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USERS' MANUAL

VIBRATING WIRE CENTER HOLE LOAD CELL

MODEL ELC-31V

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1 INTRODUCTION

The Encardio-rite model ELC-31V is a precision engineered vibrating wire hydraulic center hole load cell, specially designed for use in severe environments associated with civil engineering applications and construction activity.

The advantage of vibrating wire load cell over a more conventional electrical strain gage or semiconductor type load cell lies mainly in the use of a frequency, rather than a voltage, as the output signal. Frequency may be transmitted over long cable lengths of up to 1 km without appreciable degradation caused by variation in cable resistance that may result from water penetration, temperature fluctuations, contact resistance or leakage to ground. The load cell is often used in series with a hydraulic jack for applying load. Consequently, it verifies load as applied by the hydraulic jack.

Collapse of roof or falling of side wall in underground cavities is a factor of prime importance to geologists, design engineers and construction companies. Slope failures and landslides have been recognized as one of the several forms of natural disaster and can happen anywhere in the world without any discrimination. Whether it is giving away of roof of a mine or buckling of side wall of an underground power house cavity or a land slide or a slope failure, the disaster may cause mammoth loss of life, property, wealth and time. A large number of methods are available for taking preventive and corrective action. One of the methods is anchoring.

Anchoring has emerged as a powerful preventive method. Use of pre-stressed grouted anchors provides an active support system in all the above cases. In any optimum, safe and economic use of anchoring, anchor spacing and anchor load have to be determined. This is done by use of centre hole load cell and a suitable read out unit. At locations where several sensors are installed, a data logger may be used for ease in analysis and for studying cumulative effects.

1.1 Handling and installation of load cell

Load cell should be handled very carefully during transportation and installation. It should never be dropped as impact generated will almost certainly result in a shift of zero reading.

CAUTION: The load cell should not be dropped under any circumstances because this may lead to its permanent damage.

Direct sunlight should never fall on the load cell. This results in uneven temperature distribution across the load cell and will certainly give erroneous results. Load cell should be well covered with an insulating protective shield to reduce effect of sunlight and environment changes like those induced due to rain or wind.

NOTE: Protect load cell from direct sunlight or environmental changes like those induced by rain or wind. The load cell is a fluid filled system in which effect of eccentric loads is less than in our other types of load cells but effect of temperature variations is more because of unequal expansion of filled fluid in comparison to the enclosing steel pads. It is not possible to quantify both these effects as they depend upon field conditions and user is advised to conduct his own field tests to monitor any variations.

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 center hole load cells in your application. 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 users' manual is intended to provide sufficient information for making optimum use of vibrating wire load cell in different applications. To make the manual more useful we invite valuable comments and suggestions regarding any additions or enhancements. We also request to please let us know of any errors that are found while going through the manual.

NOTE: Installation personnel must have a background of good installation practices and knowledge of fundamentals of geotechnics. Novices may find it very difficult to carry on installation work. The intricacies involved in installation are such that even if a single essential but apparently minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

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

Installation of a load cells requires expertise. It is recommended that potential users themselves practice all the operations laid down in this manual by repeated installations.

NOTE: The sensor is normally used to monitor site conditions and will record even a minor change that may affect behaviour of structure being monitored. Some of these factors amongst others, are, seasonal weather changes, temperature, rain, barometric pressure, nearby landslides, earthquakes, traffic, construction activity around site including blasting, tides near sea coasts, fill levels, excavation, sequence of construction and changes in personnel etc. These factors must always be observed and recorded as they help in correlating data later on and also may give an early warning of potential danger or problems.

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 general description: See § 2.1 'General description'.

For understanding principle of vibrating wire centre hole load cell: See § 2.2 'Operating principle'.

For test certificate: See § 3.1 'Sample test certificate'.

For installation of centre hole load cells: See § 4 'Installation procedure'.

For trouble shooting: See § 4.6 'Trouble shooting'.

For evaluating thermistor data: See § 5 'Thermistor - temperature resistance correlation'.

2 VIBRATING WIRE LOAD CELL

2.1 General description

The model ELC-31V vibrating wire load cell is fluid filled and is constructed from stainless steel. It is available in capacities ranging from 500 kN to 2000 kN. Load cells having an internal diameter different from the standard specified range are available upon request. In addition to the above, a 2500 kN load cell without center hole is also available.

