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USERS' MANUAL

VIBRATING WIRE SISTER BAR

MODEL EDS-12V

Doc. # WI 6002.87 R02 | June 2018

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1 INTRODUCTION

The Encardio-rite model EDS-12V vibrating wire sister bar strain meter is specially designed for embedment in concrete structures. It is ideal for measurement of strain in concrete structures such as piles, diaphragm/slurry walls, bridge abutments, tunnel lining, dams, foundations, etc.

The sister bar incorporates the latest vibrating wire technology to provide digital readout on a remote vibrating wire indicator or data acquisition system on magnitude and distribution of compressive and tensile strain in concrete structures and other areas of application where strain measurement is required. As an Encardio-rite convention, the '+' sign indicates tensile strain and the '-' sign indicates compressive strain. Main purpose of the strain gage is to indirectly quantit

atively determine stress and its variation with time. Change in stress is obtained by multiplying the measured strain by modulus of elasticity.

1.1 Features

Model EDS-12V is the electrical strain meter of choice as its frequency output is immune to external noise, it is able to tolerate wet wiring common in geotechnical applications and is capable of transmission of signals to long distances. It has the following features:

- Thermally aged to minimize long term drift
- Rugged and reliable
- Can be used for embedment in soil or concrete.

The advantage of the vibrating wire strain gage over more conventional electrical resistance (or semiconductor) types lies mainly in the use of a frequency, rather than a voltage as the output signal from the strain gage. Frequency may be transmitted over a long cable length without appreciable degradation caused by variations in cable resistance, contact resistance, or leakage to ground.

For conditions requiring temperature measurement, a thermistor is permanently encapsulated inside the plucking coil assembly.

This user's manual covers description of the vibrating wire sister bar strain meter & its accessories, procedure for embedment of sensor in a concrete structure, method of taking observations and recording data.

NOTE: The sister bar is not suitable for measurement of dynamic strain.

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

This users' manual is intended to provide you with sufficient information for making optimum use of vibrating wire sister bar in your applications.

NOTE: The installation personnel must have a background of good installation practices and knowledge of the fundamentals of geotechnics. Novices may find it very difficult to carry on the 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 the best of instruction manuals cannot provide for each and every condition in the field, which may affect the performance of the sensor. Also, blindly following the instruction manual will not guarantee success. Sometimes, depending upon field conditions, the installation personnel will have to consciously depart from the written text and use their knowledge and common sense to find the solution to a particular problem.

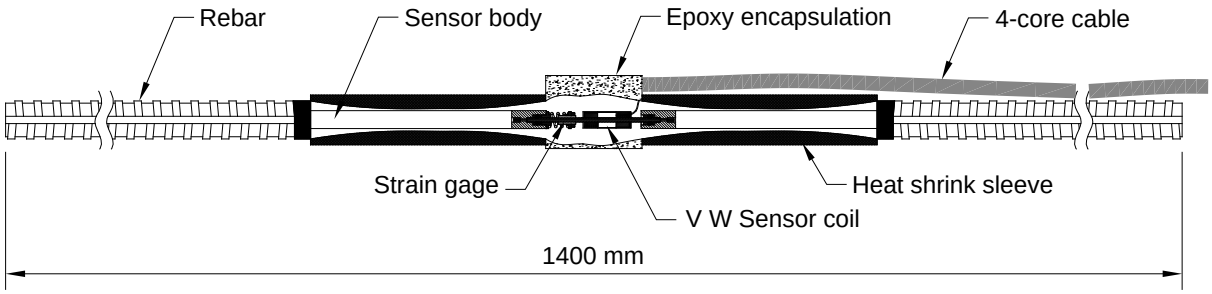
To make this manual more useful we invite your valuable comments and suggestions regarding any additions or enhancements. We also request you to please let us know of any errors, that you may find while going through this manual.

The manual is divided into a number of sections. Each section contains a specific type of information. The table of contents will guide you where to look for, in this manual if you need some specific information.

2 VIBRATING WIRE SISTER BAR STRAIN METER

2.1 General description

A sister bar is used where a load cell cannot be conveniently interposed to measure stress in a structure for reason of geometry, capacity or economy and where load and stress can be worked out with reasonable accuracy from knowledge of the relationship between stress and strain (modulus of elasticity). In such a case, it is very convenient to have a sister bar/strain gage, which can be embedded in the concrete structure.



