on monitoring requirement the tiltmeter can be mounted in two different ways as described below.

3.4.1 Rotation expected in the plane of the wall

If the structural rotation is expected to be in the plane of the surface of the wall, the tiltmeter is mounted directly on the wall using the wall mounting bracket. The use of wall mounting bracket
allows coarse levelling of the tiltmeter and the alignment of the anchors need not be very precise. The wall mounting bracket is fixed to the wall using any commercially available 8 mm anchors / fasteners suitable for brick or concrete wall.

1. Using the wall mounting bracket as a template, mark position of two mounting holes. Visually ensure that the two hole positions are aligned vertically as much as possible.

2. Drill two holes of diameter and depth suitable for the type of anchor to be used.

3. Fix the mounting anchors in holes following the manufacturer’s recommendation.

4. Mount the tiltmeter on the wall mounting bracket.

5. Fix the wall mounting bracket with the tiltmeter to the anchors on the wall.

3.4.2 Rotation expected in a vertical plane perpendicular to the wall

If the surface of the wall is expected to rotate in a vertical plane perpendicular to the wall the tiltmeter should be mounted in an orientation as shown in the accompanying figure. The use of a mounting kit is recommended as this allows easy adjustment of the tiltmeter orientation.

1. Remove tiltmeter cover. Fix the tiltmeter housing to the mounting bracket using the two mounting screws. Replace tiltmeter cover.

2. Drill 12mm diameter anchor holes to a depth of about 100 mm at the marked position.

3. Clear the hole of debris by blowing air or brushing.

4. Fix the longer (148 mm) anchors of the mounting kits with suitable epoxy grout in these holes such that around 50mm length of anchors project out of the surface after fixing. Follow epoxy manufacturer’s recommendation for fixing the anchors.

5. Allow the grout to set for the recommended time before handling.
6. Fasten angle brackets to the already grouted 148 mm anchors. Check the relative position of the nuts, washers and angle brackets from the accompanying figure.

7. Fix the 72 mm stud anchors on the angle brackets fixed to the grouted anchors.

8. Fix the tiltmeter mounting bracket on the 72 mm stud anchors as shown in accompanying figure.

9. Lightly tighten the nuts so that the spring washers are slightly compressed.

10. Ensure that the tiltmeter cover surface is both, perpendicular to the wall as well as vertical.

11. Put a drop of Loctite 290 (post assembly thread locking compound) at the accessible junction of each nut on the studs to lock them in place.

### 3.5 Installation of Vertical Beam Sensors

Vertical beam sensors are used to find the relative horizontal displacement of the two anchors at its ends. The distance between the two anchors is known as the gauge length of the beam sensor. Vertical beam sensors are generally supplied in standard gauge lengths of 1, 2 or 3 m, but other customer specified lengths are also available. The beam sensors are generally used in a string with two beam sensors sharing a common anchor for fixing.

Vertical beam sensors consist of a standard TES-AN-31EL tiltmeter, an aluminum beam, 38mm x 38 mm square and of specified gauge length and mounting hardware for mounting the tiltmeter on the beam, generally packed separately for shipment.

#### 3.5.1 Installing the anchors

1. Using a plumb line and suitable coloured chalk mark a vertical straight line along which the beam sensors would be fixed.

2. With a tape measure, on the above line, mark off distances corresponding to the gauge length of the beams to be fixed. It may be noted that the beams are slightly longer than their gauge length. If required, beams of different gauge lengths may be used in the same string. Each mark corresponds to an anchor position.

3. Drill 12mm diameter anchor holes to a depth of about 100 mm at the marked position. Ensure that the holes are as perpendicular to the wall or floor surface as possible.

4. Clear the hole of debris by blowing air or brushing.

5. Fix the longer (148 mm) anchors of the mounting kits with suitable epoxy grout in these holes such that around 50mm length of anchors project out of the surface after fixing. Follow epoxy manufacturer’s recommendation for fixing the anchors.