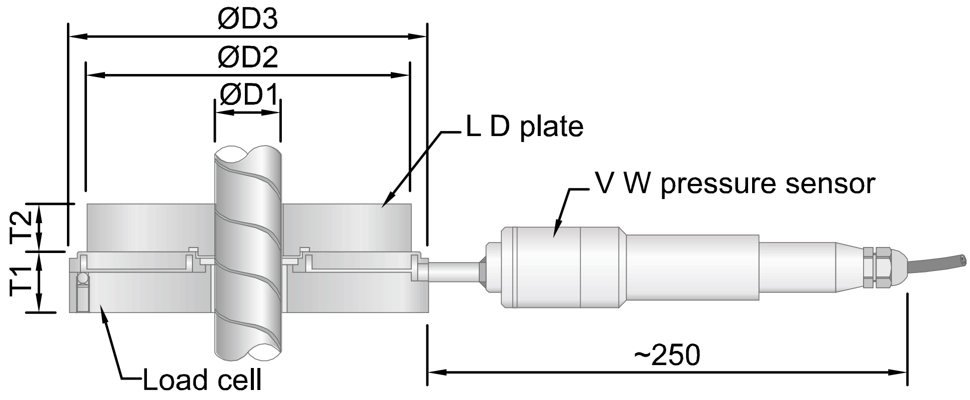

Figure 2.1

The model ELC-31V vibrating wire center hole load cell is made of a sensitive pressure pad which is formed by welding together two stiff steel discs at their periphery. The space inside the cell is filled with de-aired fluid. When load is applied to cell, pressure on the fluid changes. This change in fluid pressure is used to monitor the variation in load being applied to the cell. The load is distributed equally over the loading area of the cell by a thick, load distribution plate (L D plate).

Capacity kN	ELC-31V vibrating wire centre hole load cell				
	T1 mm	D1 mm	D2 mm	D3 mm	Weight kg
500	28	52	144	160	4.5
750	28	78	180	196	6
1000	28	105	219	235	8
1500	28	105	249	265	11
2000	30	130	265	281	12
2500	30	0	260	281	15

Capacity kN	Load distribution/bearing plate			
	OD mm	ID mm	T2 mm	Wt. kg
500	144	52	33	4
750	180	78	33	6
1000	219	105	38	9
1500	249	105	38	12
2000	260	130	48	16
2500	260	--	48	20

The fluid pressure inside the load cell is measured by a vibrating wire pressure transducer. The vibrating wire pressure transducer is of stainless steel construction and incorporates the latest vibrating wire technology to provide electrical read-out. A glass to metal seal is provided for easy cable connection. A thermistor is incorporated in the pressure sensor for monitoring temperature.

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

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

Normally, load cell is supplied without any cable attached to it. Cable jointing with required length of appropriate cable can be easily done at site. However, if specifically requested, the load cell is supplied with the requisite length of cable attached.

Data from load cell can be read by Encardio-rite model EDI-51V vibrating wire read-out unit/data logger or remotely monitored by Encardio-rite model EDAS-10 automatic data acquisition system.

Load distribution plates can be used both above and below the load cell to ensure an even distribution of load on the sensor. Bottom load distribution plate is generally not required if an adequate bearing plate has been incorporated into the proposed installation arrangement.

2.2 Operating principle

Vibrating wire pressure cell of load cell basically consists of a magnetic, high tensile strength stretched wire, one end of which is anchored and other end fixed to a diaphragm that deflects in proportion to applied pressure. Any change in pressure, deflects the diaphragm proportionally and this in turn affects tension in the stretched wire. Thus any change in load, directly affects the tension in 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 resonant frequency, with which wire vibrates, induces an alternating current in the coil magnet. The load is proportional to the square of the frequency and the readout unit is able to display this directly in engineering units.

2.3 Taking readings with the model EDI-51V vibrating wire indicator

The model EDI-51V is a microprocessor based readout unit for use with Encardio-rite's range of vibrating wire transducers. It can display the measured frequency in terms of time period, frequency, frequency squared or the value of the measured parameter directly in proper engineering units.

The EDI-51V indicator can store calibration coefficients of up to 500 vibrating wire sensors so that value of measured parameter from these sensors can be shown directly in proper engineering units. The indicator has an internal non-volatile memory with sufficient capacity to store about 4,500 readings from any, some or all of the 500 programmed transducers in any combination. Each reading is stamped with date and time of taking measurement.

