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USERS'

VIBRATING WIRE STRAIN GAGE

MODEL EDS-11V

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1 INTRODUCTION

The model EDS-11V strain gage is suitable for embedment in soil or concrete or for surface mounting by welding on steel structures. It is designed to withstand the ingress of water and the hostile environment found at large construction sites. The strain gage is ideally suited for measurement of strain in dams, bridges, underground cavities, mines, tunnels, steel structures and other areas of application where strain measurement is required. As an Encardio-rite convention, the positive sign indicates tensile strain and the negative sign indicates compressive strain.

The Encardio-rite vibrating wire strain gage basically consists of a high tensile strength wire made out of a magnetic material stretched between two cylindrical end blocks. The method of installation of the strain gage ensures that the displacement of the end blocks is always proportionally to the variation in strain. Any change in the strain directly affects the tension of the wire, resulting in a corresponding change in frequency of vibration of the wire. The change in frequency of the vibrating wire can be monitored on a data acquisition system or accurately measured by a readout unit calibrated to indicate the strain. All vibrating wire sensors manufactured by Encardio-rite use the same readout unit irrespective of the parameter being measured.

The Encardio-rite vibrating wire strain gage is hermetically sealed by electron beam welding and has a vacuum of around 0.001 Torr inside it which ensures full protection against hostile environmental conditions encountered at project sites. The sensor element is enclosed in a stainless steel body. These features result in the Encardio-rite vibrating wire strain gages being resistant to corrosive, humid, wet and other hostile environmental conditions.

Several strain gages embedded at the same site at different angles and places can also be used to measure plane and three dimensional stresses. To expedite alignment, simplify and speed up the installation procedure, Encardio-rite manufactures strain gage spiders for fixing the strain gages at the correct angles. The use of these spiders is highly recommended for proper orientation of the strain gages. Encardio-rite model EDS-12 five position spider and is available for accurately positioning strain gages for installation in concrete dams. They are precision machined to set the strain gages at the required angles during installation.

As concrete exhibits autogenous growth due to thermal effects, creep, chemical reaction and change in moisture content etc., stress measurement by the strain gage needs to be corrected. To determine the effect of autogenous growth, an additional strain gage is mounted near the existing ones, in the Encardio-rite model EDS-14 hollow two walled no stress container. The container is made of a hollow casing of copper inside and mild steel outside. This isolates the concrete specimen inside from the surrounding concrete, keeping the specimen concrete under no stress, but under the same temperature and humidity as those of the surrounding concrete. By deducting the value of strain obtained from the strain gage mounted inside the no stress container from the reading obtained from any other strain gage in the same vicinity, true stress is determined.

The same strain gage can be used for embedding in concrete or soil or for welding to steel structures. Encardio-rite model EDS-15 mild steel brackets are available for fixing the strain gage on a steel section to measure the surface strain. The strain gage brackets are welded in position by placing the Encardio-rite model EDS-17 dummy strain gage in between them to maintain the correct distance and alignment. The dummy strain gage is finally replaced by the actual strain gage. When embedding in concrete or soil, Encardio-rite model EDS-16 stainless steel flanges are fixed in position on the strain gage.

This users manual covers description of the vibrating wire strain gage & its accessories, procedure for installation of the sensor in concrete/masonry dams, soil or on steel structures, method of taking observations and recording data.

1.1 Applications

Encardio-rite vibrating wire strain gage is the electrical strain gage 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 applications in the measurement of positive or negative strain in soil, concrete mass or steel structures including:

- Measurement of strain in mass concrete
- Measurement of strain in concrete and rock construction.
- Determining and monitoring of stress distribution in concrete & masonry dams.
- Study of stress distribution in the supporting ribs of underground cavities and tunnels.
- Long term analysis of stress distribution in pressure shafts, enclosing concrete and the rock over burden.
- Measurement and monitoring of strain and consequently stress in steel structures.

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 vibrating wire strain gages in your applications.

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.

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 type of strain gages and accessories manufactured by Encardio-rite: See § 2 'Manufacturing range and accessories'.

For understanding the principle of vibrating wire strain gage: See § 3.1 'Operating principle'.

For essential tools and accessories: See § 4 'Tools and accessories required for installation".

For complete operating procedure of Vibrating Wire readout unit EDI-54V: See Doc. # WI 6002.112'

For installation of strain gage in concrete structures: See § 5 'Installation procedure'.

For temperature measurement by thermistor: See § 6 'Thermistor - temperature resistance correlation'.

2 MANUFACTURING RANGE AND ACCESSORIES

ITEM	MODEL	CAPACITY	DESCRIPTION
Strain gage	**EDS-11V**	**±1500 μ strain**	**Gage length – 140 mm** Strain gage is suitable for embedment in concrete or for surface mounting by welding. It is designed to withstand ingress of water and hostile environment at large construction sites. Gage is ideally suited for measurement of strain in dams, bridges, underground cavities, mines, tunnels, steel structures and other areas of application. Negative sign indicates compressive strain and positive sign tensile strain.
Strain gage spider	**EDS-12**	**5 position**	Permits precise and accurate installation in a concrete dam of four strain gages at angles of 0º, 45º, 90º, 135o in one plane and one strain gage at 90º to this plane.
No stress strain container	**EDS-14**		As concrete exhibits autogenous growth and thermal expansion etc., stress measurement by strain gage needs to be corrected. To determine these effects, an additional strain gage is mounted horizontally near the existing ones, in a hollow two walled container (400 mm ϕ x 600 mm height). By deducting this value from the readings obtained from the other strain gages, true stress is determined.
Strain gage brackets	**EDS-15**		For welding strain gage to steel structure to measure the surface strain.
Strain gage flanges	**EDS-16**		For mounting strain gage in concrete
Dummy strain gage	**EDS-17**		The strain gage brackets are welded in position by placing a dummy strain gage in between them to maintain the correct distance and alignment. The dummy strain gage is finally replaced by the actual strain gage.
Extender	**EDS-18**		The effective length of the model EDS-11 strain gage is increased to 280 mm by the extender, thus increasing the sensitivity by 100 %.
Junction box	**EJB-6-4-YY**		For input from six strain gages through flexible cables and output to one twenty core cable.

