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USERS' MANUAL

VIBRATING WIRE EARTH PRESSURE CELL

MODEL EPS-30V-S



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1 INTRODUCTION

The rheology of soil/rock formations is a complicated function of soil/rock type, stress history, shear and normal stress levels, boundary and drainage conditions and many other environmental effects. The accurate assessment of stress in foundation soil/rock formations and their changes caused by construction and loading is important for good engineering design. In any instrumentation scheme for geo-technical or geo-structural study associated with large civil engineering structures like tall buildings, dams, underground tunnels etc., measurement of stress plays a very important part. Encardio-rite manufactures a range of instruments for measurement of stress, including sensors, readout unit and data logger.

Study of stress fall into two basic categories:

- Measurement of total stress at a point within a soil mass/foundation rock
- Measurement of contact stress against the face of a structural element.

The development of vibrating wire stress cell introduced a reliable and fast method of taking stress readings electrically. The cable is carried from the stress cell to the read out unit or data logger and is protected against any possible damage during construction to give all around reliable data.

Encardio-rite earth pressure cell (or stress cell) is the electrical sensor of choice as the frequency output of the vibrating wire sensor is almost immune to external noise, able to tolerate wet wiring conditions common in geotechnical applications and is capable of transmission of signals to long distances. It has applications in the measurement of stress in soil or foundation rock including:

- Magnitude, orientation and distribution of principal stresses within embankments and dams as input to improve design and construction practices.
- Total stress for studying soil/structure interaction behaviour.
- Total stress on and within liners of underground excavations as input to improve design and construction practices.

For details of vibrating wire stress cells manufactured by Encardio-rite, refer to data sheet 1090-97w.

1.1 Earth pressure cell

The earth pressure cell is designed to measure total pressure in earth fills and embankments. Proper evaluation of total pressure may help in:

- Verifying design assumptions that will promote safer and more economical design and construction.
- Monitoring for safety; warning of soil pressures in excess of those the structure is designed to withstand.

The Encardio-rite earth pressure cell basically consists of a flexible, circular flat capsule, constructed from two stainless steel discs welded around the periphery and connected to a specially designed Encardio-rite pressure sensor by a stainless steel tube. The whole system is fluid filled. The vibrating wire pressure cell incorporates the latest vibrating wire technology to provide remote and digital readout. Total pressure cells manufactured by Encardio-rite, designated with a suffix 'S' are used in soil, earth or rock fills.

This user's manual covers description of the vibrating wire earth pressure cell with its connected accessories, the installation procedure and maintenance of the sensor, method of taking observations and recording the data from the sensor.

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 stress cell 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.

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 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 that 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.

For an insight into the earth pressure cell: See § 2 'Vibrating wire earth pressure cell'.

For essential tools and accessories: See § 3 'Tools and accessories required for installation'.

For installation of earth pressure cells: See § 4 'Installation procedure'.

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

For temperature measurement by thermistor: See § 5 'Thermistor - temperature resistance correlation'.

2 VIBRATING WIRE EARTH PRESSURE CELL

2.1 Introduction

Encardio-rite earth pressure cell is also called total pressure cell or total stress cell. It measures stress in soil or pressure of soil on structures. Cell responds not only to soil pressure but also to ground water pressure/pore water pressure and therefore is termed as total pressure or total stress. A simultaneous measurement of pore water pressure (ρ), using a piezometer, is necessary to separate the effective stress (σ) from the total stress (σ_t) as defined by Terzaghi's principle of effective stress:

$$\sigma_t = \sigma + \rho$$

These parameters coupled with the soil strength characteristics will determine soil behaviour under load.

2.2 General description

2.2.1 Flat stress capsule

Flat pressure capsule is 200 mm ϕ x 7 mm thick. It is constructed from two stainless steel plates electron beam welded together around the periphery to form a diaphragm so as to leave a narrow space between the plates. The flat pressure capsule is connected to a standard Encardio-rite vibrating wire pressure sensor through a 6 mm o.d. stainless steel tube welded on one side to pressure capsule and on other side to pressure sensor. Enclosed space is completely filled with de-aired fluid. De-airing materially improves fluid stiffness and performance of cell. The stress cell uses an all welded construction such that space confining hydraulic fluid is entirely metal, not requiring 'O' rings that tend to trap air and reduce cell stiffness.

2.2.2 Pressure sensor with stainless steel body

The pressure sensor constitutes of a vibrating wire and coil magnet assembly enclosed in a stainless steel body which is electron beam welded to the diaphragm. This results in a vacuum of 1/1000 Torr inside the sensor making it completely immune to the effect of any ingress of water. As the pressure sensor is of stainless steel construction, it is not affected by normal chemical corrosion at locations in which it is used. The pressure sensor normally employed is the Encardio-rite pore pressure meter model EPP-30/36V that is available in several different pressure ranges (0.2, 0.3, 0.5, 0.7, 1.0, 1.5, 2.0, 3.5, 5.0 & 10.0 MPa). Sensors upto capacity of 35 MPa are also available.