6. Allow the grout to set for the recommended time before handling.

7. Measure and record the exact centre distances between each anchor in the string. Hint: As the anchor centres may be difficult to locate, measure the distance between the left side of each anchor.

#### 3.5.2 Mounting the tiltmeter on the beam

Mount the tiltmeter on the beam as described below. The accompanying figure shows the details.
1. Slide the beam through the clamp opening of the mounting hardware. Lightly tighten the clamp around the middle of the beam. The mounting angles of the beam should lie towards the clamping screw side of the clamp opening.

2. Remove the tiltmeter cover.

3. Fix the tiltmeter to the mounting plate using the two fixing screws.

4. Clamp tiltmeter to the beam by tightening the two clamp nuts.

### 3.5.3 Fixing the beams

The sensor beams are provided with two mounting angles on each side. The beams can be fixed to the anchors directly using these mounting angles. However, if the string of beams are subject to any torsional movement the separately available beam mounting kits provide more flexibility and are strongly recommended.

1. Fasten angle brackets to the already grouted 148 mm anchors. Check the relative position of the nuts, washers and angle brackets from the drawing.

2. Fix the 72 mm stud anchors on the angle brackets fixed to the grouted anchors.

3. Slightly loosen the mounting angle at both sides of each beam by loosening the hex nut holding it to the beam.

4. Fix the beams on the 72 mm stud anchors as shown in drawing. Use the double shouldered nylon washer between the mounting angles of two adjacent beams. The beams should be roughly parallel to the wall surface.

5. Lightly tighten the nuts so that the spring washers are slightly compressed.

6. Tighten the bolt head holding the mounting angles to the beam ends.

7. Check that the top of the tiltmeter enclosure is level. If not, then remove cover, loosen the two mounting screws and rotate housing. Tighten mounting screws and replace cover when done.

8. Put a drop of Loctite 290 (post assembly thread locking compound) at the accessible junction of each nut on the stud anchors to lock them in place.
Thumb nut side should be away from wall.
4 Working with half bridge output sensors (option R)

The instructions in this section apply to sensors with raw half bridge output (output option R) only. See the next section for initial adjustment of sensors provided with a voltage output.

The TES-AN-31EL and TES-AN-31EL-B are identical sensors except that in TES-AN-31EL the sensor beam and the signal board are mounted one above the other and in TES-AN-31EL-B the sensor beam and the signal board are mounted side by side.

4.1 Making connections

As the sensor is sensitive to very minute changes in tilt (of the order of 1 arc seconds) it is recommended that the signal cable be connected to the sensor output terminals before zero adjustment is carried out. After connecting the signal cable, it should be secured to the wall or any other stationary structural member so that the cable cannot move and affect the sensor position.

Use a good quality 3 or 4 conductor shielded cable for making connections between the sensor and the read out or datalogger unit. TRITECH type EC-0107 or Belden type 8723 cables are recommended for this application.

A suggested wiring colour code for connecting above cables is shown below:

<table>
<thead>
<tr>
<th>Sensor terminal</th>
<th>Wire colour</th>
<th>Signal name</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1</td>
<td>Red</td>
<td>AC Excitation</td>
</tr>
<tr>
<td>J2</td>
<td>Not used</td>
<td>(reference half bridge mid point)</td>
</tr>
<tr>
<td>J3</td>
<td>Green</td>
<td>Sensor output (AC)</td>
</tr>
<tr>
<td>J4</td>
<td>Black</td>
<td>Analog ground</td>
</tr>
<tr>
<td>Drain wire</td>
<td>Not connected to sensor. Should be connected to ground at datalogger end only, if required, to reduce noise pickup.</td>
<td></td>
</tr>
</tbody>
</table>

However, the user can use any other suitable cable or colour scheme without affecting performance.