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

The model EDI-54V vibrating wire indicator (see figure 2.1) 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.

Figure 2.1: 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-11V group strain gage is given in the test certificate provided with every supply of strain gages. The initial reading IR will be the actual reading in digits from the strain gage 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.

3 VIBRATING WIRE STRAIN GAGE

3.1 Operating principle

The vibrating wire 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. Any change in the strain, directly effects the tension of the wire, resulting in a corresponding change in frequency of vibration of the wire.

The wire is plucked by a coil magnet. Proportionate to the tension in the wire, it resonates at a frequency 'f', which can be determined as follows:

$$f = [\sigma g/\rho]^{1/2} / 2l \ \text{Hz}$$

Where:

σ = tension of wire in kg/cm^2

g = 980 cm/sec^2

ρ = density of wire in kg/cm^3

l = length of wire in cm

The length of the wire in the model EDS- 11V strain gage is 14 cm. Consequently the formula can be reduced to:

$$f_{14} = 12.5\ [\sigma]^{1/2} \ \text{Hz}$$

The resonant frequency, with which the wire vibrates, induces an alternating current in the coil magnet. This is read by the read out unit.

The modulus of elasticity 'E' of the wire used in the strain gage is 2.11 x 10^6 kg/cm^2. As, within elastic limits, $\sigma/\varepsilon = E$, by substituting the value of 'E' in the above formula, the actual strain 'ε' can be determined as follows:

$$\varepsilon_{14} = 0.0031\ f^2\ \mu \text{ strain}$$

To summarize, any variation in strain causes the strain gage to deflect. This changes the tension in the wire thus affecting the frequency of vibration of the wire when it is vibrating at its natural frequency. The strain is proportional to the square of the frequency and the read out unit is able to display this directly in μ strains.

3.2 Temperature effect

The strain gage is one of the two vibrating wire sensor manufactured by Encardio-rite which is not temperature compensated, the other sensor for obvious reasons being the temperature sensor. The temperature sensor cannot be temperature compensated because it is variation in temperature that it is measuring. The reason in the case of strain gage is not so obvious and needs some explanation.

3.2.1. Strain gage used for measurement of strain on a steel section

For fixing the strain gage on a steel section, Encardio-rite model EDS-15 mild steel brackets are welded in position by placing the Encardio-rite model EDS-17 dummy strain gage in between them to maintain the correct distance and alignment. The dummy strain gage is finally replaced by the actual strain gage and tightened into position with the M5 screws provided (figure 3.2). The strain gage is thus rigidly fixed to the steel section. Due to the rubberized bellows provided in the body of the strain gage (figure 3.1), its modulus of elasticity is very low and the magnetic strain gage plucking wire in it precisely follows the deflection of the steel section on which the strain gage is mounted. It is not affected by the material or the coefficient of thermal expansion of the strain gage element or its body. No temperature compensation is therefore provided.

NOTE: The coefficient of thermal expansion of the magnetic plucking wire used in all Encardio-rite vibrating wire sensors is 11.0 ppm per ^{o}C.

3.2.2. Strain gage used for embedment in concrete

The strain gage magnetic plucking wire precisely follows the deflection of concrete in which it is embedded. However as discussed in §1, concrete exhibits autogenous growth due to thermal effects, creep, chemical reaction and change in moisture content etc. To determine the effect of autogenous growth, an additional strain gage is mounted near the existing ones, in a two walled no stress container. This isolates the concrete specimen inside from the surrounding concrete, keeping the specimen concrete under no stress, but under the same temperature and humidity as those of the surrounding concrete. By deducting the value of strain obtained from the strain gage mounted inside the no stress container from the reading obtained from any other strain gage in the same vicinity, true stress is determined. This nullifies any effect due to temperature changes.

It is anyway a good practice to record the temperature at the time of taking strain reading. A thermistor is provided inside the strain gage for this purpose.

3.3 General description

The model EDS-11V strain gage has a range of ±1500 μ strains, gage length of 14 cm and an overall length of 19 cm. The model EDS-18 extender allows to increase sensitivity by 100 % by increasing the effective length to 28 cm.

3.3.1. Stainless steel body

The vibrating wire and coil magnet assembly is enclosed in a stainless steel enclosure (refer to figure 3.1). The stainless steel enclosure is electron beam welded to two stainless steel tubes with integral stainless steel bellows that are rubberized for protection. The purpose of the bellows is to reduce the modulus of elasticity of the strain gage such that it truly reflects the expansion and contraction of the concrete that it is embedded in or the steel structure to which it is welded. The bellows are a special feature of Encardio-rite strain gages. The ends of the stainless tubes are electron beam welded to two cylindrical end blocks, one of which has a 'V' groove around its circumference. The face of this end block is tapped with a M6 x 12 threading. The total system is enclosed with a permanent vacuum of 1/1000 Torr inside the sensor resulting in it becoming immune to the effect of any ingress of water. As the strain gage is of stainless steel construction, it is not affected by normal chemical corrosion at locations in which it is used.