Encardio-rite model EDS-12V vibrating wire sister bar strain meter consists of a hollow bar with vw strain gage mounted co-axially inside. The hollow bar is extended on the two sides with 12 or 16 mm ϕ (nominal) reinforced bars. The reinforced extensions are long enough to ensure full transfer of the strain within the concrete to the strain gage.

The sensor is supplied ready for embedment in concrete by tying it alongside an existing length of rebar in the rebar cage. The strain transfer from the surrounding concrete to sister bar strain meter is uniform and equal. Sister bars can also be installed in pairs on both the sides of neutral axis to separate bending moments from axial load.

An in-built thermistor is provided for temperature measurement for accurate determination of effective strain.

2.2 Operating principle

The vibrating wire sensor/strain gage basically consists of a magnetic, high tensile strength stretched wire, one end of which is anchored and the other end is displaced proportionally to the variation in strain. The stretched wire is thermally aged to minimize long-term drift and changes in calibration.

The strain gage works on the principle that if a coil/magnet assembly plucks a fixed length stretched magnetic wire; its frequency of vibration is proportional to the tension in the wire. Any change in strain, directly affects the tension in the wire, resulting in a corresponding change in its frequency of vibration. The strain is proportional to the square of the frequency that can be measured and displayed directly in μ strain by Encardio-rite's EDI-54V vibrating wire indicator.

2.3 Taking readings with the model EDI-54V vibrating wire indicator

The model EDI-54V vibrating wire indicator is a microprocessor-based read-out unit for use with Encardio-rite's range of vibrating wire sensors. It can display the measured frequency in terms of time period, frequency, frequency squared or the value of measured parameter directly in proper engineering units. It uses a smartphone with Android OS as readout having a large display with a capacitive touch screen which makes it easy to read the VW sensor.

EDI-54V Vibrating wire indicator

The EDI-54V vibrating wire indicator can store calibration coefficients from 10,000 vibrating wire sensors so that the value of the measured parameter from these sensors can be shown directly in proper engineering units. For transducers with built-in interchangeable thermistor, it can also display the temperature of the transducer directly in degree Centigrade.

The vibrating wire indicator has an internal non-volatile memory with sufficient capacity to store about 525,000 readings from any of the programmed sensors. Each reading is stamped with the date and time the measurement was taken.

Refer instruction manual WI-6002.112 of model EDI-54V for entering the transducer calibration coefficients. The gage factor of the model EDS-12V sister bar is given in the test certificate provided with every supply. The initial reading IR will be the actual reading in digits from the sister bar after it is embedded and properly set in concrete.

An internal 6 V 4 Ah rechargeable sealed maintenance-free battery is used to provide power to the vibrating wire indicator. A battery charger is provided to charge the internal battery which operates from 90 V to 270 V AC 50 or 60 Hz V AC mains. A fully discharged battery takes around 6 hours to get fully charged. The indicator uses a smartphone as a readout that has its own internal sealed rechargeable Li-ion maintenance battery as a power source. A separate battery charger/adapter unit for the smartphone, operating from universal AC mains supply is supplied with each EDI-54V indicator unit.

The EDI-54V vibrating wire indicator is housed in an impact resistant plastic moulded housing with weatherproof connectors for making connections to the vibrating wire transducer and the battery charger.

For operating EDI-54V See: Doc. # WI 6002.112 R01.

2.4 Tools & accessories required for installation

The following tools and accessories are recommended for proper installation of the sister bar.

1. Temperature controlled soldering iron 25 Watt
2. 63/37 rosin core solder wire
3. Acetone (commercial)
4. Hacksaw with 150 mm blade
5. Cable cutter
6. Surgical blade with holder
7. Wire stripper
8. Pliers 160 mm
9. Digital multimeter
10. Vibrating wire indicator (EDI-54V)

2.5 Sample test certificate

TEST CERTIFICATE

Instrument	:	Sister bar strain gage	Date	:	25.06.2018
Model	:	EDS-12V	Temperature	:	31°C
Bar diameter	:	12 mm nominal			
Operating temperature	:	-20 to 80°C			
Serial No.	:	xxxxxxx			

Applied load	Observed digit			Best fit	Non-linearity
(kg)	Cycle # 1	Cycle # 2	Average	(kg)	(%FS)
100	7370.4	7372.2	7371	105.24	0.17
500	7630.1	7629.8	7630	496.90	0.10
1000	7959.1	7958.1	7959	994.55	0.18
1500	8290.4	8292.7	8292	1498.72	0.04
2000	8624.1	8625.3	8625	2003.19	0.11
2500	8956.2	8955.4	8956	2504.56	0.15
3000	9280.3	9281.5	9281	2996.84	0.11
				Max error (%FS) :	0.18

***** Regression zero (digit) = 7301.80

* The above calculation uses a linear regression method. The value of regression zero given is ideal for straight line non-linearity calculation but is different from actual no load zero reading.