If the optional thermistor is provided for monitoring sensor temperature, the thermistor terminals are available on screw terminals marked T1 and T2. In this case a 5 or 6 conductor cable (3 conductors for tilt sensor, 2 conductors for thermistor) would be required.

4.2 Setting the DIP switches

The sensor printed circuit board (PCB) contains two banks of slide switches, SW1 comprising of two switches and SW2 comprising of four switches. The individual switches are in ON position when the raised actuators of the individual switches are towards the position marked ON on the switch. In the other position, the switches are OFF.
Whenever the signal cable connected to the output terminals need to be tested for continuity or proper wiring etc. using equipment like multimeter all switches should be set to the OFF position. Failure to do this may cause serious damage to the electrolytic sensing element as it is very sensitive to dc current or voltage.

4.3 Initial or Mechanical Zero Adjustment

The tilt measurement range of TES-AN-31EL/31EL-B Electrolytic beam sensors is very small, i.e. of the order of $\pm 1^\circ$. While mounting the sensor it is not practically possible to very precisely level the sensor. In most cases the initial sensor tilt would be much greater than its specified tilt measurement range. It is very important that the sensor element, SB in figure below, is initially set to its true horizontal (i.e. zero) position after mounting so that its full tilt measurement range can be utilized.

The TES-AN-31EL/31EL-B sensor is provided with a double thumb wheel arrangement, N1 and N2 that allows the sensor to be precisely leveled after mounting. A level correction range of approximately $\pm 4^\circ$ from true horizontal is provided.

In principle, to level (i.e. zero adjust) the sensor a suitable read out unit is connected to the sensor output terminals and the twin adjusting thumb wheels rotated to level the sensor holding beam while monitoring the sensor output.

4.4 Setting sensor zero

A readout unit has to be connected to the sensor before zero adjustment so that the required amount of adjustment can be displayed.
A CR10X datalogger can be used as a readout during zero adjustment if it is located adjacent to the sensor. Otherwise a suitable commercially available indicator like model EL-35 (not supplied by TRITECH) can be used with the sensor. The EL-35 indicator is suitable for zero adjustment only. It cannot be used for regular tilt observation for which a CR10X datalogger is essential.

Follow the steps given below if an EL-35 indicator is used for zero adjustment:

1. Set switch position as follows

<table>
<thead>
<tr>
<th>Bank</th>
<th>Switch</th>
<th>Switch position</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW2</td>
<td>1</td>
<td>OFF</td>
</tr>
<tr>
<td>SW2</td>
<td>2</td>
<td>OFF</td>
</tr>
<tr>
<td>SW2</td>
<td>3</td>
<td>OFF</td>
</tr>
<tr>
<td>SW2</td>
<td>4</td>
<td>OFF</td>
</tr>
<tr>
<td>SW1</td>
<td>1</td>
<td>ON</td>
</tr>
<tr>
<td>SW1</td>
<td>2</td>
<td>OFF</td>
</tr>
</tbody>
</table>

2. Plug the EL-35 readout signal cable connector to the DB9 socket on the sensor board and switch on the readout.

3. The EL-35 displays 600 counts for +20 arc minutes and –600 for –20 arc minutes from true horizontal position.

4. If the EL-35 sensor shows a reading other than zero rotate the two thumb nuts so that the display shows a reading as near to zero as possible. The display reading will become more positive if the pointed end of sensor beam moves up and more negative when it moves down. DO NOT loosen the sensor beam retaining screw as it is a friction clutch that introduces a controlled amount of friction to the beam movement. Finger tight the two thumb nuts to the sensor beam.

5. Wait for some time to ensure that the zero reading is stable otherwise a readjustment is required.

6. Put a drop of post assembly thread locking compound, such as Loctite 290, at the junction of the thumb nut and threaded stud to prevent the thumb nuts from loosening.

7. The EL-35 readout unit can now be turned off and disconnected from the sensor board.

The TES-AN-31EL/31EL-B beam sensor is now ready for use.