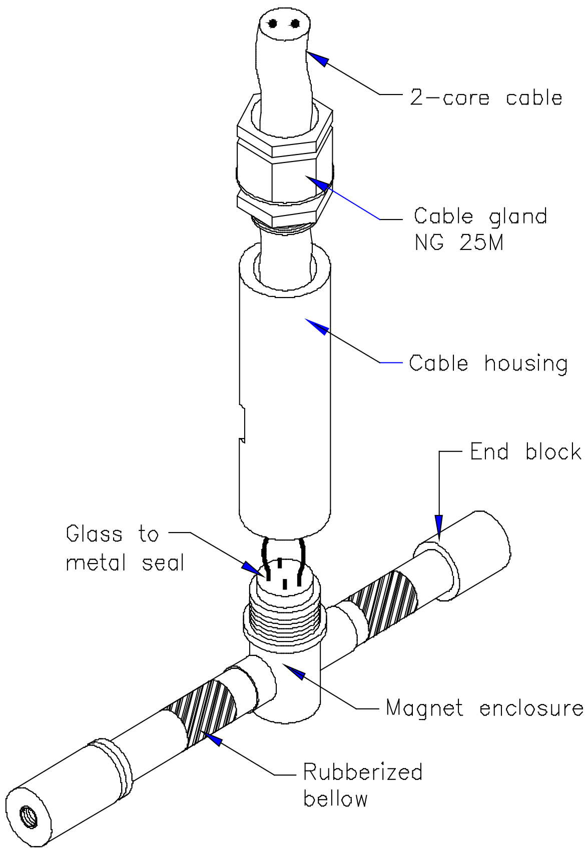

Figure 3.1 - in case temperature has to be monitored use 4-core cable

3.3.2. Cable connection:

The leads from the coil magnet are terminated on a glass to metal seal which is integrally electron beam welded to the stainless steel body of the strain gage. The two pins marked red and black on the glass to metal seal are connected to the coil magnet. The other two pins are connected to a thermistor for measurement of temperature. A cable joint housing and cable gland is provided for the cable connection. For cable jointing, refer to Users Manual 6002.11.

3.3.3. Mild steel brackets and stainless steel flanges

Mild steel brackets, 40 mm x 40 mm x 10 mm wide are used when the strain gage is used for welding applications on steel structures or attaching to concrete structures with saddle mounts. The brackets are mounted on the dummy strain gage and welded in position. The dummy strain gage is removed and replaced by the actual strain gage. One of the brackets fits into the 'V' groove of the left hand end block (refer figure 3.1). The other bracket is clamped in position on the other end block.

The 48 mm diameter stainless steel flanges are used when the strain gage is used for embedment in concrete. One of the flanges fits into the 'V' groove of the left hand end block of the strain gage (refer figure 3.1).

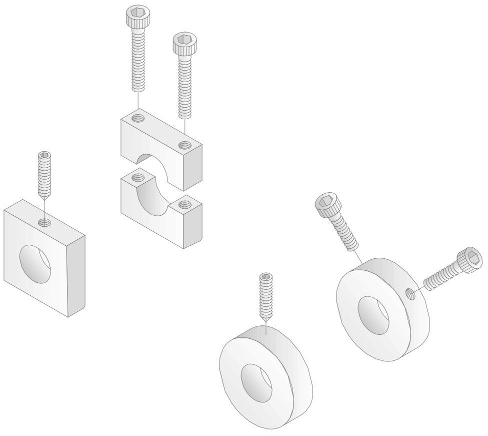

Figure 3.2

The other stainless steel flange is fixed at a center distance of 140 mm from the first flange.

3.3.4. Spiders for strain rosettes

Encardio-rite manufactures spiders for five and thirteen position strain rosettes. The spider is precision machined to the specified angles. A five position Encardio-rite model EDS-12 spider is illustrated in figure 3.3. The strain gages are screwed on to 200 mm rods attached to the spider at the correct angular positions.

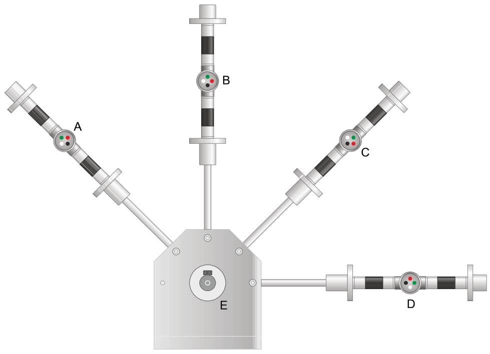

Figure 3.3

The Encardio-rite model EDS-12 five position spider permits precise and accurate installation in a concrete dam or structure of four strain gages at angles of 0º, 45º, 90º, 135º in one plane and one strain gage at right angles to this plane.

3.3.5. No stress strain container

The strain gage is designed to respond to change in dimensions of the concrete in which it is embedded, whether the deformation is due to stress, creep, temperature change, moisture change or chemical growth of the concrete. The main purpose of the strain gage, however, is to determine stress although indirectly. Change in stress is revealed by multiplying change in measured strain by the modulus of electricity. For stress that develops over a long period of time, account must be taken of changes in modules of elasticity and of deformation due to creep and to all causes other than stress.