A tripolar plasma surge arrestor inside the transducer housing protects the vibrating wire pluck and read coils from electrical transients such as may be induced by direct or indirect lightning strikes.

A thermistor is provided to monitor temperature.

2.2.3 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 stress cell. The two pins marked red and black are connected to the coil magnet. The other two pins are free and may be used in case a thermistor is required for measurement of temperature. A cable joint housing and cable gland is provided for the cable connection. The cable is attached to the transducer in a sealed, water-resistant manner. For earth pressure cells located inside a soil mass the cable may be armoured and provided with strain relief at the cell to reduce the likelihood of pull-out. For cable jointing, refer to Users Manual 6002.11.

2.3 Earth pressure cell construction

Encardio-rite earth pressure cell has a stainless steel diaphragm that is generally round in shape. Dimensional details of fluid filled earth pressure cell are standardized and are as follows:

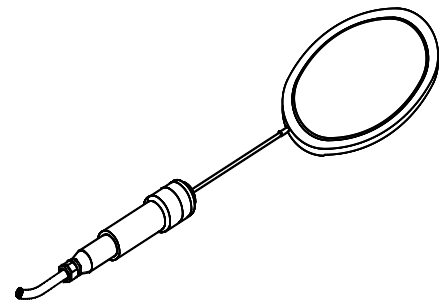


Figure 2.1

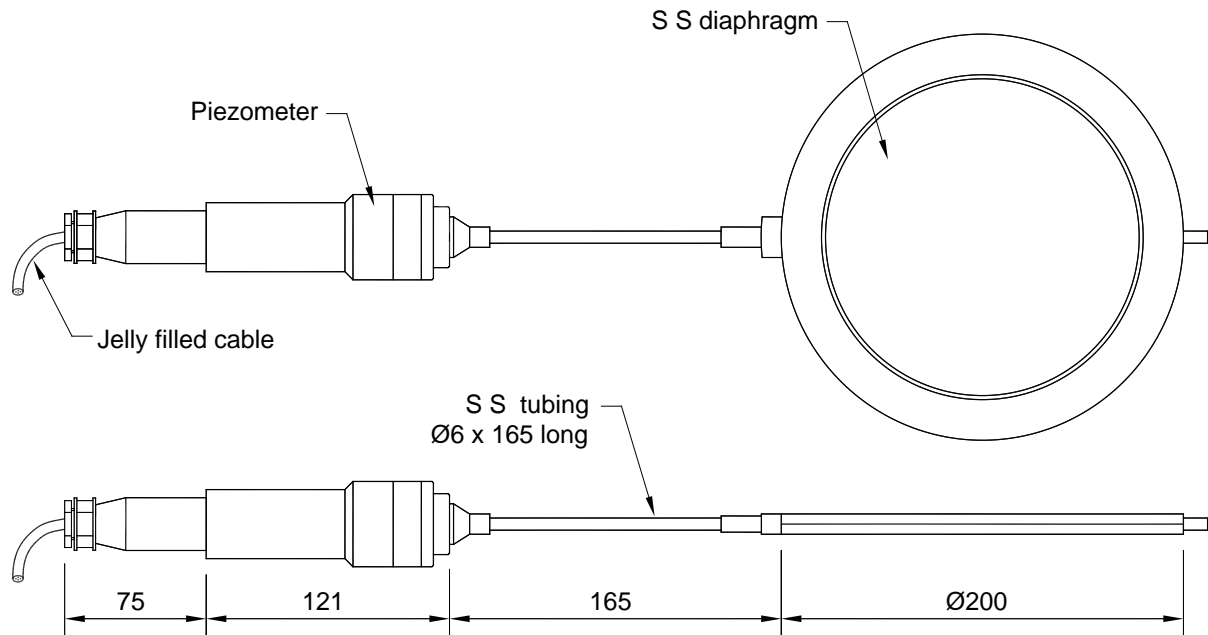


Figure 2.2- earth pressure cell with circular diaphragm

2.4 Pressure sensor operating principle

Pressure sensor of a vibrating wire stress cell consists of a magnetic, high tensile strength stretched wire, one end of which is anchored and the other end fixed to a circular diaphragm. The diaphragm deflects in some proportion to applied pressure. Any change in pressure, deflects diaphragm proportionally affecting tension in stretched wire and in turns frequency of vibration. The stress is proportional to the square of the frequency and the read out unit is able to display this directly in engineering units.

