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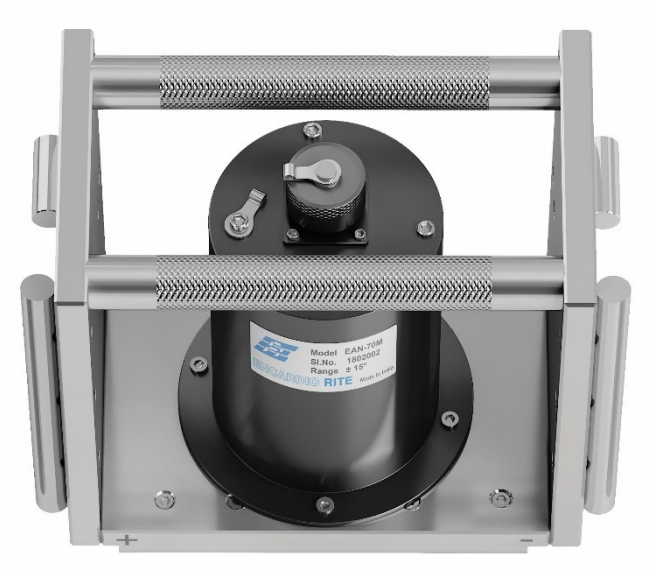
USERS' MANUAL

PORTABLE TILT METER

MODEL EAN-70M



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1 INTRODUCTION

Encardio-rite model EAN-70M portable high resolution uniaxial tilt meter is suitable for monitoring inclination and vertical rotation in structures. It is rugged in construction and has excellent temperature stability.

Tilt changes in a structure may be caused by construction activity such as excavation, tunnelling or de-watering that may affect ground that supports the structure. Change in tilt may also result from loading of a structure, such as loading of a dam during impoundment, loading of a diaphragm wall during excavation or loading of a bridge deck due to wind and traffic. Data from tilt meter provides early warning of threatening deformation, allowing time for corrective action to be taken or if necessary, for safe evacuation of the area.

EAN-70M tilt measurement system consists of two components – a portable tilt meter and a number of Aluminium tilt plates. Individual tilt plates are Tilt plates are typically anchored to the structure, but may also be bonded to a smooth clean surface i.e. granite, stone, tiles. To monitor tilt, the user places the portable tilt meter on the mounted tilt plate and gets the tilt reading at that location. The portable tilt meter has to be carried from one tilt plate to another to get readings at different locations. Although EAN-70M is a uniaxial tilt meter it can be used to take biaxial measurements at any particular location by rotating the tiltmeter by 90^{o} on the tilt plate and taking a second reading.

In case automatic data acquisition is required, Encardio-rite offers a different tilt meter model EAN-90M for use with data acquisition systems.

1.1 Applications

EAN-70M can be used for measurement of tilt of a structure along any vertical plane or along two orthogonal vertical planes. Following are some examples of its use:

- Monitoring critical structures in zone of influence of cut and cover excavation/tunnelling activity.
- Monitoring vertical rotation of retaining walls.
- Monitoring inclination of dams, piers and piles etc.
- Monitoring stability of structures in landslide areas.
- Monitoring performance of bridges.

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.

1.3 How to use this manual

The users' manual is intended to provide sufficient information for making optimum use of the portable tilt meter in different applications.

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

NOTE: Installation personnel must have a background of good installation practices and knowledge of fundamentals of geotechnics. Novices may find it very difficult to carry on installation work. The intricacies involved in installation are such that even if a single essential but apparently

minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

A lot of effort has been made in preparing this instruction manual. However best of instruction manuals cannot provide for each and every condition in field that may affect performance of the sensor. Also, blindly following the instruction manual will not guarantee success. Sometimes, depending upon field conditions, installation personnel will have to consciously depart from written text and use their knowledge and common sense to find solution to a particular problem.

Installation and measurements using portable tilt meter requires expertise. It is recommended that potential users themselves practice all operations laid down in this manual by repeated installations.