Calibration coefficients are given in the individual '**Test Certificate**' provided with each transducer. Refer to model EDI-51V instruction manual WI-6002.26 for entering the transducer calibration coefficients. The gage factor given in the test certificate and the zero reading in frequency[2] (digits) at the time of installation are used for setting up the transducer coefficients in the readout unit.

For transducers with a built-in interchangeable thermistor, the model EDI-51V can also display and record the temperature of the transducer directly in degree Centigrade. Any Encardio-rite vibrating wire sensor with the exception of the temperature sensor has a thermistor incorporated in it for temperature measurement, unless not required specifically by the customer.

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

The readout indicator is powered by an internal 6 V rechargeable sealed maintenance free battery. A fully charged new battery provides nearly 60 hours of operation on a single charge. A separate battery charger is provided with the EDI-51V indicator to charge the internal battery from 230 V AC mains.

The EDI-51V indicator is housed in a splash proof resin moulded enclosure with weatherproof connectors for making connections to the vibrating wire transducer and the battery charger.

2.4 Sample Test Certificate

Encardio-rite Electronics Pvt. Ltd.
A-7 Industrial Estate, Talkatora Road, Lucknow, UP-226011 India
E-mail: sales@encardio.com, encardio@sancharnet.in; Website: www.encardio.com
Tel. +91 (522) 2661039/40/41/42 Fax +91 (522) 2661043

ISO 9001 DNV CERTIFICATED FIRM

TEST CERTIFICATE

Customer: Date: 21.03.2009
P.O. No. Temp. 36 °C

Instrument: Model: ELC-31V vibrating wire type anchor bolt load cell

Capacity: 750 kN

Mfg. Sr. No. 1087

Dimension details

	.D.(mm)	O.D.(mm)	Height (mm)
Load cell	78	196	28
L.D. plate	78	180	40

Test data:

Input Load (kN)	Observed Values (Digits)		Average (Digits)	End point fit (kN)	Non-linearity (% fs)
	Cycle 1	Cycle 2			
0	6731.9	6732.6	6732.3	0.00	0.0
150	6581.5	6580.4	6581.0	151.03	0.1
300	6428.7	6432.0	6430.4	301.36	0.2
450	6275.4	6275.9	6275.7	455.78	0.8
600	6130.8	6139.9	6135.4	595.83	0.6
750	5982.5	5979.3	5980.9	750.00	0.0

Max. non linearity 0.77 % fs
Linear Gage Factor -0.998 kN/digit (digit = $f^2/1000$)

Wiring Configuration:

Colour	Description
Black- Red	Sensor
Green- White	Thermistor

Cable Length: NIL

Checked by Tested by

3 TOOLS & ACCESSORIES REQUIRED FOR INSTALLATION

The following tools and accessories are required for proper cable jointing and installation of the load cell:

3.1 Soldering iron 25 watt, temperature controlled

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

3.1 Thread sealant (Loctite 577 or equivalent)

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

3.1 Accessories for cable jointing compound i.e. rotary tin cutter, stainless steel rod 2 mm ϕ, 150 mm length for stirring, spatula & pouring funnel

3.1 Acetone (commercial)

3.1 Spanner 20/22 and 26/28

3.1 Hacksaw with 150 mm blade

3.1 Surgical blade with holder

3.1 Wire stripper and Cable Cutter

3.1 Pliers 160 mm

3.1 Locking nut spanner

3.1 Toothbrush

3.1 Cloth for cleaning (lint less)

3.1 Digital multimeter

3.1 EDI-51V portable readout unit/Data logger

4 INSTALLATION PROCEDURE

4.1 Preparation of 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 colours. These are internally wired to the coil of the magnet assembly inside the sensor. The other two terminals are utilized for measurement of temperature using a thermistor. Clean the terminals with a toothbrush.

NOTE: Do not use any acetone for cleaning the terminals as it may damage the glass to metal seal. Acetone should be used to clean the other portions of the sensor.

4.1.1 Check working of the 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 room temperature from thermistor temperature resistance chart in § 5. This resistance should be approximately equal to that between pins marked green and white. For example, if room temperature were 25°C, the resistance would be 3,000 Ohm.

The resistance between any lead and the protective armour should be > 500 M Ohm.

Connect sensor to Encardio-rite model EDI-51V 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.

4.1.2 Connect required length of cable to the sensor as described in operating manual on cable jointing WI-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 by 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.