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:

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

where, σ = tension of wire in kg/cm²

g = 980 cm/sec²

ρ = density of wire in kg/cm³

l = length of wire in cm

The length of the wire in the stress cell being 5.5 cm, the formula can be reduced to:

$$f = 32 [\sigma]^{1/2} \text{ Hz}$$

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

2.5 On interpreting data

The hydraulic type stress cell described above is a standard internationally used design and is manufactured by most reputed manufacturers. Depending upon the application and how and where it is used, it may generally give a reading upto 10 % different from the actual. To understand the reason for this difference in reading from the actual, the following explanation is given:

Two flat plates are welded together at periphery and are separated by a small gap filled with hydraulic fluid.

The soil pressure squeezes the two plates together building up a pressure on the fluid. The plates being thin relative to their lateral extent, are quite flexible. However, please note that there is some supporting effect of the welded periphery at center of the plate that may affect the reading.

Introduction of a flat stress cell into a mass alters stress field dependent on relative stiffness of cell with respect to surrounding material and also with respect to aspect ratio of cell; that is ratio of width of the cell to its thickness. A thick cell will alter stress more than a thin cell. Therefore, a thin stiff cell is best and studies have shown an aspect ratio of at least 20 to 1 to be desirable.

Preferably, the cell should be as stiff (compressible) as the material in which it is embedded. In practice, this is difficult. This is explained by the following examples in which the surrounding material could be soil or rockfill.

If the cell is stiffer (less compressible) than the material in which it is embedded (like soil) then it will over-register the pressure because a zone of material immediately around the cell is “sheltered” by the cell and does not experience the full pressure.

There is a stress concentration (figure 2.3) at the rigid rim but in the center of the cell the stress is only slightly higher than the mean stress, that is, only slightly higher than the normal stress had the pressure cell not been there.

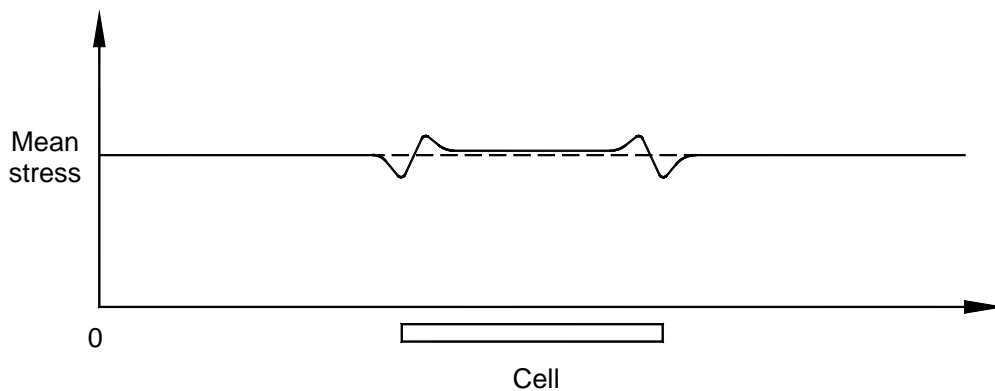


Figure 2.3- stress redistribution - weak surrounding material with a stiff cell

In a stronger surrounding material the de-stressed zone around the edge of the cell is more extensive and hence at the center of the cell the degree of over-registration of the mean stress is greater. This is represented schematically in Figure 2.4.

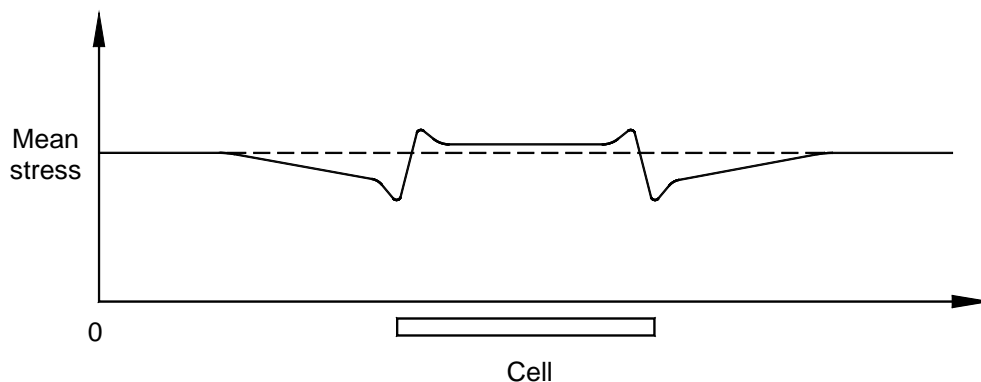


Figure 2.4- stress redistribution - strong surrounding material with a stiff cell

In a stiff surrounding material (like concrete) the cell may be less stiff (more compressible), in which case the cell will under-register the mean stress as the stress in the surrounding material tends to “bridge” around the cell. This is represented schematically in Figure 2.5.