2 PORTABLE TILT METER

2.1 General description

Model EAN-70M tilt meter is built around a precision accelerometer and suitable signal conditioning circuit mounted inside an anodized aluminium housing. The accelerometer senses force of acceleration due to gravity which is maximum when accelerometer is rotated to full 90^o tilt position and is zero (minimum) when the tilt angle of the accelerometer is 0^o. For in-between angles, force experienced by accelerometer is equal to product of sine of tilt angle and acceleration due to gravity. Tilt sensor provides a bipolar DC voltage output proportional to sine of tilt angle measured by the tilt meter. Output is zero volts for a truly vertical sensor.

The sensor provides a relatively low cost tilt measurement solution with excellent resolution, long term stability and low thermal sensitivity.

The tilt meter can be used to measure change in tilt of any vertical surface or horizontal floor by placing it on a suitable reference tilt plate, available separately.

The EAN-70M is not intended for absolute determination of tilt of structures. It measures change in tilt of structures to which reference tilt plate is attached. Initial tilt reading for each tilt plate is recorded after it is mounted on structure to be monitored. Subtracting initial tilt reading from subsequent tilt readings give change in tilt of structure over a period of time.

2.1.1 Tilt plate

Tilt plate is a Aluminium disc about 142 mm in diameter. It is fixed to the structure with four Hilti anchors HPS 1-6/15x40 # 260350 or equivalent. In case the structure has a smooth surface like marble or granite, the tilt plate may be bonded to it by epoxy. The four pegs on the tilt plate are used to orient the tilt meter.

Horizontally mounted tilt plate allows tilt readings in two planes that are at 90^o to each other. Vertically mounted tilt plate allows tilt readings along one vertical plane only.

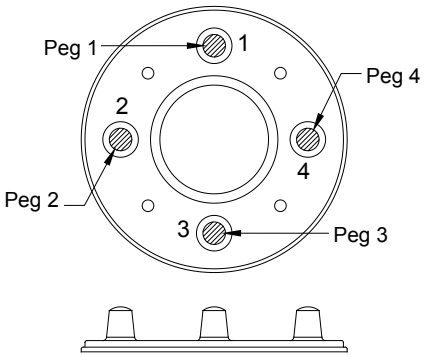
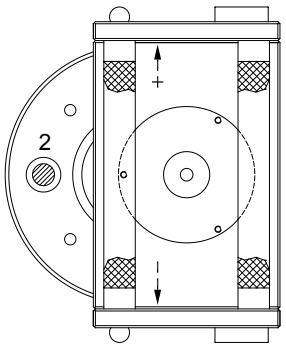


Figure 1 tilt plate

2.1.2 Tilt meter

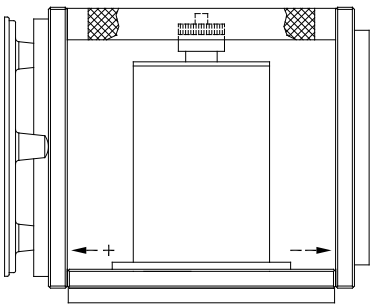
Portable tilt meter is carried from one tilt plate to another to obtain tilt readings. Alignment bars provided on bottom, front and rear side of tilt meter are used to accurately position the tilt meter on the tilt plate.

Two readings are taken for each tilt plane - one reading in plus direction and another in minus direction. The base plate of tilt meter has + and - marks to assist proper orientation of the tilt meter.



Tiltmeter placed onto a horizontal tilt plate

Figure 2



Tiltmeter placed against a vertical tilt plate

Figure 3

2.1.3 Readout unit

Encardio-rite digital readout unit model EDI-53UTM is used to take observations from portable tilt meter. It displays readings in terms of sine (tilt angle). The sign of reading is (+ or -) according to direction of tilt.