4.5 Reading the raw output sensors

TES-AN-31EL/31EL-B sensors with raw half bridge output behave as a resistive half bridge between the output terminals. The electrolyte fluid used in the sensors gets irreversively damaged in the presence of even very small dc voltages across the sensor terminals. It is very important that these sensors are always measured using pure ac excitation voltage sources.

The TES-AN-31EL/31EL-B sensors can be read with any indicator or datalogger that has ac half bridge measurement function. However, TRITECH recommends using Campbell Scientific (USA) CR10X datalogger for acquiring data from a number of sensors for reasons mentioned below.

Although the TES-AN-31EL/31EL-B is a very sensitive, high resolution and high repeatability tilt sensor, it is a very non-linear sensor. The sensor parameters also vary a lot between units. For these reasons each sensor has to be supplied with an individual calibration sheet. The calibration data is usually supplied in the form of a fifth order polynomial coefficients. The polynomial coefficients can be used only if the measurement at the user end is also carried out in the same way as it was done at the factory.

TRITECH uses a calibrated Campbell Scientific CR10X datalogger for computing the polynomial coefficients during calibration of these sensors. Users are advised to use the following CR10X instructions and parameters while writing their program.
1. Use P78 (High Resolution) parameter to ensure that data transfer to final storage area is made in high resolution format (i.e. maximum data value = 99999 counts, ignoring decimal point position).

2. Use P5 (AC Half Bridge) instruction with following parameter values; 2500 mV Fast Range, 2500 mV Excitation, Multiplier = 10.

4.6 Connecting sensor to CR10X

The wiring between TES-AN-31EL/31EL-B sensor and the CR10X depends on how many multiplexers are being used in the system and the control program. However, a typical direct interconnection between a single sensor and a CR10X can be made as follows. The suggested colour codes are for TRITECH type EC-0107 or Belden type 8723 cable.

<table>
<thead>
<tr>
<th>CR10X Terminal</th>
<th>Sensor terminal</th>
<th>Wire colour</th>
<th>Signal name</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1 (or any of the 2 excitation channels)</td>
<td>J1</td>
<td>Red</td>
<td>AC Excitation</td>
</tr>
<tr>
<td>J2</td>
<td></td>
<td></td>
<td>Not used</td>
</tr>
<tr>
<td>H or L (i.e. any SE channel)</td>
<td>J3</td>
<td>Green</td>
<td>Sensor output (AC)</td>
</tr>
<tr>
<td>AG</td>
<td>J4</td>
<td>Black</td>
<td>Analog ground</td>
</tr>
<tr>
<td>G</td>
<td></td>
<td>Drain wire</td>
<td>Not connected to sensor. Should be connected to ground at datalogger end only to reduce noise pickup.</td>
</tr>
</tbody>
</table>

The switches on the TES-AN-31EL/31EL-B sensor board should be set to the following position:

<table>
<thead>
<tr>
<th>Bank</th>
<th>Switch</th>
<th>Switch position</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW2</td>
<td>1</td>
<td>ON</td>
</tr>
<tr>
<td>SW2</td>
<td>2</td>
<td>OFF</td>
</tr>
<tr>
<td>SW2</td>
<td>3</td>
<td>ON</td>
</tr>
<tr>
<td>SW2</td>
<td>4</td>
<td>ON</td>
</tr>
<tr>
<td>SW1</td>
<td>1</td>
<td>OFF</td>
</tr>
<tr>
<td>SW1</td>
<td>2</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Use CR10X function P55 (5th Order Polynomial) to calculate sensor tilt in terms of ‘mm per metre’ from raw data readings. The coefficients C0 to C5 given in the TRITECH sensor test certificate correspond to coefficients C0 to C5 of instruction P55.
5 Working with voltage output sensors (Option V)

The instructions in this section apply to sensors with voltage output (output option V) only. See the previous section for initial adjustment of sensors with raw half bridge output.