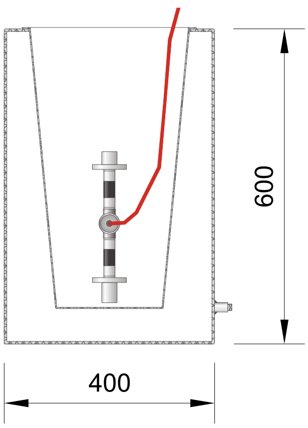

Figure 5.4

It is often desirable to measure separately the deformation due to all causes other than stress. This is done by installing a "no stress strain gage" which is exposed to the same conditions as the surrounding concrete except as to stress. The Encardio-rite model EDS-14 no stress strain container is a two walled hollow cylinder with a dimension of 400 mm ϕ x 600 mm height. The purpose of the gap between the walls is to prevent true stress from acting on the strain gage that is installed inside the container. This strain gage therefore only reads deflection that takes place in the concrete due to autogenous growth of the concrete.

3.3.6. Extender

The Encardio-rite model EDS-18 extender allows to increase the length as well as sensitivity of the model EDS-11V strain gage. The extender has a male M6 x 10 threads that fits into the female tapping of the strain gage end block. The effective length of the strain gage is increased to 280 mm by the extender, thus increasing the sensitivity by 100 %.

4 TOOLS & ACCESSORIES REQUIRED FOR INSTALLATION

The following tools and accessories are required for proper cable jointing and installation of the strain gage (also refer user's manual on cable jointing - 6002.11):

4.1 Soldering iron 25 watt
4.2 Rosin 63/37 solder wire RF-3C, 30 swg.
4.3 Thread sealant (Loctite 290 or equivalent)
4.4 Cable jointing compound (MS 853 and hardener MSH 283 - Mahendra Engineering & Chemical Products Ltd. or equivalent)
4.5 Acetone (commercial)
4.6 Spirit level
4.7 Hacksaw with 150 mm blade
4.8 Cable Cutter
4.9 Surgical blade with holder
4.10 Wire Stripper
4.11 Pliers 160 mm
4.12 Screw driver 20 cm
4.13 Allen key M3, M4 & M6
4.14 600 mm width 45o set square
4.15 Plumb bob with line
4.16 Angle protractor
4.17 Pouring funnel
4.18 Stainless steel rod 5 mm □ 150 mm length
4.19 Spatula
4.20 Rotary tin cutter
4.21 Fixture for jointing upto six strain gages (refer figure 4.1)
4.22 Tooth brush
4.23 Cloth for cleaning (lintless)
4.24 Wooden cable spacer
4.25 Wooden cable rake
4.26 Digital multimeter
4.27 Model EDI-54V portable read- out unit (to be ordered separately)

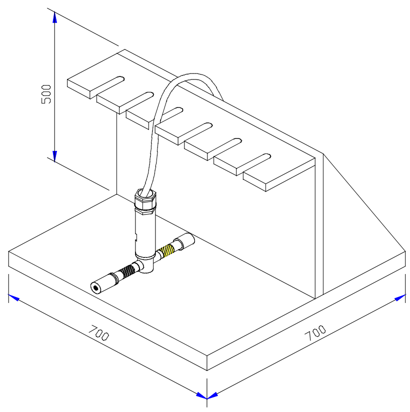

Figure 4.1

5 INSTALLATION PROCEDURE

5.1 Preparation of the sensor before installation

5.1.1 Remove the cable joint housing from the sensor. This gives access to the four pin terminal. The terminals are marked with red, black, green and white colours. Clean the terminals with a toothbrush.

NOTE: Do not use any acetone for cleaning as it may damage the glass to metal seal. Acetone should be used for cleaning the other parts of the strain gage.

NOTE: If specifically ordered, the strain gages are supplied integral with the requested length of four core cable attached. The cable cores are red/black (for sensor coil) and white/green (for thermistor).

Strain gages to be mounted on a spider (EDS-12) and inside a no stress strain container (EDS-14) for embedment in concrete structures are normally supplied integral with a 2 m cable. The ends of these cables can be terminated in the model EJB-6-4-YY junction box described in § 2.

5.1.2 Check the working of the sensor as follows:

- The coil resistance measured by the digital multimeter should lie between 120-150 Ohm. Determine the resistance at the ambient temperature from the thermistor temperature resistance chart in § 6. This resistance should be equal to that between pins marked green and white (or green and white cores on the cable). For example, in case the room temperature is 25°C, this resistance would be 3,000 Ohm.
- Connect the sensor to the EDI-54V read-out indicator. The initial offset reading in frequency should lie between 900 - 1100 Hz. This initial reading on the portable readout unit should be stable.

  NOTE: Check sensor for proper functioning before installation. Each sensor is provided with a test report. The zero reading given in the test report should not differ from the current zero reading by more than 50 μ strain after due regard to corrections made for difference in temperature, barometric pressure, height above sea level and actual cell position (whether standing up or lying down).

- The resistance between any lead and the protective armour should be > 500 M Ohm.
- This initial reading on the portable strain indicator should be stable. A crude but a simple and very effective method of checking whether the sensor is responding to changes in strain is as follows:
- Connect the sensor to the EDI-54V read-out unit.
- Press the two ends of the strain gage gently between the fore fingers and verify that the strain reading on the indicator increases. Pulling the ends gently will decrease the strain reading.
- This change in reading ensures that the deformation produced by straining the strain gage is transmitted to the vibrating wire sensing element.

5.1.3 In case the strain gages have not been supplied integral with the cables, connect the required length of cable to the sensor as suggested in the operating manual on cable jointing - 6002.11.

5.1.4 Check the working of the sensor again following the procedure described above.

CAUTION: The 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 a zero shift or even permanently damaging it.

5.1.5 Cable should be marked with permanent markers every 5 m by the use of stainless steel tags stamped with appropriate strain gage numbers tied by stainless steel wire. Alternatively plastic tabs are also available. Temporary identification can be done by writing the serial number of the strain gage, 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 in the junction box and to insure correct splicing if cable is cut or, broken.