Digit	:	$f^2/1000$	(where f is frequency in Hz)
Gage factor (G)	:	5.989E-01	µ-strain / digit

µ-strain is calculated using following equation:

µ-strain = G(R1 - R0)

where R1 = current reading

R0 = Initial reading in digits and must be recorded at the time of Installation.

Pin configuration/wiring code:

Red & black : Signal Green & white: Thermistor

Cable length : 10 feet/3 m; CS0702 4 core cable

Checked by Tested by

3 INSTALLATION PROCEDURE AND TROUBLE SHOOTING

3.1 Preparation of the sensor before installation

The first step is to check the sensor before installation for proper functioning. This should be done in an environmentally clean atmosphere, conducive to maintaining good quality at a location like a steel yard or warehouse. All preliminary work on the sensor should be done at a covered location remote from the dirt and adverse weather that may exist at the work site.

Check the working of the sensor as follows:

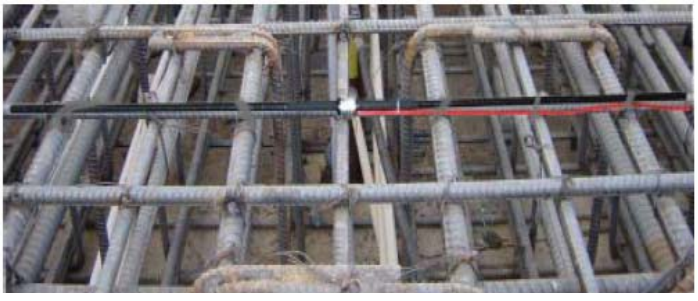
- Coil resistance measured by digital multimeter between red and black leads should lie between 45-65 Ohm at 25°C. Determine resistance at room temperature from thermistor temperature resistance chart in § 5. This resistance should be equal to that between pins marked green and white. For example, in case room temperature is 25°C, this resistance would be 3,000 Ohm.
- The resistance between any lead and the protective armour should be > 500 M Ohm.
- Connect sensor to model EDI-54V portable vibrating wire indicator. Initial offset reading in frequency should be stable and between 2300–3000 Hz.
- Press 'TEMP' key on vibrating wire indicator. The display will indicate the room temperature in degree Centigrade.

CAUTION: The sister bar strain gage is a delicate and sensitive instrument. It should be handled with care. Twisting it or applying too much force on it may result in permanently damaging it. While checking the sister bar strain gage, do not apply too much tension as the wire may break.

3.2 Installation procedure

Driven piles, drilled shafts, diaphragm walls, rafts normally involve simple cross sections of reinforced bars subjected to compression and some bending. Location of sister bars should be selected carefully taking into consideration any bending involved.