2.2 Taking readings

Allow time for tilt meter to adjust to ambient temperature. If possible, store tilt meter at same temperature as at time of taking readings. Connect tilt meter to readout and power up. Take readings as follows:

2.2.1 Reading horizontal tilt plates

- Take reading in plane "A" first. In figures 4 below, pegs 1 and 3 define direction of plane "A". Place "+" end of tilt meter on peg 1, wait for reading to stabilize, and record it. Rotate tilt meter 180^{o} and place "-" end of tilt meter on peg 1, wait for reading to stabilize and record it.
- Repeat steps two to three times to ensure readings are repeatable. In theory A+ and A - readings should be identical except for different sign (+/-). In practice there is a difference up to 0.003 on Encardio-rite readout unit EDI-53UTM between two readings due to bias of sensor and small irregularities in tilt plate.
- Figure 4 below shows positioning of portable tilt meter on tilt plate for taking readings in plane A.

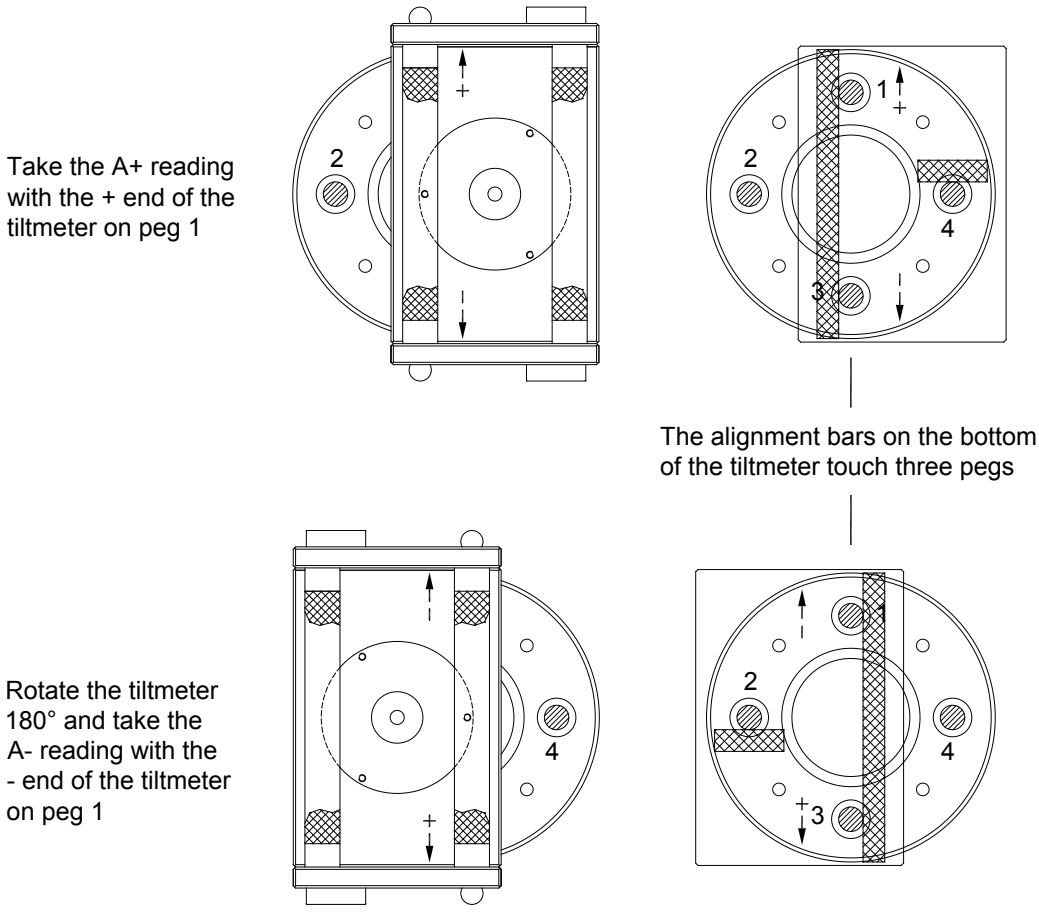


Figure 4 taking readings in plane A

- Take readings in plane B next. Plane B is defined by direction of pegs 2 and 4. Place "+" end of tilt meter on peg 4, wait for reading to stabilize and record it. Rotate tilt meter 180^{o} and place "-" end of tilt meter on peg 4, wait for reading to stabilize and record it. Figure 4 & 5 explain positioning of portable

tilt meter on tilt plate to take readings in plane A and B respectively.