CAUTION: The single most important factor leading to loss of worthwhile data from sensors is losing track of identification of the cable ends. Proper identification and marking of the cables is generally taken most casually. Care should also 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 accidentally cut.

5.2 Installing the strain gage in a concrete dam

Installing of the strain gage in a concrete dam has to be done with perfection. To get proper results, great care has to be taken during the installation.

As a first step, the stainless steel flanges are fixed to the strain gage at the correct center distance. The flange with the one M5 screw is fixed to the grooved end block of the strain gage (refer figure 3.1). In case of model EDS-11V strain gage, the other stainless steel flange is fixed at a center distance of 140 mm from the first flange.

CAUTION: Great care should be taken while tightening the stainless steel flanges to their respective strain gages such that no torque is applied across the length of the strain gage. While tightening, the strain gage should only be held with the end block to which the flange is being fixed. It should never be held at the end block on the other side because this will generate a torque across the length of the strain gage and damage it.

There is no 'standard' method of placement of the strain gages. However, schemes successfully deployed by field and design engineers are detailed below:

5.2.1. Embedment procedure for separate single strain gage

The mounting of a single strain gage is usually done by embedding it near the top of a lift. The embedment procedure is described below:

5.2.1.1. At any particular chainage where single strain gages have to be installed, raise the level of the dam to around 25 cm below the requisite elevation. Mark the positions on the concreted surface where the strain gages have to be installed. Raise the level of the concrete by around 50 cm leaving trenches of around 1 m x 1 m at the marked positions.

5.2.1.2. Back-fill the trench to the level to provide a bed, in case the strain gage is to be mounted horizontally. For strain gage to be installed vertically or at an inclination, back fill to the level that the strain gage would be fully covered.

5.2.1.3. For strain gage to be installed horizontally lay it in the correct position and direction. For strain gage to be installed vertically or diagonally, use an electric laboratory vibrator to make a hole for the gage in the correct position and direction. Insert the strain gage in to the hole.

5.2.1.4. Check angles, direction and depth. A protractor level is most useful for this application. A plumb line and 60 cm wide angle protractor may be alternatively used.

5.2.1.5. Vibrate around a deeply embedded gage or hand puddle around a shallow gage.

5.2.1.6. Continue back ***filling*** by hand and shovelling, using the same concrete as the mass concrete used in the construction and hand puddle. When concrete is poured over the strain gage, take care not to move the strain gage. Pour the concrete by hand until a 10 cm cushion is built up on top of each gage.

5.2.1.7. Finish with light shallow vibrations and protect the area with a light board barrier. Mark with area with yellow painted metal stakes so that the strain gage installation is not damaged before the concrete sets in.

5.2.1.8. The procedure for cable laying is separately dealt in § 5.3.

5.2.2. Embedment procedure of strain gage in groups

When strain gages have to be installed in groups of up to a maximum of 13 sensors, a more elaborate arrangement is necessary to assure the correct installation in the limited time available before the mass concrete begins to set in. Therefore, the alignment of the strain gages has to be expedited and simplified. This is done by mounting the strain gages on a spider that correctly orients them and keeps them in position while the concrete is filled in the trench manually. The installation procedure is different in details from that of mounting individual strain gages.

It is important to install the strain gages quickly such that the concrete around the sensors is essentially the same as that in the surrounding mass. Time is saved if the installation begins before the lift is completed. A five position spider assembly is illustrated in figure 5.1. It consists of a spider base (1) fastened to the spider hub (2) with two Allen head M8x15 bolts (4). The spider hub is provided with holes at the correct orientation. Fully insert the unthreaded side of 200mm X 8mm diameter spider rods (3) inside the holes provided on the spider hub and tighten them with the Allen head M8x15 bolts (5) provided.

S no.	Item	Qty
1	Spider base	1
2	Spider hub	1
3	Spider rod	5
4	Allen head bolt M8x15	2
5	Allen head bolt M5x8	5