The TES-AN-31EL sensor is supplied in an aluminum enclosure and is suitable for use either as a tiltmeter or for mounting on a vertical beam using suitable clamps. The TES-AN-31EL-B sensor is suitable for mounting inside a 38 mm x 38 mm square aluminum beam and is generally provided mounted inside a customer specified 1, 2 or 3 m long beam. The basic TES-AN-31EL-B sensor is also available for those customers who would like to fabricate the beam themselves.

The TES-AN-31EL and TES-AN-31EL-B are identical sensors except that in TES-AN-31EL the sensor beam and the signal board are mounted one above the other and in TES-AN-31EL-B the sensor beam and the signal board are mounted side by side.

5.1 Making connections

As the sensor is sensitive to very minute changes in tilt (of the order of 1 arc seconds) it is recommended that the signal cable be connected to the sensor output terminals before zero adjustment is carried out. After connecting the signal cable, it should be secured to the wall or any other stationary structural member so that the cable cannot move and affect the sensor position.

Use a good quality 3 or 4 conductor shielded cable for making connections between the sensor and the read out or datalogger unit. TRITECH type EC-0107 or Belden type 8723 cables are recommended for this application.

A suggested wiring colour code for connecting above cables is shown below:

<table>
<thead>
<tr>
<th>Sensor terminal</th>
<th>Wire colour</th>
<th>Signal name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS +</td>
<td>Red</td>
<td>Excitation supply – positive</td>
</tr>
<tr>
<td>PS –</td>
<td>Black</td>
<td>Excitation supply – negative</td>
</tr>
<tr>
<td>OP +</td>
<td>Green</td>
<td>Sensor output – positive</td>
</tr>
<tr>
<td>OP –</td>
<td>White</td>
<td>Sensor output – negative</td>
</tr>
<tr>
<td>Drain wire</td>
<td></td>
<td>Not connected to sensor. Should be connected to ground at datalogger end only, if required, to reduce noise pickup.</td>
</tr>
</tbody>
</table>

However, the user can use any other suitable cable or colour scheme without affecting performance.

If the optional thermistor for monitoring sensor temperature is also provided the thermistor terminals are available at screw terminals marked T1 and T2.

The voltage output sensors have a Printed Circuit Board (PCB) that contains the signal conditioning circuitry and screw terminals for making external connections.
There are two pair of terminals on the four position terminal block. The terminals marked P/S + and P/S – have to be connected to a stable dc power source with an output voltage between 5.5 to 13 V. The sensor draws around 1 mA current from the power supply.

The sensor output is available as a dc voltage between terminals marked O/P + and O/P –. The output voltage is bipolar, i.e. the O/P + terminal can be either positive or negative with respect to the O/P – terminal. With respect to the O/P – terminal the voltage at the O/P + terminal is generally adjusted to give nearly ±1 V dc at full scale tilt value (0.7° for a 1° tilt sensor).

Any suitable dc voltage source that can supply up to 1 mA current can be used as sensor supply. Any ordinary 3 ½ digit voltmeter or multimeter with 2 V measurement range can be used to measure the sensor output.

Most of the commercially available dataloggers have provision for providing the power supply required by the sensor. The model CR10X datalogger from Campbell Scientific, USA is one of the popular dataloggers that is widely used by geotechnical instrumentation engineers worldwide for this application.

5.2 Initial or Mechanical Zero Adjustment

The tilt measurement range of TES-AN-31EL/31EL-B Electrolytic beam sensors is very small, i.e. of the order of ±1°. While mounting the sensor it is not practically possible to very precisely level the sensor. In most cases the initial sensor tilt would be much greater than its specified tilt measurement range. It is very important that the sensor element, SB in figure below, is initially set to its true horizontal (i.e. zero) position after mounting so that its full tilt measurement range can be utilized.

The TES-AN-31EL/31EL-B sensor is provided with a double thumb wheel arrangement, N1 and N2 that allows the sensor to be precisely leveled after mounting. A level correction range of approximately ±4° from true horizontal is provided.