- Repeat steps two to three times to ensure readings are repeatable. In theory B+ and B - readings should be identical except for different sign (+/-). In practice there is a difference up to 0.003 on Encardio-rite readout unit EDI-53UTM between two readings due to bias of sensor and small irregularities in tilt plate.
- Figure 5 below shows positioning of portable tilt meter on tilt plate for taking readings in plane B.

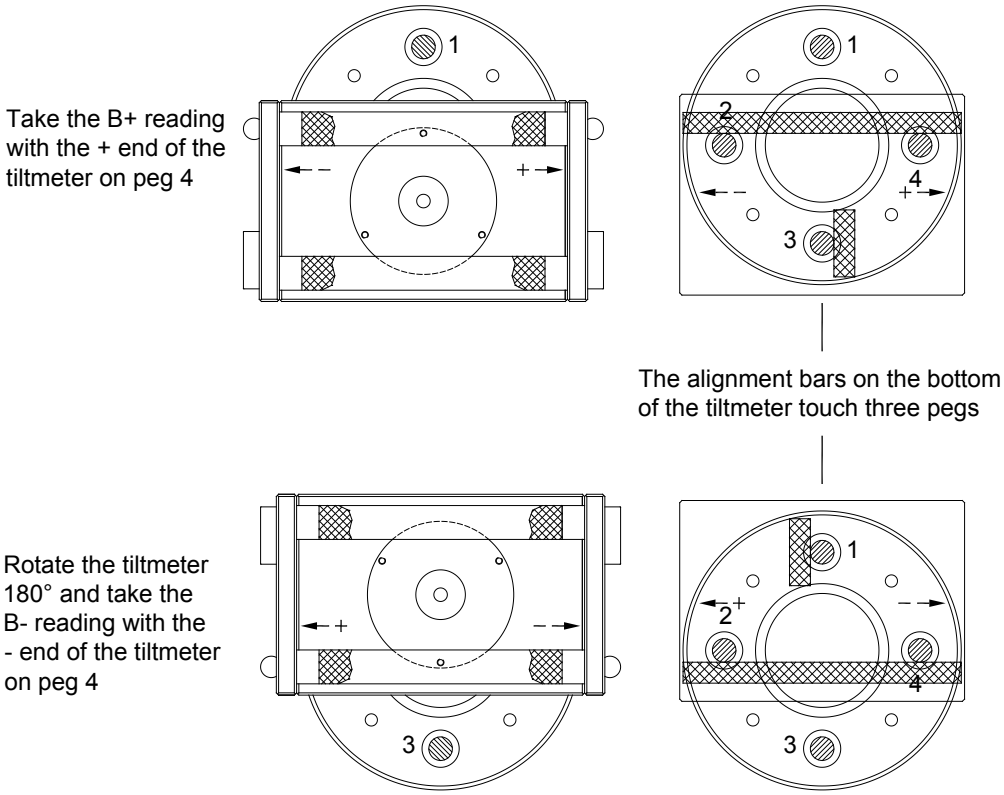


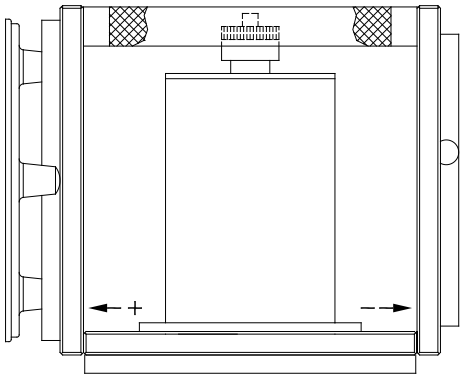
Figure 5 taking readings in plane B

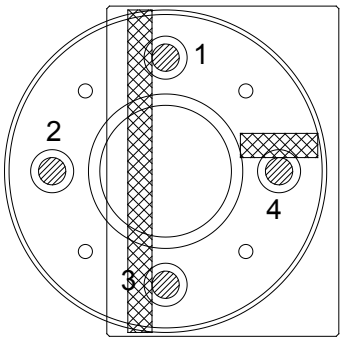
2.2.2 Reading vertical tilt plates

Vertical tilt plate allows reading in tilt plane A defined by direction of pegs 1 and 3. The tilt meter is aligned using alignment bars at ends of tilt meter.