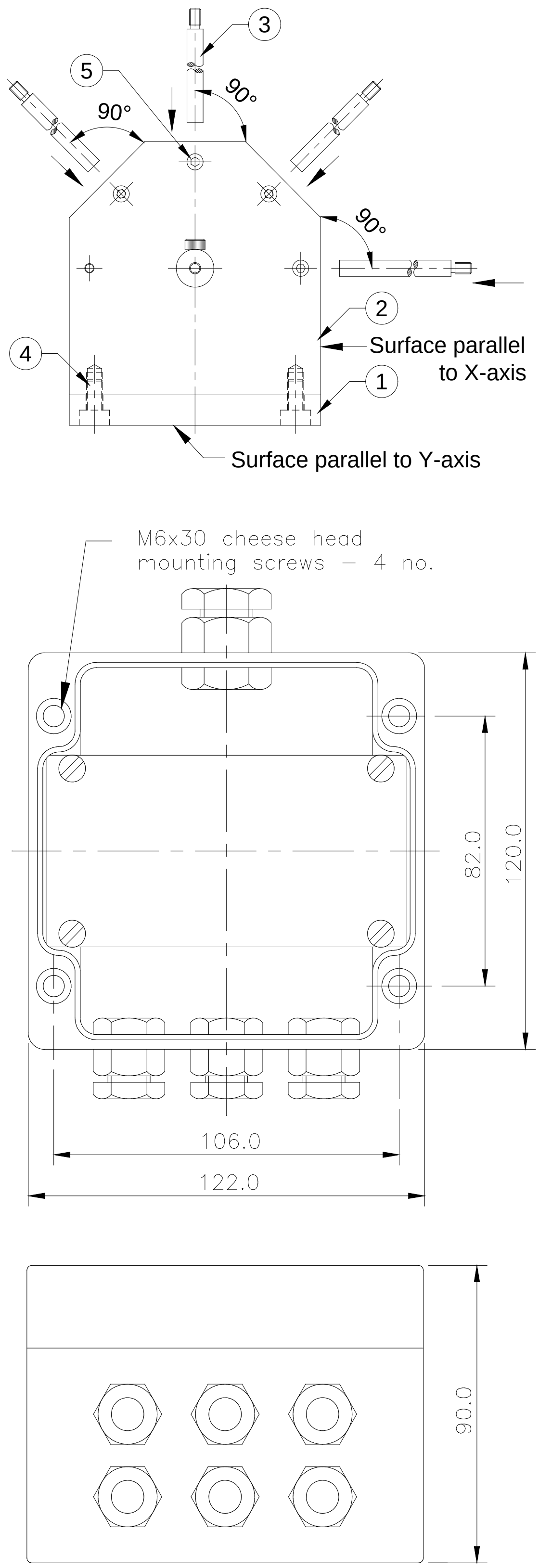

Figure 5.1 Spider assembly

The embedment procedure is as follows:

5.2.2.1. At any particular chainage where the group of strain gages have to be installed, raise the level of the dam to the requisite elevation. Mark the positions on the concreted surface where the strain gages have to be installed. Raise the level of the concrete by around 75 cm leaving a trench of around 1 m wide x 2 m long at the marked positions to take the strain rosette and the no stress strain container. Level the bed using a level protractor. Apply a layer of mortar (cement: sand = 3:1) on the concrete bed to get a smooth surface.

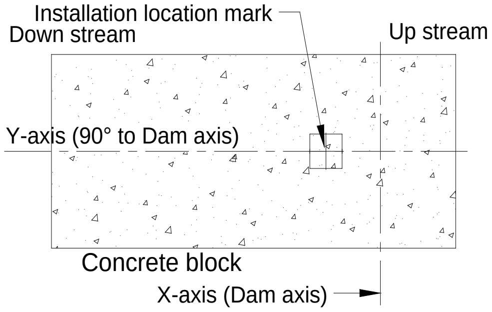

Figure 5.2

NOTE: If a trench cannot be provided for placing the strain gage assembly/no stress strain container, enclose the marked installation area with the help of steel shuttering (LxB = 1x2m).

5.2.2.2. Place assembled spider on this smooth surface. Pressing down the spider assembly ensure that the measurement axes are parallel to the X & Y axes (X refers to dam axis and Y perpendicular to dam axis respectively). Use spirit level, 45o angle protractor, plumb line and tie wires to properly orient the spider assembly. It is recommended that proper orientation of the spider assembly be checked by surveying methods. Cover the spider base of spider assembly with mortar so that it firmly sets in the concrete bed. Allow 24 hours for setting of mortar.

5.2.2.3. Screw each strain gage to the M6 x 10 threaded portion of 200 mm long spider rods already fixed to the spider hub and again check that the assembly is properly oriented.

CAUTION: Great care should be taken while tightening the strain gages to their respective rods such that no torque is applied across the length of the strain gage. While tightening, the strain gage should only be held with the end block with the groove. It should never be held at the end block on the other side because this will generate a torque across the length of the strain gage and damage it.

NOTE: Check the angles, direction and depth of the strain gage spider and the strain gages mounted on the spider. Check the orientation of the strain gages on the spider with the plumb line and the 60 cm wide angle protractor provided. In case it is not all right, correct it by slightly bending the rods with the 160 mm pliers. To maintain the correct orientation, tie strings may be used as they make the fixing easier. Care should be taken that in the process, the strain gages are not subjected to any stress.

Figure 5.3

5.2.2.4. Check no stress strain container for leakage. The easiest method is to fill it to the brim with water and check for any reduction in level during the next four hours.

5.2.2.5. Place no stress strain container inside the trench and secure it to the previously laid concrete by stay wires and anchors such that it does not lift up during the filling up of the trench with concrete. As an Encardio-rite convention, the spider assembly is placed away from the vertical shaft and the no stress strain container is placed closer to the vertical shaft. This helps in properly placing the cable and also identifying it.

CAUTION: The no stress container should be checked for any leakage. This check is necessary to prevent concrete filling in between the walls of the container and making it useless for measurement of strain in no stress conditions.

5.2.2.6. Fill no stress container with mass concrete. Use an electric laboratory vibrator to make a hole for the strain gage in the middle of the container. Insert the strain gage into the hole. Route the cable as is described in the next section.

5.2.2.7. Back fill by hand and shovelling, using the same concrete as the mass concrete used in the construction and hand puddle. When concrete is poured over the strain gages, take care not to move the strain gage rosette. Pour the concrete by hand until a 10 cm cushion is built up on top of each gage. Finish with light shallow vibrations up to the top of the lift.

CAUTION: Avoid direct shocks to the gages. Be very careful that the orientation of the strain gages is not disturbed.

5.2.2.8. Mark the area with yellow painted metal stakes so that the strain gage installation is not damaged before the concrete sets in. Allow no traffic in this area. Put a flag on the embedment location for easy identification. Protect the area with a light board shuttering and finish up the lift all around this location. The shuttering prevents dumping of the concrete into the demarcated area.