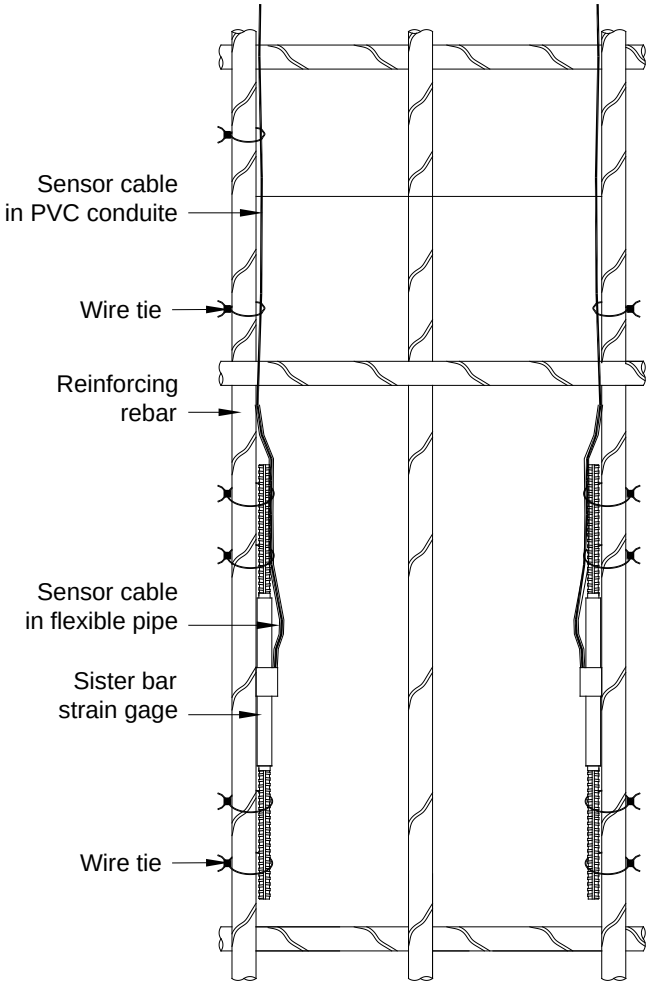
For installation, soft iron wires/cable ties are usually used to attach the sister bar to reinforcing bars at desired locations. Normally, the tie wires should be aligned perpendicular to the axis of the sister bar such that any movement of reinforcing bars during the pouring of the concrete will not exert a pull on the strain gage and distort or damage it. Tie wires should normally be tied near the ends of the sister bar rod as shown in the figure.



Route the sensor cable along the reinforce bar to the junction box, tying it at every 1 m with nylon cable ties. Do not use soft iron ties on cable as it can cut the cable.

While installation, remember to note the location and serial number of all sister bars. This is necessary for applying correct calibration factors from respective test certificate for readings.

NOTE: Sister bars are usually installed in pairs on both the sides of neutral axis to separate bending moments from axial load.



3.3 Extension of cable

Very careful and skilled cabling is required in installation of sister bar as sensor/cable joint and a large part of cable is permanently embedded and no future access is available for maintenance or corrective action.

Sister bars are supplied with standard PU sheathed 4- core cable color coded as follows.

Red/Black	VW sensor
Green/White	Thermistor

Length of cable depends on customer requirement. It is recommended that sensors be supplied with the complete length of cable required.

However, in case client wants to extend different cable at site, sister bars can be supplied with standard 1 m length of cable. Cable can be extended at site using a 1:1 junction box available from Encardio-rite. The cable joint should be made watertight by using an epoxy based splicing kit. Cable jointing compound 3M Scotch Cast Electrical Kit 2131 is stocked by Encardio-rite and is available in 100, 200 and 500 cc packing.

After completing the cable extension, make sure to check the working of the sensor again following the procedure described above in § 3.1.

Note: Any suitable two component cable jointing compound available in your region can be used in place of the 3M Scotch Cast Electrical Kit 2131. If required, you can also procure the compound from us.

3.4 Taking initial reading

1. Take one reading before concreting. While concrete sets, take daily strain gage temperature reading (by pressing TEMP button) and frequency^2/1000 (digits) reading (by pressing FREQ^2 button) of EDI-54V read-out unit. Go on taking these reading till concrete sets properly. Initial reading 'IR' to be entered in EDI-54V should be considered only after concrete sets properly and reading in digits is almost constant. The initial reading in digits is very important because all future readings are referred

to this initial reading to determine any change in stress. The initial reading in digits along with the gage factor (from individual test certificate), constitute the calibration constants required to be fed into the EDI-54V vibrating wire indicator as set-up data for model EDS-12V.

2. Feed the calibration constants. The EDI-54V is programmed to accept this initial reading as 'IR' in set-up data. The indicator will then prompt to enter the gage factor 'GF'. Enter the gage factor as specified in the batch test certificate. After set-up ends restart indicator. In engineering units mode for this channel, pressing the 'UNITS' key on the vibrating wire indicator will now display around '0.0 ue' (micro strain). Any subsequent reading at any other time by pressing the 'UNITS' key will show an increase or decrease from this reading and automatically give the microstrains developed during the period.

NOTE: The initial frequency reading is very important because all future readings are referred to this initial reading to determine any change in stress. Consequently a minimum of two readings taken daily after installation should be repeatable. It is a good practice to take readings regularly during the first few days to ensure that the data is stable and a correct initial reading is fed into the vibrating wire indicator as a calibration constant. In case the readings are not repeatable within a certain tolerance, the installation, strain gage or the vibrating wire indicator may be defective. The cause must be evaluated and if there is a problem, it should be rectified.