- Place "+" end of tilt meter against peg 1, wait for reading to stabilize and record it. Refer to figure 6.
- Place "-" end tilt meter against peg 1, wait for readings to stabilize and record it.
- Repeat these steps three times to ensure that you have good repeatable readings.
- Repeat steps two to three times to ensure readings are repeatable. In theory readings should be identical except for different sign (+/-). In practice there is a difference up to 0.003 on Encardio-rite readout unit EDI-53UTM between two readings due to bias of sensor and small irregularities in tilt plate.
- Figure 6 below shows position of portable tilt meter on tilt plate for taking readings in vertical plane B.

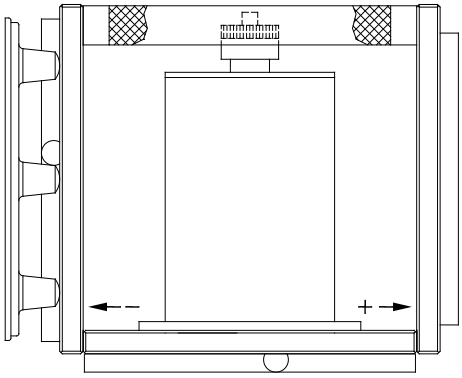
Take the A+ reading with the + end of the tiltmeter placed against pegs 1, 3 & 4





The alignment bars on the bottom of the tiltmeter touch three pegs

Rotate the tiltmeter 180° and take the A- reading with the - end of the tiltmeter placed against pegs 1 , 3 & 2



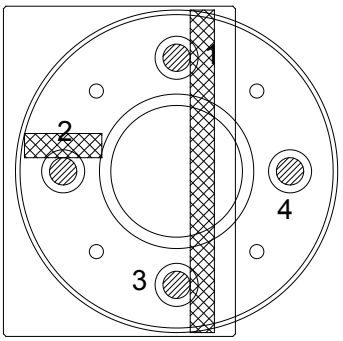


Figure 6 taking readings in vertical plane

2.2.3 Taking readings with Encardio-rite model EDI-53 UTM readout unit

For detailed description, refer to User's Manual WI-6002.67 on EDI-53 series Digital Indicators and EDI-53 UTM Addendum.

Encardio-rite model EDI-53 UTM portable readout unit is a microprocessor based indicator that reads sine of tilt angle when parameters of a typical portable tilt meter are fed.

The EDI-53 indicator can store initial data from up to 250 tilt plates so that change in tilt angle measured from these tilt plates can be determined in proper engineering units.

The indicator has an internal non-volatile memory with sufficient capacity to store about 3600 readings from any of the 250 programmed tilt plates in any combination. You can store either 3600 readings from any one tilt plate or 14 sets of readings from all 250 tilt plates. Each reading is stamped with the date and time the measurement was taken.

The stored readings can either be uploaded to a host computer using the serial interface or can be printed out on any text printer equipped with a RS-232C serial communications interface. The setup information (calibration coefficients) for all the channels can also be printed out for verification.

Setting up the EDI-53 UTM indicator is easy as all the prompts and error messages are in plain simple English language. Power on self tests and a separate test mode operation for more detailed diagnostics are an added advantage.

An internal 6V rechargeable sealed maintenance free battery is used to provide power to the indicator. A fully charged new battery provides nearly 60 hours of operation on a single charge. A separate battery charger is provided with the EDI-53 UTM indicator to charge the internal battery from 230 V AC mains.

The EDI-53 UTM indicator is housed in a splash proof plastic moulded enclosure with weather proof connectors for making connections to the transducer and the battery charger.