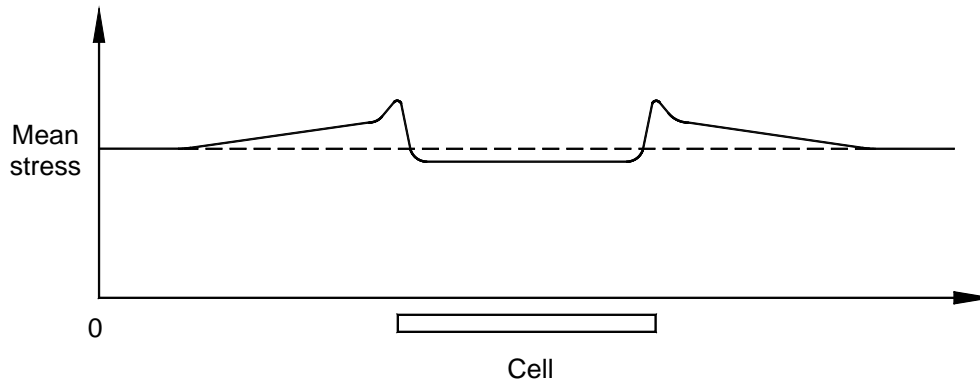


Figure 2.5 - Stress redistribution - stiff surrounding material with a weak cell

Any closed hydraulic system is sensitive to temperature effects. The stress cell when embedded in soil acts like a closed hydraulic system. Any change in temperature of surrounding soil therefore gives an unauthentic or false reading, magnitude of which depends upon elasticity of surrounding soil and relative coefficient of expansions of materials in contact & filled fluid inside stress cell. A thermistor is incorporated in each sensor to assist in determining temperature compensation factors that may be calculated by closely observing in-situ stress cell performance.

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

The model EDI-54V vibrating wire indicator (figure 2.3) 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.



Fig 2.3 (a) – 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 EPS-30V-S earth pressure cell is given in the test certificate provided with every supply. The initial reading IR will be the actual reading in digits from the pressure cell 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/adaptor 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.

2.7 Sample test certificate to be used with EDI-51V Readout Unit

TEST CERTIFICATE

DWT Traceable to standard no. : G010601 RED 090 TC

Customer			
P.O. No.			
Instrument	Earth pressure cell	Date	02.02.2008
Serial number	7241	Temperature	16°C
Capacity	10 MPa	Atm. pressure	0.100 MPa

Pressure transducer calibration data

Input pressure (MPa)	Observed value			Average (Digit)	End Point Fit (MPa)
	Up1 (Digit)	Down (Digit)	Up2 (Digit)		
0.000	6561.3	6561.3	6561.3	6561	0.000
2.000	6258.5	6261.0	6258.5	6259	2.015
4.000	5958.0	5963.4	5958.0	5958	4.014
6.000	5657.3	5662.5	5657.3	5657	6.015
8.000	5356.4	5361.5	5356.4	5356	8.017
10.000	5057.1	5057.1	5059.8	5058	10.000

Error (%FS) 0.17

Digit	$f^2 / 1000$	
Pressure transducer gage factor	6.654E-03	MPa/digit
Thermal factor	-0.001	MPa/°C

Earth pressure cell calibration data

Cell constant (multiplier)	1.0270
Linear gage factor	6.834E-03 MPa/digit

(Use gage factor with minus sign with our read out unit Model: EDI-51V)


Pin configuration/wiring code:

Red & black:	Signal	Green & white:	Thermistor
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Checked by

Tested by

2.8 Sample calibration constants of EPS-30V-S to be used with EDI-54V



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Calibration Constants for EDI-54V Data Loggers

The constants will be used to read the Sensor Output in engineering unit (MPa)

Sl.No.	Pressure Sensor Sl. No.	Polynomial Constants				Linear Constants		
		A5,A3,A1	A4	A2	A0	A5,A4,A3,A1	A2	A0
1	43995	0	1.8362E-15	-4.6259E-07	2.5110E+00	0	-4.4249E-07	2.8314E+00
2	44006	0	1.9630E-16	-4.2461E-07	2.6567E+00	0	-4.2309E-07	2.6543E+00
3	44007	0	-2.9337E-16	-4.0744E-07	2.5885E+00	0	-4.1132E-07	2.6019E+00
4	44020	0	-1.9308E-16	-4.2233E-07	2.6675E+00	0	-4.2498E-07	2.6776E+00
5	44050	0	4.0604E-16	-4.4961E-07	2.8401E+00	0	-4.4592E-07	2.8302E+00
6	44066	0	3.5270E-15	-4.3925E-07	2.6177E+00	0	-4.0173E-07	2.5213E+00
7	44148	0	4.9612E-16	-4.5513E-07	2.8694E+00	0	-4.5044E-07	2.8609E+00
8	44155	0	2.2529E-15	-4.2783E-07	2.5889E+00	0	-4.0411E-07	2.5281E+00
9	44169	0	-6.8315E-16	-3.9056E-07	2.5110E+00	0	-3.9862E-07	2.5358E+00
10	44175	0	-4.9131E-17	-4.1682E-07	2.6646E+00	0	-4.1791E-07	2.6691E+00
11	44186	0	-1.8561E-15	-3.8740E-07	2.5307E+00	0	-4.0856E-07	2.5914E+00
12	44192	0	-9.7324E-16	-3.9361E-07	2.5154E+00	0	-4.0469E-07	2.5459E+00
13	44222	0	6.4001E-16	-4.1122E-07	2.5154E+00	0	-4.0489E-07	2.5608E+00
14	44255	0	7.2646E-16	-4.3504E-07	2.7026E+00	0	-4.2797E-07	2.6870E+00