In principle, to level (i.e. zero adjust) the sensor a suitable read out unit is connected to the sensor output terminals and the twin adjusting thumb wheels rotated to level the sensor holding beam while monitoring the sensor output.
5.3 Setting sensor zero

A readout unit has to be connected to the sensor before zero adjustment so that the required amount of adjustment can be displayed.

A CR10X datalogger can be used as a readout during zero adjustment if it is located adjacent to the sensor. Otherwise a suitable 3½ digit indicator or multimeter with 2 V measurement range (not supplied by TRITECH) together with a DC power supply (or a suitable battery) can be used with the sensor.

Follow the steps given below for zero adjustment:

1. Connect the indicator / power supply or the CR10X to the tilt sensor and turn on power to the sensor.
2. If the indicator sensor shows a reading other than zero rotate the two thumb nuts so that the display shows a reading as near to zero as possible. The display reading will become more positive if the pointed end of sensor beam moves up and more negative when it moves down. DO NOT loosen the sensor beam retaining screw as it is a friction clutch that introduces a controlled amount of friction to the beam movement. Finger tight the two thumb nuts, N1 and N2, to the sensor beam.
3. Wait for some time to ensure that the zero reading is stable otherwise a readjustment is required.
4. Put a drop of post assembly thread locking compound, such as Loctite 290, at the junction of the thumb nut and threaded stud to prevent the thumb nuts from loosening.
5. The indicator / power supply or the CR10X can now be turned off and disconnected from the sensor board.

5.4 Reading the voltage output sensors

The TES-AN-31EL/31EL-B sensors can be read with any indicator or datalogger that has +/- 2 V measurement function. Most dataloggers will have some provision for supplying power to the tilt sensor. An additional 5.5 V to 13 V dc power supply would be required if a multimeter or an indicator is used as readout.

Although the TES-AN-31EL/31EL-B is a very sensitive, high resolution and high repeatability tilt sensor, it is a very non-linear sensor. The sensor parameters also vary a lot between units. For these reasons each sensor is supplied with an individual calibration sheet. The calibration data is usually supplied in the form of a fifth order polynomial coefficients. As a lot of processing is required to get accurate tilt data, a datalogger with polynomial calculation function is strongly suggested for use with these tilt sensors.

5.5 Connecting sensor to CR10X

The wiring between TES-AN-31EL/31EL-B sensor and the CR10X depends on how many multiplexers are being used in the system and the control program. However, a typical direct interconnection between a single sensor and a CR10X can be made as follows. The suggested colour codes are for TRITECH type EC-0107 or Belden type 8723 cable.

<table>
<thead>
<tr>
<th>CR10X Terminal</th>
<th>Sensor terminal</th>
<th>Wire colour</th>
<th>Signal name</th>
</tr>
</thead>
<tbody>
<tr>
<td>12V</td>
<td>PS +</td>
<td>Red</td>
<td>Power supply - positive</td>
</tr>
<tr>
<td>G</td>
<td>PS -</td>
<td>Black</td>
<td>Power supply - negative</td>
</tr>
<tr>
<td>1H (of any DIFF channel)</td>
<td>O/P +</td>
<td>Green</td>
<td>Sensor output - positive</td>
</tr>
</tbody>
</table>
1L | O/P - | White | Sensor output - negative |
---|---|---|---|
G | Drain wire | Not connected to sensor. Should be connected to ground at datalogger end only to reduce noise pickup.

If using the CR10X use the following instructions to acquire data in your program.

1. Use P78 (High Resolution) parameter to ensure that data transfer to final storage area is made in high resolution format (i.e. maximum data value = 99999 counts, ignoring decimal point position).

2. Use P2 (measure Differential Volts) instruction with following parameter values; 2500 mV Slow Range, Multiplier = .001, Offset = 0.