5.2.2.9. Procedure for cable laying is separately dealt in following section.

5.3 Cable laying in concrete dams

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

As access galleries are available in concrete dams, the cable from the sensors is first routed to the gallery. These cables may be terminated in junction boxes inside the gallery. The data from the various sensors can then be taken or logged from the junction boxes with the help of a read out unit or data logger. Alternatively, if required, the signals from the junction boxes may be carried through multi core cables to any observation room outside the dam structure.

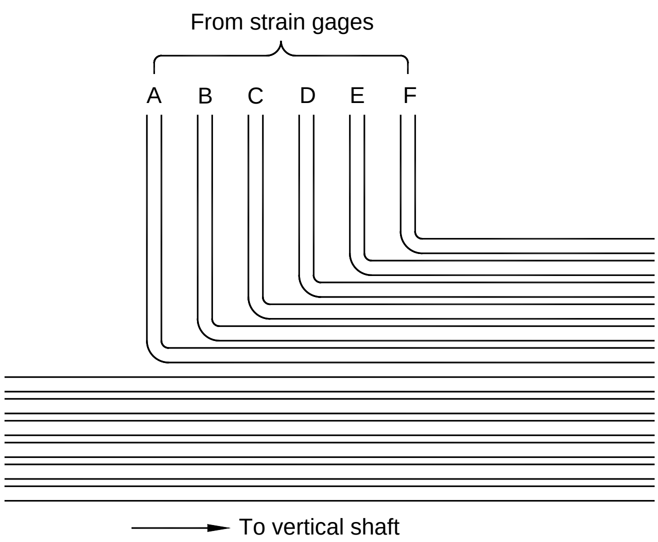

Figure 5.4

In a concrete dam, a number of strain gages along other sensors are installed at selected elevations at different cross sections, as illustrated in figure 5.5 on the next page. For example, three pore pressure meters, five strain rosettes, five no stress strain containers and two temperature meters are installed at elevation 312 m. Cables from these sensors have to be taken to junction boxes to be mounted inside one of the cross galleries. The gallery may be above or below the elevation at which the sensors are to be installed. As a general practice, all the cables from sensors at any particular elevation are routed to a vertical shaft on the upstream side of the dam. The cables are then lowered or lifted through the vertical shaft to the gallery.

At any cross section, the filling of the dam is allowed to continue to an elevation of around 75 cm higher than where the sensors are to be mounted, leaving 1 m wide x 2.5 m long x 75 cm deep trenches at the positions where the sensors are to be placed.

The cable from the sensors should be routed through a carefully marked channel trench ending into the vertical shaft and running parallel to the line of the sensors (refer figure 5.4). The depth and width of the channel trench depends upon the number of cables the trench has to carry. In case all the cables at an elevation fit in one row, the depth of the channel can be around 10 cm. If more than one row is required to lay all the cables, the depth should be increased by 10 cm per row. Before laying the cables, the channel trench should be properly cleaned and leveled. Any sharp rocks or objects should be removed to prevent the cable from accidentally getting damaged. The center distance between successive cables should be kept at a distance of 25 mm with the help of the wooden cable spacer and cable rake provided. To take care of settlement effects and temperature effects during concrete setting, the cable should be zig zagged by providing a uniformly distributed slack of around 0.5 m in a 15 m length of each cable. After laying the cable in any row, it should be covered with concrete by a hand shovel to a depth of around 10 cm and allowed to set. This is necessary to prevent any accidental damage to the cables.

Precaution must be taken that the cables are properly tagged, onward from the point from which they come out of the dam into the vertical shaft. 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 vertical shaft end towards the sensor, the cable from the most distant sensor is always at the left hand side and the offset trenches are to the right of the channel trench. In that order, the cable from the closest sensor is at the extreme right. Moreover, when strain gage groups are mounted on a spider and a no stress strain container is provided, the cables are placed left to right from the strain gages 'A' to 'F' looking from the vertical shaft. This is illustrated in figure 5.4.

CAUTION: All cables should be properly identified by tagging them every 5 m or closer, onwards from the point from which they come out of the dam body into the vertical shaft. The tags should be of a non-corrosive material like stainless steel or plastics.