3.5 Care of cable

1. Care should be taken that the installed sister bars (strain gage) and the cable are properly protected. Protect cable from accidental damage by heavy equipment or flying rocks and debris. Use any practical method to protect the cable. Conduits should not be used where flow of water along the instrument leads must be prevented.

2. Keep the ends of the lead wires clean and dry. In case several sister bars are installed at the same location, they may be terminated in an IP-67 junction/switch box and a multi-core cable used for transmitting the readings to any central observation post.

3. Cable should be marked with permanent markers by the use of stainless steel or plastic tags stamped with the appropriate sister bar serial number. The tags should be such that they do not damage or cut the cable. Temporary identification can be done by writing the serial number of the sister bar, its code number and the location at which it is installed, on a strip of paper, placing the strip on the cable and covering it with a transparent plastic cello tape. Permanent identification is necessary to prevent errors in making proper connections and to insure correct splicing if cable is cut or, broken.

   With the best possible precautions, mistakes may still occur. Tags may get lost due to the cable getting accidentally cut. Encardio-rite uses the convention that looking from the observation post towards the sensor, the cable from the most distant sensor is always at the left hand side. In that order, the cable from the closest sensor is at the extreme right.

CAUTION: The single most important factor leading to loss of worthwhile data from sensors is losing track or identification of cable ends. Proper identification and marking of cables should not be taken casually. Care should be taken to put an identification tag at the point where the cable comes out of the structure such that cable identity is not lost if the cable gets cut or damaged. Route the cable properly to the location where readings have to be taken, taking care that it is suitably protected. Lead wires must be protected from mechanical damage and their ends from water.

3.6 Lightning protection

Lightning during thunderstorms can induce short spikes of sufficiently high electrical energy in the wires connecting the vibrating wire sensor to the readout instrument that can damage the coils in the sensor assembly. Some measure of lightning protection for the vibrating wire sensor is recommended if the sensor is mounted in the field or in open areas and connected to the readout instrument through long wires. However, these protection schemes will not protect the sensor against direct or near direct lightning strikes. Lightning protection is generally not required if the connecting wire is very short, say only a few meters in length, or both the sensor and the vibrating wire indicator is used inside a shielded structure, e.g. a building.

Model EDS-12V vw sister bar strain meter is not available with any integral lightning protection component. If lightning protection is desired one of the following options may be used:

- Surge arrestors like Gas Discharge Tubes (GDT) or TransZorbs→ (registered trademark of General Semiconductor Industries) may be fixed to the gage cable as near to the gage as possible and epoxy potted in place. The ground conductor would have to be connected to an earthing stake or the steel structure itself.
- If the sister bar is mounted close to a junction box or a multiplexer, the surge arrestor component can be mounted in the junction box or the multiplexer box itself. Encardio-rite can provide junction boxes and multiplexers with lightning protection installed as an option (specify while ordering).
- Lightning arrestor boards and enclosures are available from Encardio-rite, which can be installed at the exit point of the structure being monitored. Consult the factory for additional information on these or alternate lightning protection schemes.

3.7 Trouble shooting

After installation, the sister bar is usually inaccessible. Maintenance and troubleshooting of the Model EDS- 12V vw sister bar strain meter is consequently limited to periodic checks of cable connections and maintenance of terminals.

3.7.1 Symptom: Strain gage reading unstable

- Check the insulation resistance. The resistance between any lead and the protective armour should be > 500 M Ohm.
- Check if the vibrating wire indicator works with another strain gage? If not, the vibrating wire indicator may have a low battery or be malfunctioning. Consult the manual of the vibrating wire indicator for charging or trouble shooting instructions.
- Use another vibrating wire indicator to take the reading.
- Check if there is a source of electrical noise nearby? General sources of electrical noise are motors, generators, transformers, arc welders and antennas. If so, the problem could be reduced by shielding from the electrical noise.
- The reading may be outside the specified range (either compressive or tensile) of the strain gage? The gage may have become too slack or too tight. Inspection of data collected might indicate this possibility.

3.7.2 Symptom: Strain gage fails to give a reading

- The cable may be cut or crushed? Check the nominal resistance between the two gage leads using an Ohmmeter. It should be within 45 - 65 Ohm.
- Check if the vibrating wire indicator works with another strain gage? If not, the vibrating wire indicator may have a low battery or be malfunctioning. Consult the manual of the vibrating wire indicator for charging or trouble shooting instructions.
- Use another vibrating wire indicator to take the reading. The reading may be outside the specified range (either compressive or tensile) of the strain gage? The gage may have become too slack or too tight. Inspection of data collected might indicate this possibility.