Use CR10X function P55 (5th Order Polynomial) to calculate sensor tilt in terms of ‘mm per metre’ from raw data readings. The coefficients C0 to C5 given in the TRITECH sensor test certificate correspond to coefficients C0 to C5 of instruction P55.
6 Dimensions

6.1 TES-AN-31EL Tiltmeter

6.2 TES-AN-31EL-B Horizontal Beam Sensor (bare sensor assembly)

(Note: all dimensions in mm.)
6.3 TES-AN-31EL-B Horizontal Beam Sensor (assembled beam)
7 Thermistor Resistance vs. Temperature table

**Thermistor type:** Dale 1C3001-B3

**Temperature resistance equation**

\[ T = \frac{1}{[A + B(LnR) + C(LnR)^3]} - 273.2 \, ^\circ C \]

- \( T \) = temperature in \( ^\circ C \)
- \( LnR \) = Natural log of thermistor resistance
- \( A = 1.4051 \times 10^{-3} \)
- \( B = 2.369 \times 10^{-4} \)
- \( C = 1.019 \times 10^{-7} \) Ohm

<table>
<thead>
<tr>
<th>Ohm</th>
<th>Temp. °C</th>
<th>Ohm</th>
<th>Temp. °C</th>
<th>Ohm</th>
<th>Temp. °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>201.1k</td>
<td>-50</td>
<td>16.60k</td>
<td>-10</td>
<td>2417</td>
<td>+30</td>
</tr>
<tr>
<td>187.3k</td>
<td>-49</td>
<td>15.72k</td>
<td>-9</td>
<td>2317</td>
<td>31</td>
</tr>
<tr>
<td>174.5k</td>
<td>-48</td>
<td>14.90k</td>
<td>-8</td>
<td>2221</td>
<td>32</td>
</tr>
<tr>
<td>162.7k</td>
<td>-47</td>
<td>14.12k</td>
<td>-7</td>
<td>2130</td>
<td>33</td>
</tr>
<tr>
<td>151.7k</td>
<td>-46</td>
<td>13.39k</td>
<td>-6</td>
<td>2042</td>
<td>34</td>
</tr>
<tr>
<td>141.6k</td>
<td>-45</td>
<td>12.70k</td>
<td>-5</td>
<td>1959</td>
<td>35</td>
</tr>
<tr>
<td>132.2k</td>
<td>-44</td>
<td>12.05k</td>
<td>-4</td>
<td>1880</td>
<td>36</td>
</tr>
<tr>
<td>123.5k</td>
<td>-43</td>
<td>11.44k</td>
<td>-3</td>
<td>1805</td>
<td>37</td>
</tr>
<tr>
<td>115.4k</td>
<td>-12</td>
<td>10.86k</td>
<td>-2</td>
<td>1733</td>
<td>38</td>
</tr>
<tr>
<td>107.9k</td>
<td>-41</td>
<td>10.31k</td>
<td>-1</td>
<td>1664</td>
<td>39</td>
</tr>
<tr>
<td>101.0k</td>
<td>-40</td>
<td>9796</td>
<td>0</td>
<td>1598</td>
<td>40</td>
</tr>
<tr>
<td>94.48k</td>
<td>-39</td>
<td>9310</td>
<td>+1</td>
<td>1535</td>
<td>41</td>
</tr>
<tr>
<td>88.46k</td>
<td>-38</td>
<td>8851</td>
<td>2</td>
<td>1475</td>
<td>42</td>
</tr>
<tr>
<td>82.87k</td>
<td>-37</td>
<td>8417</td>
<td>3</td>
<td>1418</td>
<td>43</td>
</tr>
<tr>
<td>77.66k</td>
<td>-36</td>
<td>8006</td>
<td>4</td>
<td>1363</td>