To read sine of tilt angle one has to setup EDI-53UTM channel as follows:

Units [UNITS]	No units (key 9)
Initial reading [IR]	Set to zero
Gauge factor [GF]	2/portable tilt meter gage factor in volts/sin 90
Coeff. Of X^2	Set to zero
Decimal point [DP]	as required

2.3 Sample test certificate

Encardio-rite Electronics Pvt. Ltd.
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E-mail: sales@encardio.com, encardio@sancharnet.in; Website: www.encardio.com
Tel. +91 (522) 2661039/40/41/42 Fax +91 (522) 2661043

TEST CERTIFICATE

Customer :
P.O. :
Item : Portable tilt meter (Uniaxial)
Model : EAN-70M
Range : ±15º
Serial no. : 0705002

Date :18.05.2007
Temperature :33 ºC

Test data

Test position arc degrees	Sin(A)	*Calculated out-put	Observed output (+A axis)	Observed output (-A axis)	Average	Best fit Sin(A)	Error	Non-conform-ance
(A)	(X)	(V1)	(V2)	(V3)	(V4)	(Y)	(X~Y)	%fs
			Volts					
1	0.01746	0.2794	0.277	-0.281	0.279	0.01743	0.00003	0.011
2	0.03491	0.5586	0.555	-0.559	0.557	0.03491	0.00001	0.002
3	0.05236	0.8377	0.833	-0.837	0.835	0.05239	0.00003	0.011
6	0.10457	1.6731	1.664	-1.667	1.666	0.10460	0.00003	0.012
9	0.15650	2.5040	2.49	-2.491	2.491	0.15647	0.00003	0.010
12	0.20799	3.3279	3.309	-3.311	3.310	0.20799	0.00000	0.000
15	0.25892	4.1427	4.118	-4.122	4.120	0.25892	0.00000	0.000

Max non-conformance (% fs) : 0.012

Sensor gauge factor (G) 6.287E-02 Sin(90)/Volts
[Sensor gage factor for read out unit Model : EDI-53 UTM is **15.905** Volts/Sin (90)**]
Regression zero (R0) 1.770E-03

Calculation of tilt value (arc degree)

$SinA = G * (R1 - R0)$
$A = Sin^{-1}\{G*(R1 - R0)\}$

R1 =Current display reading in volts
R0 =Regression zero
G =Gage factor

Wiring code :

Pin ID	Signal
A	+ 12 V (supply)
B	- 12 V (supply)
C	0 V (supply)
D	Output 'A' axis
E	Output 'B' axis NA
F	Output common

Note :

*Calculated output Voltage (V_1) worked out based on nominal gauge factor of 16.000 V/ g (i.e. 16V X Sin A).

**Calculation of GF shall be done as per notes given in test certificate of read out unit EDI-53 UTM.

Checked by Tested by

3 INSTALLATION PROCEDURE

Tilt plates are placed on structural members that are representative of the large structure. When a single location does not represent the structure, additional tilt plates are placed at other locations.

Number of tilt plates needed is determined by stiffness of the structure and accuracy desired. Stiffer structures require fewer plates. To achieve high accuracy, more plates are required. Tilt plates are generally placed with one set of pegs oriented to the expected direction of rotation. Location of tilt plate shall be chosen such they are easily accessible.

Be careful to avoid installation of tilt plates on expensive exteriors like marble, granite, tiles or special materials where cost of make good would be very high.