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

NOTE: Add cable resistance when checking resistance between the leads after the cable jointing. For the model CS 0401 cable, the resistance is 26 Ohm/km and for the model CS 0406 cable, the resistance is 48 Ohm/km. (multiply by 2 for both leads). In case any other cable is used, make necessary addition in resistance value.

4.1.4 After extension of the cable, check working of sensor again following procedure described above.

NOTE: Remember to add the cable resistance when checking the resistance between the leads after the cable jointing. For the model CS 0406 cable, the resistance is 48 Ohm/km. (multiply by 2 for both leads). In case any other cable is used, make the necessary addition in the resistance value.

4.2 Installation on anchor bolt or cable anchor

4.2.1 Before installation of load cell take temperature and initial zero reading of the load cell. Subsequent readings will be compared against this initial zero reading to get the correct load. This data is used to feed the initial reading in the model EDI-51V.

4.2.2 Carefully grout seating pad perpendicular and concentric with anchor bolt/cable anchor. Inserting a suitable bush between anchor bolt/ cable anchor and bored hole can do this. The bush should be subsequently removed.

4.2.3 Install center hole load cell between flat seating pad and load distribution plates. These plates should be parallel to each other and normal to axis of load cell. Anchor can be centralized by carefully positioning load cell over it. Alternatively, a suitable bush can be used in annular space between load cell and anchor to centralize it. If a bush is used, take care that it does not interfere with loading pattern of load cell. In case surface of flat seating pad and load distribution plates cannot be maintained parallel, use spherical settings or wedges or compensation washers made of copper/high density plastic material.

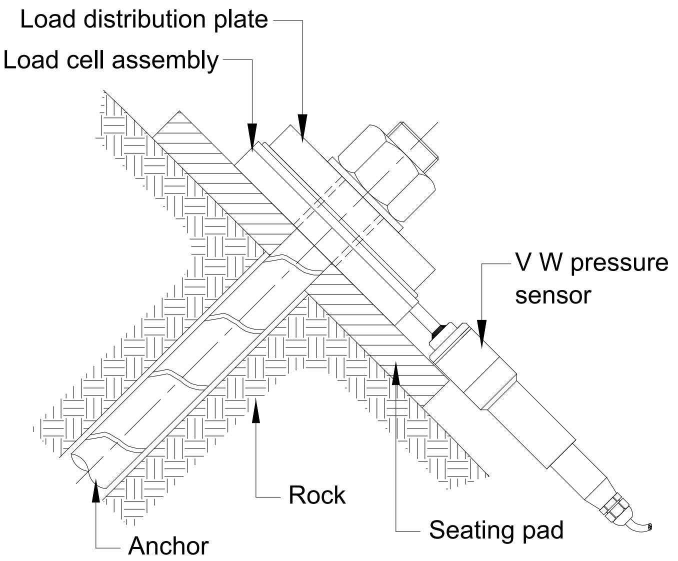

Figure 4.1

4.3 Installation on struts

Installation of load cells for measurement of axial load should be carefully designed. It varies from installation to installation and also depends upon type of struts used. A typical installation is illustrated below:

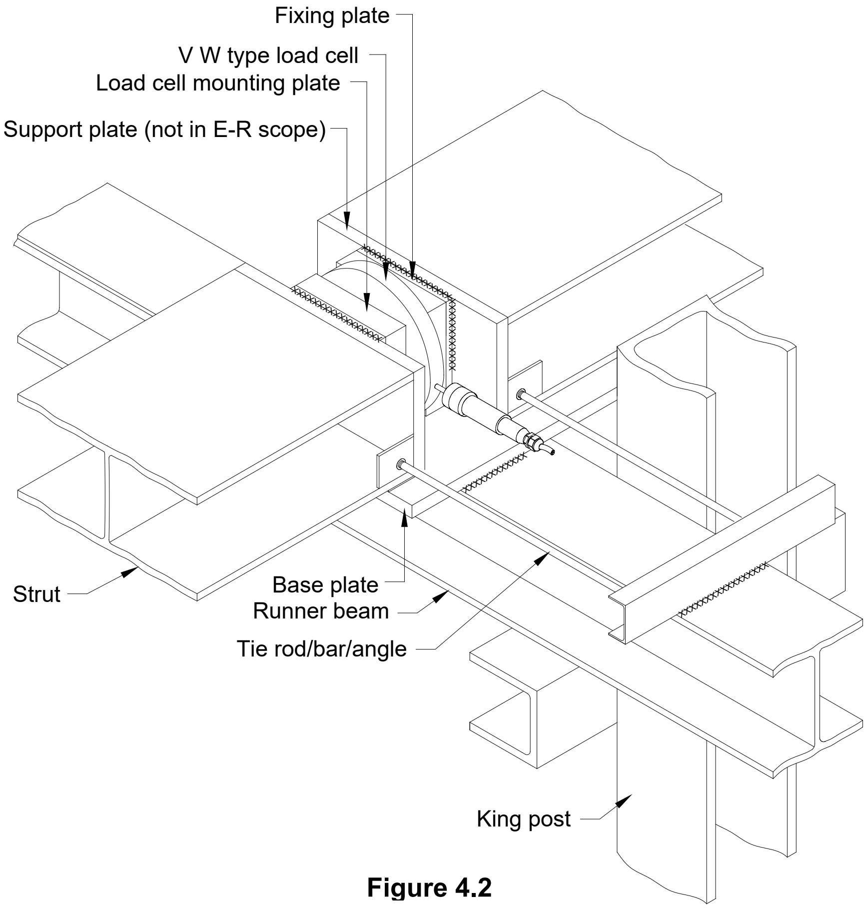

Figure 4.2

4.4 General precautions in the mounting of load cell

Load cell should be handled very carefully during transportation and installation. It should never be dropped as impact generated will almost certainly result in a shift of zero reading.

CAUTION: The load cell should not be dropped under any circumstances because this may lead to its permanent damage.

Direct sunlight should never fall on the load cell. This results in uneven temperature distribution across the load cell and will certainly give erroneous results. Load cell should be well covered with an insulating protective shield to reduce effect of sunlight and environment changes like those induced due to rain or wind.

NOTE: Protect load cell from direct sunlight or environmental changes like those induced by rain or wind. The load cell is a fluid filled system in which effect of eccentric loads is less than in our other types of load cells but effect of temperature variations is more because of unequal expansion of filled fluid in comparison to the enclosing steel pads. It is not possible to quantify both these effects as they depend upon field conditions and user is advised to conduct his own field tests to monitor any variations.

4.5 General precautions in the mounting of the cable

Careful and skilled cabling is required in installation of a load cell. The load cell/cable joint and a large part of cable may be exposed to blasting and construction work. Part of the cable may be permanently embedded and no future access may be available for any maintenance and corrective action. In general, take following precautions:

- Protect cable from damage by angular/sharp particles of material in which it is embedded.
- Cables may be spliced without affecting sensor reading; nevertheless splicing should be avoided wherever possible. If necessary, use special cable jointing kits available from factory.

Take precaution that cables are properly tagged all along. With best possible precautions, mistakes may still occur. Tags may get lost due to cable getting accidentally cut. Encardio-rite uses convention that looking from junction box or observation room towards sensor, cable from most distant sensor is always at the left hand side. In that order, cable from closest sensor is at 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.

Similarly, cable from most distant sensor should be connected to extreme left socket in junction box. Succeeding cables from sensors are connected progressively towards right in junction box.

4.6 Trouble shooting

Once installed, 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 to following list of problems and possible solutions should problems arise. For any additional help, consult factory.

4.6.1 Symptom: Load cell reading unstable

- Check insulation resistance. 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 read-out work with another load cell? If not, read-out may be malfunctioning or have a low battery. Consult manual of readout unit for charging or trouble shooting instructions.
- Use another read-out unit to take 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 problem could be reduced by shielding from

the electrical noise.

4.6.2 Symptom: Load cell fails to read

- Cable may be cut or crushed? Check nominal resistance between the gage leads using an Ohmmeter. It should be within 120 - 150 Ohm. The correct value is given in test certificate. Please add cable resistance when checking. For model CS 0401 cable, the resistance is 26 Ohm/km and for the model CS-406 cable, the resistance is 48 Ohm/km. (multiply by 2 for both leads). 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 read-out work with another load cell? If not, read-out is malfunctioning or may have low battery. Consult manual of readout unit for charging or trouble shooting instructions.
- Use another read-out unit to take the reading.

5 THERMISTOR - TEMPERATURE RESISTANCE CORRELATION

Thermistor type Dale 1C3001-B3

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

5.1 Measurement of temperature

Thermistor for temperature measurement is provided in all Encardio-rite vibrating wire load cells. The thermistor gives a varying resistance output related to the temperature (see § 5). 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-51V read-out unit gives the temperature from the thermistor reading directly in engineering units.