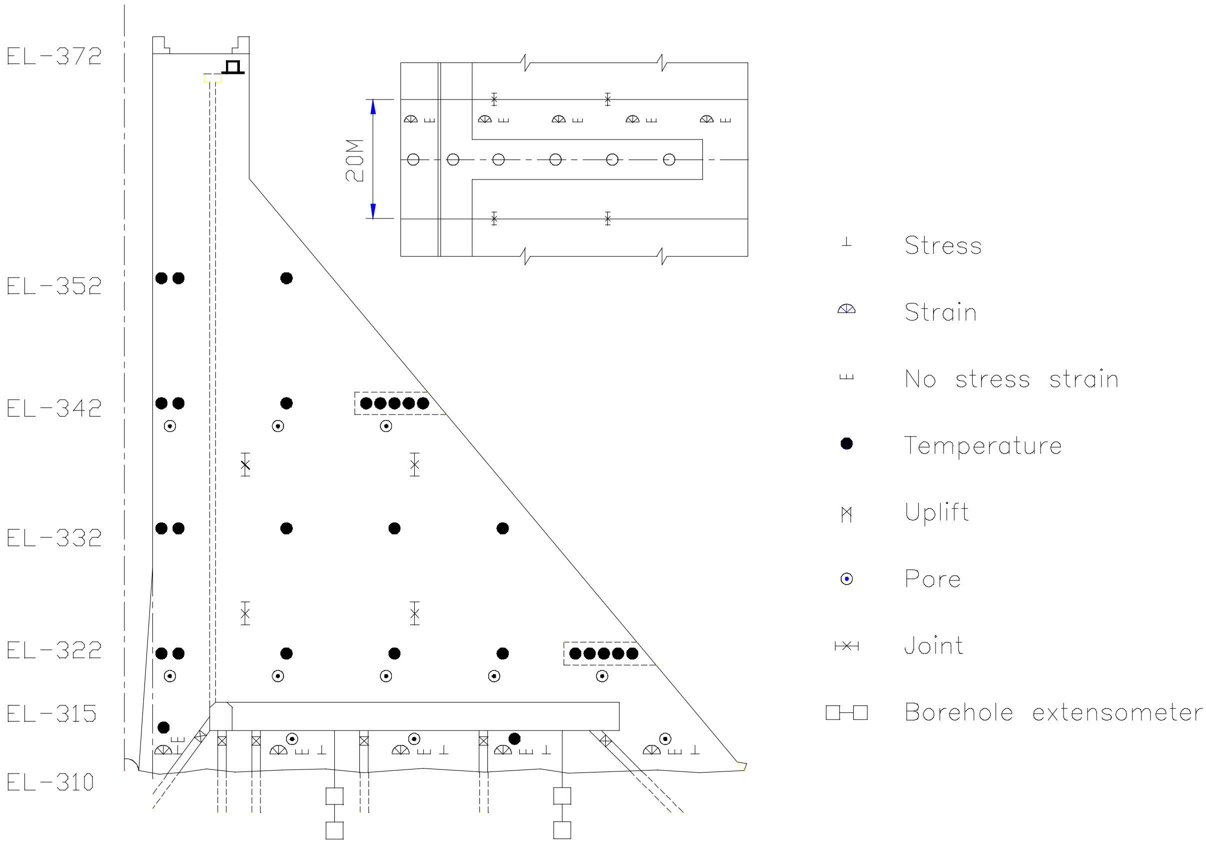

Figure 5.5

CAUTION: To take care of any of any settlement and/or contraction of concrete due to temperature effects, the cable should be zigzagged by providing a uniformly distributed slack of around 0.5m in a 15m length of each cable.

It is good practice to grout the cable in the vertical shaft at 2 m distances such that the left to right alignment is maintained.

Similarly, as an Encardio-rite convention, the cable from the most distant sensor at any elevation should be connected to the extreme left socket in the junction box. Succeeding cables from the sensors are connected progressively towards the right in the junction box. Welding the strain gage to a steel structure.

The mounting of the strain gage to a steel structure is a fairly simple operation. A dummy strain gage is provided for this purpose. In case of Encardio-rite model EDS-11V strain gage, the length of the stainless steel dummy strain gage is 150 mm. This length is 260 mm in case of the model EDS- 12V strain gage.

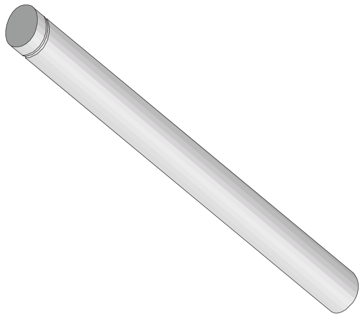

Figure 5.6

Place the mounting blocks on a surface plate with the screws at the top and tighten the M5 screws with an Allen key. The faces of the dummy strain gages should coincide with the end faces of the mounting brackets. Take care that the bottom face of the mounting brackets sit flush with the surface plate and there is no wobble in the mounting blocks.

Clamp the assembly to the steel structure and weld the mounting brackets to the steel structure. Remove the dummy strain gage and insert the strain gage in position.

Route the cable properly to the location where readings have to be taken, taking care that it is suitably protected.

CAUTION: Great care should be taken while tightening strain gage between mounting brackets such that no torque or bending moment is applied across the length of the strain gage.

6 THERMISTOR - TEMPERATURE RESISTANCE CORRELATION

Thermistor type: Dale 1C3001-B3 or equivalent

Temperature resistance equation

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

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

7 OTHER CONSIDERATIONS/TROUBLE SHOOTING

7.1 Trouble shooting

Strain gage is embedded in soil or concrete or for surface mounting by welding on steel structures. Once installed, the sensor is usually inaccessible and remedial action is limited. Maintenance and trouble shooting is consequently confined to periodic checks of cable connection and functioning of the read-out unit. Refer the following list of problems and possible solutions should problems arise. For any additional help, consult the factory.

7.1.1. Symptom: Strain sensor reading unstable

- Check the insulation resistance. The resistance between any lead and the protective armour should be > 500 M Ohm. If not, cut a meter or so from the end of cable and check again.
- Does the read-out work with another strain gage? If not, the read-out may have a low battery or be malfunctioning. Consult the manual of the readout unit for charging or trouble shooting instructions.
- Use another read-out unit 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.

7.1.2. Symptom: Strain sensor fails to read

- The cable may be cut or crushed? Check the nominal resistance between the two gage leads using an Ohmmeter. It should be within 120 - 150 Ohm. The correct value is given in the strain gage test certificate. Please add the cable resistance when checking. For the model CS-0601 series of cable, the resistance is 48 Ohm/km and for the model CS-0407 series of cable, the resistance is 84 Ohm/km. In case any other cable is used, make the necessary addition in the resistance value. If the resistance reads infinite or a very high value, a cut in the cable is suspected. If the resistance reads very low (<100 Ohm), a short in the cable is likely.
- Does the read-out work with another strain gage? If not, the read-out may have a low battery or be malfunctioning. Consult the manual of the readout unit for charging or trouble shooting instructions.
- Use another read-out unit to take the reading.

8 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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