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2.9 Sample calibration constants of EPS-30V-S to be used with ESDL-30



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Calibration Constants for ESDL-30 Series Data Logger

The constants will be used to read the Sensor Output in engineering unit (MPa)

Sl.No.	Pressure Sensor Sl. No.	Polynomial Constants			Linear Constants		
		A2	A1	A0	A2	A1	A0
1	43995	1.8362E-15	-4.6259E-07	2.5110E+00	0	-4.4249E-07	2.8314E+00
2	44006	1.9630E-16	-4.2461E-07	2.6567E+00	0	-4.2309E-07	2.6543E+00
3	44007	-2.9337E-16	-4.0744E-07	2.5885E+00	0	-4.1132E-07	2.6019E+00
4	44020	-1.9308E-16	-4.2233E-07	2.6675E+00	0	-4.2498E-07	2.6776E+00
5	44050	4.0604E-16	-4.4961E-07	2.8401E+00	0	-4.4592E-07	2.8302E+00
6	44066	3.5270E-15	-4.3925E-07	2.6177E+00	0	-4.0173E-07	2.5213E+00
7	44148	4.9612E-16	-4.5513E-07	2.8694E+00	0	-4.5044E-07	2.8609E+00
8	44155	2.2529E-15	-4.2783E-07	2.5889E+00	0	-4.0411E-07	2.5281E+00
9	44169	-6.8315E-16	-3.9056E-07	2.5110E+00	0	-3.9862E-07	2.5358E+00
10	44175	-4.9131E-17	-4.1682E-07	2.6646E+00	0	-4.1791E-07	2.6691E+00
11	44186	-1.8561E-15	-3.8740E-07	2.5307E+00	0	-4.0856E-07	2.5914E+00
12	44192	-9.7324E-16	-3.9361E-07	2.5154E+00	0	-4.0469E-07	2.5459E+00
13	44222	6.4001E-16	-4.1122E-07	2.5154E+00	0	-4.0489E-07	2.5608E+00
14	44255	7.2646E-16	-4.3504E-07	2.7026E+00	0	-4.2797E-07	2.6870E+00

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3 TOOLS & ACCESSORIES REQUIRED FOR INSTALLATION

The following tools and accessories are required for proper cable jointing and installation of the stress cell (also refer users manual on cable jointing - 6002.11):

Temperature controlled soldering iron 25 watt

Rosin 63/37 solder wire RF-3C, 30 swg

Thread sealant (Loctite 577 or equivalent)

Cable jointing compound (MS 853 and hardener MSH 283 - Mahendra Engineering & Chemical Products Ltd. or equivalent. For alternatives, refer to note on page 3-4 of Encardio-rite user's manual "cable jointing of sensors" 6002.11)

Acetone (commercial)

Spanner 28/32 and 38/40

Hacksaw with 150 mm blade

Hammer

Cable Cutter

Surgical blade with holder

Wire Stripper

Pliers 160 mm

Pouring funnel

Stainless steel rod 2 mm □□ 150 mm length

Spatula

Rotary tin cutter

Fixture for jointing upto six earth pressure cells (refer figure 3.1)

Toothbrush

Cloth for cleaning (lintless)

Digital multimeter

Vibrating wire Indicator EDI-54V

NOTE: A simple wooden fixture as shown below may be fabricated at site for faster cable jointing. It is also available from Encardio-rite.

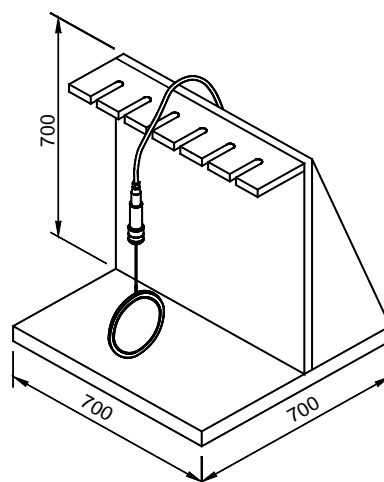


Figure 3.1

4 INSTALLATION PROCEDURE

4.1 Preparation of the sensor before installation:

Remove cable joint housing from cable end of sensor. This gives access to the four pin terminal. Two of the terminals are marked with red and black colors. These are internally wired to coil of magnet assembly inside sensor. The other two terminals are utilized for measurement of temperature using a thermistor. Clean the terminals with a toothbrush.