4 GENERAL CONSIDERATIONS

4.1 Conversion of reading to strain changes

By selecting the channel number and pressing the 'UNITS' key, the EDI-54V readout when connected to Model EDS-12V vibrating wire sister bar strain meter, will display the change in strain directly in μ strain. Thus, the change in strain between the initial state (ε_0) and any subsequent state (ε_1) can be directly read on the EDI- 54V vibrating wire indicator. Compressive strain is indicated by a '-'sign and tensile strain by a '+' sign.

$$\mu\in_{apparent} = (\varepsilon_1 - \varepsilon_0)$$

4.2 Stress strain relationship

$$\frac{\sigma}{\varepsilon} = E$$

Strain data is rarely of interest. Whereas strain gages measure strain or deformation of the structure, the designer is more interested in the structural load or stress. This requires a conversion from the measured strain to computed stress. In case of steel, if modulus of elasticity is known, deformation is in elastic limits and temperature is recorded, conversion from strain to stress is straightforward.

Strain changes with time are computed from the sister bar readings taken at different intervals, and by comparing with some initial reading taken at time zero. Selection of the initial reading depends upon the purpose of the measurement. If actual stress in the structural member is required, the initial reading is best taken when the structural member is under no load.

Temperatures should be recorded at the time of each reading along with notes concerning construction activity taking place. This data might supply logical reasons for observed changes in the readings.

5 THERMISTOR - TEMPERATURE RESISTANCE CORRELATION

Thermistor type Dale 1C3001-B3

5.1 Temperature resistance equation

$T = 1/[A + B(LnR) + C(LnR)^3] - 273.2\ ^oC$

where T = temperature in ^oC
LnR = Natural log of thermistor resistance
A = 1.4051×10^{-3}
B = 2.369×10^{-4}
C = 1.019×10^{-7}

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

5.2 Temperature effect

The thermal coefficient of expansion of the embedment strain gage is 11.0 ppm/^{o}C and concrete varies from 10 – 13 ppm/^{o}C. Correction for temperature variation is seldom required in field use. In case correction is required for any specific application, it is best to embed a sister bar strain meter from the same batch in a representative concrete block and conduct actual temperature tests under controlled conditions. The difference in thermal coefficient of expansion so obtained can then be applied as a temperature correction.

6 WARRANTY

The Company warrants its products against defective workmanship or material for a period of 12 months from date of receipt or 13 months from date of dispatch from the factory, whichever is earlier. The warranty is however void in case the product shows evidence of being tampered with or shows evidence of damage due to excessive heat, moisture, corrosion, vibration or improper use, application, specifications or other operating conditions not in control of Encardio-Rite. The warranty is limited to free repair/replacement of the product/parts with manufacturing defects only and does not cover products/parts worn out due to normal wear and tear or damaged due to mishandling or improper installation. This includes fuses and batteries

If any of the products does not function or functions improperly, it should be returned freight prepaid to the factory for our evaluation. In case it is found defective, it will be replaced/repaired free of cost.

A range of technical/scientific instruments are manufactured by Encardio-rite, the improper use of which is potentially dangerous. Only qualified personnel should install or use the instruments. Installation personnel must have a background of good installation practices as 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.

The warranty is limited to as stated herein. Encardio-rite is not responsible for any consequential damages experienced by the user. There are no other warranties, expressed or implied, including but not limited to the implied warranties of merchantability and of fitness for a particular purpose. Encardio-rite is not responsible for any direct, indirect, incidental, special or consequential damage or loss caused to other equipment or people that the purchaser may experience as a result of installation or use of the product. The buyer's sole remedy for any breach of this agreement or any warranty by Encardio-rite shall not exceed the purchase price paid by the purchaser to Encardio-rite. Under no circumstances will Encardio-rite reimburse the claimant for loss incurred in removing and/or reinstalling equipment.

A lot of effort has been made and precaution for accuracy taken in preparing instruction manuals and software. However best of instruction manuals and software cannot provide for each and every condition in field that may affect performance of the product. Encardio-rite neither assumes responsibility for any omissions or errors that may appear nor assumes liability for any damage or loss that results from use of Encardio-rite products in accordance with the information contained in the manuals or software.

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