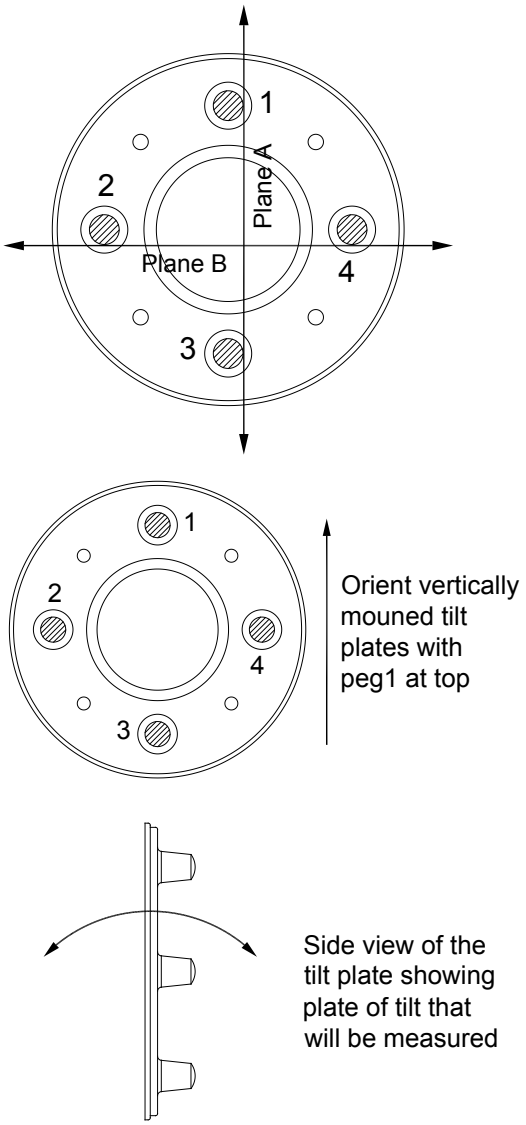

Figure 7 tilt plate mounting on horizontal surface

3.1 Orientation of horizontal tilt plates

Horizontal plates provide two planes of measurement. Plane A is defined by pegs 1 & 3. Peg 1 is usually oriented towards the direction of tilt. Plane B is defined by pegs 2 & 4. Peg 4 is usually oriented toward the direction of tilt.

3.2 Orientation of vertical tilt plates

Vertical tilt plates should be aligned so that a vertical line can be drawn through pegs 1 and 3.

3.3 Mounting procedure of tilt plates

Tilt plates can be fixed to the structure with anchors and screws or with grout. When tilt plate experiences temperature changes or weather, a combination of both anchors and grout works best.

3.3.1 Anchors and screws

- Prepare a clean flat surface.
- Place tilt plate on structure in its intended orientation. Mark location of anchors.
- Drill holes large enough and deep enough to accommodate anchors.
- Screw the tilt plate to anchors.
- Check and ensure correctness of horizontal and vertical position of tilt plate by using a sprit level.

3.4 Tools & accessories required for installation

- Hilti Impact fastener polyamide no. HPS 1-6/15X40 or equivalent
- Star head screw driver
- Sprit level 150mm Drill bit 6mm
- Power drill machine
- Ball point hammer, 250 gm.

4 DATA REDUCTION

One is generally interested in finding change in tilt of a structure. To find change in tilt, subtract initial tilt from current tilt and convert result in degrees or displacement.

4.1 Displayed readings

Encardio-rite readout unit model EDI-53UTM display the readings in terms of sin (tilt angle).

Displayed readings = sin(A)

where A = angle of tilt

4.2 Combining + and – readings

Obtain two readings for each tilt plane, a "+" reading a "-" reading. In the data reduction process, add the two readings to eliminate sensor bias. Denote this value by "DIFF"(algebraic difference). A positive DIFF value indicate tilt toward + end of tilt meter.

DIFF = (+ reading) - (- reading)

4.3 Calculating tilt

To convert the DIFF value to tilt in degrees, divide it by 2 because the DIFF value comprises of two readings.

Take inverse sine of this value to get angle of tilt in degrees.

Angle of tilt = $\sin^{-1}$ (DIFF/2)

To calculate change in tilt use following formula:

Change in tilt = $\sin^{-1}(DIFF_2/2) - \sin^{-1}(DIFF_1/2)$

where $DIFF_1$ is the initial reading (tilt reading taken just after installation) and $DIFF_2$ is the current tilt reading (reading taken on a subsequent date)

Angle of tilt = $\sin^{-1}$ (DIFF/2)

To calculate change in tilt use following formula:

Change in tilt = $\sin^{-1}(DIFF_2/2) - \sin^{-1}(DIFF_1/2)$

where $DIFF_1$ is the initial reading (tilt reading taken just after installation) and $DIFF_2$ is the current tilt reading (reading taken on a subsequent date).