CAUTION: Do not use any acetone for cleaning as it may damage the glass to metal seal.

Check working of sensor as follows:

- The coil resistance measured by a digital multimeter between the red and black pins, should lie between 120-150 Ohm. Determine resistance at the room temperature from thermistor temperature chart in § 5. This resistance should be equal to that between pins marked green and white. For example, in case the 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 the sensor to the Encardio-rite model EDI-54V portable readout unit and switch it on. The display will show something like:

Freq: 2629.8 Hz

where the actual figure will vary depending on the transducer connected to the indicator.

For the stress cell, the initial reading (offset) in frequency as read on the portable readout unit should be stable.

- Check whether sensor is responding to changes in pressure. A crude but simple and effective method of checking whether the sensor is responding to changes in pressure is as follows:
- Press the diaphragm with the thumb and verify that the frequency reading on the indicator decreases.
- This change in reading ensures that the deformation produced by the pressure of the thumb on the diaphragm is transmitted to the vibrating wire sensing element.

Connect required length of cable to sensor as described in cable jointing manual - 6002.11.

NOTE: The cable should always be unreeled by turning cable drum so that cable is laid out on the flooring. Cables should never be unreeled by pulling on cable itself as the internal conductors can get damaged from excessive strain. Under no circumstances should the cable be unwound from any one side of the drum. This can happen, for example, when the cable drum is kept on its side and the cable is taken out without rolling the drum.

Check the working of the sensor again following the procedure described above in § 4.1.2.

NOTE: Remember to add the cable resistance when checking the resistance between the leads after the cable jointing. For the model CS 0601 cable, the nominal resistance is 48 Ohm/km and for CS 0406 cable, the resistance is 48 Ohm/km. In case any other cable is used, make the necessary addition in the resistance value.

Cable should be marked with permanent markers every 5 m by use of stainless steel tags tied by stainless steel wire stamped with appropriate concrete pressure cell number. Alternatively, plastic tabs are also available. Temporary identification is done by writing serial number of sensor, its code number and location at which it is installed on a strip of paper, placing strip on cable and covering it with a transparent cello tape. Permanent identification is necessary to prevent error in making proper connections in junction box and to insure correct splicing if cable is cut or broken.

CAUTION: Single most important factor leading to loss of worthwhile data from sensors is losing track of

identification of cable ends. Proper identification and marking of cables is necessary. Care should also be taken to put an identification tag at point where cable comes out of structure such that cable identity is not lost if cable gets accidentally cut.

4.2 Installation of earth pressure cell in earth or rock fills and embankments

Installing the earth pressure cell is a fairly simple operation. In case effective stress is to be determined, a pore pressure meter must be installed close by. An earth pressure cell is normally installed with flat surfaces horizontal to measure vertical stress. However, it can be placed at other orientations, inside the fill, to measure stress in other directions i.e. a cell placed with the flat surfaces vertical will measure horizontal stress in a direction perpendicular to the diaphragms of the cell.

NOTE: The earth pressure cell measures the total stress. In case effective stress is to be measured a pore pressure meter must be installed close by.

At any cross section, the filling of the dam is allowed to continue to an elevation of around 0.5 to 1 m higher than where the earth pressure cell is to be mounted. The position where the earth pressure cell is to be mounted is carefully marked. Offset trenches (around 1 m x 1 m) to reach the correct required elevation are dug at these positions.

NOTE: Earth pressure cells may be installed single or in clusters either in a trench below lift, or in a ramp above the lift. In a dam, for example, it is usually convenient to install in a trench in the impervious rolled fill core and in a ramp in the filter zones and compacted rockfill shell zones. In an earth embankment it is convenient to install in a trench. By doing so, adequate degrees of compaction of the backfill can be more easily obtained without damage to the cell clusters or the cable trench. As the cells are being covered and compacted, repeated readings should be taken to ensure that the cells are continuing to function properly.

The earth pressure cell should be enclosed by the material of the fill rather than another material (e.g. sand) because if the compaction is performed properly, the stiffness will conform better to the rest of the fill. When installing the cell, it is important to avoid direct contact with large or sharp rocks. Such contact may locally deform the two diaphragm plates pinching them together such that the external pressure is no longer transmitted entirely to the interior fluid. It is recommended that all chunks larger than 10 mm should be removed from the material immediately surrounding the cell.

NOTE: Record initial reading and temperature with EDI-54V for permanent record, when cell is placed in position and is about to be covered with fill material. This will form the zero reading for the pressure cell. Also note the barometric pressure with the initial reading.

At locations where there is an appreciable amount of coarse material, it is recommended to have a layer of fine material from the same fill in contact with the diaphragms of the sensor. This should be enclosed in transitional layers of successively coarser material in order to establish an outward graduation to the maximum size material.