<td>44</td>
</tr>
<tr>
<td>72.81k</td>
<td>-35</td>
<td>7618</td>
<td>5</td>
<td>1310</td>
<td>45</td>
</tr>
<tr>
<td>68.30k</td>
<td>-34</td>
<td>7252</td>
<td>6</td>
<td>1260</td>
<td>46</td>
</tr>
<tr>
<td>64.09k</td>
<td>-33</td>
<td>6905</td>
<td>7</td>
<td>1212</td>
<td>47</td>
</tr>
<tr>
<td>60.17k</td>
<td>-32</td>
<td>6576</td>
<td>8</td>
<td>1167</td>
<td>48</td>
</tr>
<tr>
<td>56.51k</td>
<td>-31</td>
<td>6265</td>
<td>9</td>
<td>1123</td>
<td>49</td>
</tr>
<tr>
<td>53.10k</td>
<td>-30</td>
<td>5971</td>
<td>10</td>
<td>1081</td>
<td>50</td>
</tr>
<tr>
<td>49.91k</td>
<td>-29</td>
<td>5692</td>
<td>11</td>
<td>1040</td>
<td>51</td>
</tr>
<tr>
<td>46.94k</td>
<td>-28</td>
<td>5427</td>
<td>12</td>
<td>1002</td>
<td>52</td>
</tr>
<tr>
<td>44.16k</td>
<td>-27</td>
<td>5177</td>
<td>13</td>
<td>965.0</td>
<td>53</td>
</tr>
<tr>
<td>41.56k</td>
<td>-26</td>
<td>4939</td>
<td>14</td>
<td>929.6</td>
<td>54</td>
</tr>
<tr>
<td>39.13k</td>
<td>-25</td>
<td>4714</td>
<td>15</td>
<td>895.8</td>
<td>55</td>
</tr>
<tr>
<td>36.86k</td>
<td>-24</td>
<td>4500</td>
<td>16</td>
<td>863.3</td>
<td>56</td>
</tr>
<tr>
<td>34.73k</td>
<td>-23</td>
<td>4297</td>
<td>17</td>
<td>832.2</td>
<td>57</td>
</tr>
<tr>
<td>32.74k</td>
<td>-22</td>
<td>4105</td>
<td>18</td>
<td>802.3</td>
<td>58</td>
</tr>
<tr>
<td>30.87k</td>
<td>-21</td>
<td>3922</td>
<td>19</td>
<td>773.7</td>
<td>59</td>
</tr>
<tr>
<td>29.13k</td>
<td>-20</td>
<td>3748</td>
<td>20</td>
<td>746.3</td>
<td>60</td>
</tr>
<tr>
<td>27.49k</td>
<td>-19</td>
<td>3583</td>
<td>21</td>
<td>719.9</td>
<td>61</td>
</tr>
<tr>
<td>25.95k</td>
<td>-18</td>
<td>3426</td>
<td>22</td>
<td>694.7</td>
<td>62</td>
</tr>
<tr>
<td>24.51k</td>
<td>-17</td>
<td>3277</td>
<td>23</td>
<td>670.4</td>
<td>63</td>
</tr>
<tr>
<td>23.16k</td>
<td>-16</td>
<td>3135</td>
<td>24</td>
<td>647.1</td>
<td>64</td>
</tr>
<tr>
<td>21.89k</td>
<td>-15</td>
<td><strong>3000</strong></td>
<td>25</td>
<td>624.7</td>
<td>65</td>
</tr>
<tr>
<td>20.70k</td>
<td>-14</td>
<td>2872</td>
<td>26</td>
<td>603.3</td>
<td>66</td>
</tr>
<tr>
<td>19.58k</td>
<td>-13</td>
<td>2750</td>
<td>27</td>
<td>582.6</td>
<td>67</td>
</tr>
<tr>
<td>18.52k</td>
<td>-12</td>
<td>2633</td>
<td>28</td>
<td>562.8</td>
<td>68</td>
</tr>
<tr>
<td>17.53k</td>
<td>-11</td>
<td>2523</td>
<td>29</td>
<td>525.4</td>
<td>70</td>
</tr>
</tbody>
</table>