The material around sensor should be placed by hand shovel and compacted with a light duty pneumatic or petrol backfill tamper. The first layer of material over sensor should be 250 mm high and compacted properly. Similar layers of material should be put over this and compacted properly until at least 500 mm of material has been placed. Rubber tired equipment can now cross this location, but no vibratory rollers should be permitted over sensor until a compacted thickness of at least 1 m is laid.

4.3 Cable laying

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

Procedure for laying of cables differs with individual installations. In general, however, all installations have the following common requirement:

- The cable must be protected from damage by angular and sharp particles of the material in which the cable is embedded.
- The cable must be protected from damage by compaction equipment.
- In earth and rock embankments and backfill, the cable must be protected from stretching as a result of differential compaction of the embankment,
- Cables may be spliced without affecting the sensor reading; nevertheless splicing should be avoided wherever possible. If necessary, use special cable jointing kits available from the factory.

In an earth and rock fill dam, earth pressure cells and a number of other sensors are installed at selected elevations at different cross sections, as illustrated in figure 4.1. For example, three stress cells and nine pore pressure meters are installed in offset trenches, at elevation 438 m.

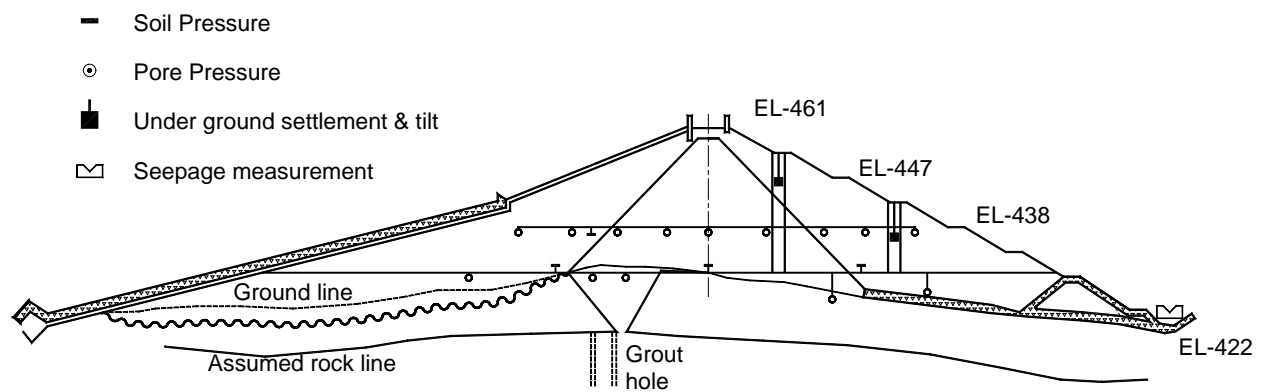


Figure 4.1

A cable trench around 400 - 800 mm wide and upto 500 mm deep is dug along the offset trenches, as shown in figure 4.2 on next page. The depth and width depends upon the number of cables the trench has to carry. Based upon the cable layout designed, the trench runs into the abutment and then along the abutment to the downstream side or directly to the downstream side towards the observation room. These cable trenches carry the individual cables from the earth pressure cells to the observation room.

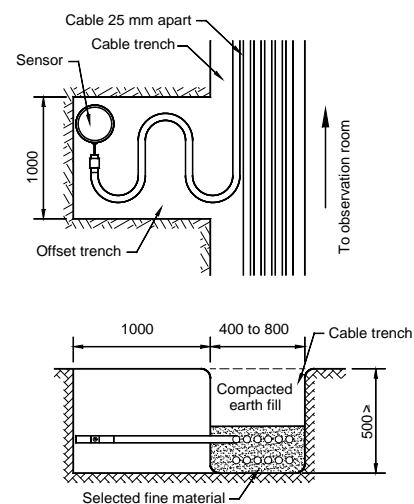


Figure 4.2

Before laying cables, trench should be properly cleaned and leveled with 100 mm of fine sand or properly compacted fill material at bottom of trench along the path. Any sharp rocks should be removed to prevent cable from accidentally getting damaged. Center distance between successive cables should be kept at a distance of 25 mm with help of a wooden cable spacer. A distance of 100 mm must be left free from the sides of the trench.

Cables coming out of the dam should be properly tagged. 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 end of the trench 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 cable trench. In that order, the cable from the closest sensor is at the extreme right.

NOTE: A simple code for remembering this is "LL-SR". Longer (cable) left, shorter (cable) right when

viewing the sensors from the observation room.

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

NOTE: In embankments, cables may be embedded in a protective covering of sand or selected fine embankment materials. A typical installation might, for example comprise the positioning of a series of cables on a prepared layer consisting of not less than 100 mm of compacted selected fine material. In order to establish an acceptable grade without undue interference with construction operations, the prepared layer may be located either in a trench or on an exposed ramp. In rockfill dams with earth fill cores, for example, it is frequently convenient to install cable in trenches in the core and fine filter zones and in ramps in the coarse filter and compacted rock fill shell zones. In instances in which more than one layer of cables must be placed in a given array, the cables should be separated from each other by a vertical interval of not less than 100 mm of hand compacted sand or selected fine embankment material.

During backfill of trenches in earth dams, a plug approximately 0.5 m in width, made of a mixture of 5% bentonite (by volume) exhibiting a free swell factor of approximately 500 % and 95 % embankment material, can be placed in trench at intervals of not greater than 20 m. Purpose of bentonite plugs is to reduce the possibility of water seepage through the embankment core along the back filled trenches.

CAUTION: Care should be exercised when installing instrument cables to keep them as far away as possible from sources of electrical interference such as power lines, generators, motors, transformers, arc welders, etc. Cables should never be buried or run with AC power lines. Instrument cables will pick up 50 or 60 Hz (or other frequency) noise from the power cable and this will likely cause a problem obtaining a stable reading. Contact factory concerning filtering options available for use with dataloggers and readouts should difficulties arise.

5 THERMISTOR - TEMPERATURE RESISTANCE CORRELATION

Thermistor type: Dale 1C3001-B3 or equivalent

Temperature resistance equation

$$T = 1/[A + B(\text{Ln}R) + C(\text{Ln}R)^3] - 273.2 \text{ } ^\circ\text{C}$$

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

Ohm	temp. $^\circ\text{C}$	Ohm	temp. $^\circ\text{C}$	Ohm	temp. $^\circ\text{C}$
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	-42	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

5.1 Measurement of temperature

Thermistor for temperature measurement is incorporated in the sensor. The thermistor gives a varying resistance output related to the temperature). The thermistor is connected between the green and white leads. The resistance can be measured with an Ohmmeter. The cable resistance may be subtracted from

the Ohmmeter reading to get the correct thermistor resistance. However the effect is small and is usually ignored.

The Encardio-rite model EDI-54V read-out unit gives the temperature from the thermistor reading directly in engineering units.

5.2 Temperature correction

A pressure-temperature variation correlation factor (k) is provided in the test certificate for the pressure sensor of the earth pressure cell. In case correction for temperature effect is required in cell, use following equation:

$$P_{\text{correction}} = K (\text{current temperature} - \text{initial temperature})$$

The temperature correction value is added to the pressure value read from the EDI-54V read-out.

The effect of the temperature coefficient of expansion of soil on stress cell is almost impossible to determine. Temperature effect caused by mismatch between the temperature coefficient of cell and surrounded soil is not quantifiable and hence no correction factor for this effect is supplied. If required, user may conduct his own tests under controlled conditions. Please once read again § 2.5.7 in this connection.

6 OTHER CONSIDERATIONS/TROUBLE SHOOTING

6.1 Barometric pressure correction

The pressure transducer used in the Encardio-rite vibrating wire earth pressure cell is evacuated and hermetically sealed and will respond to barometric pressure fluctuation. In fact all earth pressure cells will respond to barometric pressure fluctuations unless they are manufactured in the gage pressure version and a capillary tube is provided in the cable which opens into the atmosphere.

Since the magnitude of barometric pressure fluctuations is of the order of $\pm 0.03 \text{ kg/cm}^2$, correction is generally not required. If a correction for these fluctuations is required then it is necessary to record the barometric pressure at the time of taking the reading. The initial barometric pressure corresponding to the zero reading at the time of installation is to be considered (refer to third note in § 4.2). The correction can be made by using the following equation:

$$P_{\text{correction}} = (\text{initial barometric pressure} - \text{current barometric pressure})$$

The pressure correction value is added to the pressure value read from the EDI-54V read-out.

6.2 Trouble shooting

Earth pressure cell is embedded in soil. Once installed, the cell 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.

6.2.1 *Symptom: pressure cell reading unstable*

- Check the insulation resistance. The resistance between any lead and the protective armour should be $> 500 \text{ M Ohm}$. If not, cut a meter or so from the end of cable and check again.
- Does read-out work with another earth pressure cell? If not, read-out may have a low battery or be malfunctioning. Consult manual of readout unit for charging or trouble shooting instructions.
- Use another read-out unit to take the reading.
- Check if there 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.

6.2.2 *Symptom: pressure cell fails to read*

- The cable may be cut or crushed? Check the nominal resistance between the two gage leads using an Ohm meter. It should be within $120 - 150 \text{ Ohm}$. The correct value is given in the concrete pressure cell test certificate. For the model CS 0601 cable, the nominal resistance is 48 Ohm/km and for the model CS 0406 cable, the resistance is 48 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 ($< 100 \text{ Ohm}$), a short in the cable is likely.
- Does the read-out work with another earth pressure cell? 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.

7 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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