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USERS' MANUAL

VIBRATING WIRE TEMPERATURE METER

MODEL ETT-10V

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1 INTRODUCTION

The Encardio-rite model ETT-10V vibrating wire temperature meter is used for measurement of internal temperature in concrete structures, soil or water. Encardio-rite also manufactures the model ETT-10TH temperature sensor that incorporates a thermistor and the model ETT-10PT temperature sensor that incorporates a RTD element.

1.1 Purpose

Temperature is generally measured in concrete structures to determine:

- Heat of hydration.
- Temperature gradients
- Number of freeze-thaw cycles experienced at each location.

The study and measurement of temperature in concrete structures has the following main purposes:

- One of the greatest factor that causes stress in mass concrete is change arising due to temperature variation. Another major factor is the procedure adopted during construction and the stress caused due to the weight of the concrete itself. For analyzing development of thermal stress and for control of artificial cooling, it is necessary to monitor temperature variation of concrete during construction. To do this, the temperature should be accurately measured at many points in the structure, in water and in air. Sufficient number of sensors should be embedded to get a correct picture of temperature distribution at various points in the structure. In a large concrete dam, a typical scheme would be to place a temperature probe every 15 - 20 m along the cross-section and every 10 m along the elevation. For smaller dams, the spacing may be reduced.
- Temperature probes placed in the upstream face of a dam, evaluate the reservoir temperature as it varies throughout the year. This is much easier than dropping a thermometer in the reservoir every now and then to take observations.
- During operation of a concrete dam, diurnal and seasonal changes in the environment, play havoc as far as development of thermal stresses in the structure is concerned. The effect is more pronounced on the down stream side. A few temperature sensors should be placed near and in the downstream face of the concrete dam to evaluate the rapid daily and weekly fluctuation in temperature.

1.2 Features

Encardio-rite vibrating wire sensors have the following features:

- Rugged, waterproof and stainless steel construction for high reliability.
- Excellent linearity and hysteresis.
- Vibrating wire technology assures long-term stability, quick and easy readout.
- Sensor hermetically sealed by electron beam welding with a vacuum of 1/1000 torr inside it.
- Weather proof enclosure conforming to IP 68.
- Readily adaptable to data loggers.

1.3 Applications

The Encardio-rite vibrating wire temperature meter is the temperature sensor of choice as its frequency output is immune to external noise, it is able to tolerate wet wiring common in geotechnical applications and it is capable of transmission of signals to long distances. Some of the applications of the temperature meter are listed below:

- For verifying design assumptions that will promote safer and economical design and construction.
- Temperature rise during process of curing of concrete.
- Soil and rock temperatures near liquid gas storage tanks and ground freezing operations.
- Water temperatures in reservoirs and bore holes.
- Interpretation of temperature related stress and volume changes in dams.
- Study of temperature effect on other installed instruments.

1.4 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.

1.5 How to use this manual

This users' manual is intended to provide sufficient information for making optimum use of vibrating wire temperature meter in your application. This users manual covers description of the temperature meter with its connected accessories, the installation procedure and maintenance of the sensor, method of taking observations and recording data from the sensor.

NOTE: The installation personnel must have a background of good installation practices and knowledge of the fundamentals of geotechnics. Novices may find it very difficult to carry on 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, installation personnel will have to consciously depart from the written text and use their knowledge and common sense to find the solution to a particular problem.

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

The manual is divided into a number of sections. Each section contains a specific type of information. The list given below tells you where to look for in this manual if you need some specific information.

For understanding principle of vibrating wire temperature meter: See ξ 2.1 `Operating principle'.

For description of the vibrating wire temperature meter: See ξ 2.2. `General description'.

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

For installation of temperature meter: See ξ 4 `Installation procedure'.

2 VIBRATING WIRE TEMPERATURE METER

2.1 General description

2.1.1 Stainless steel body

The vibrating wire and coil magnet assembly is enclosed in a stainless steel body which is electron beam welded. This results in a vacuum of 1/1000 Torr inside the sensor resulting in it becoming immune to the effect of any ingress of water. As the temperature meter is of stainless steel construction, it is not affected by normal chemical corrosion at locations in which it is used.

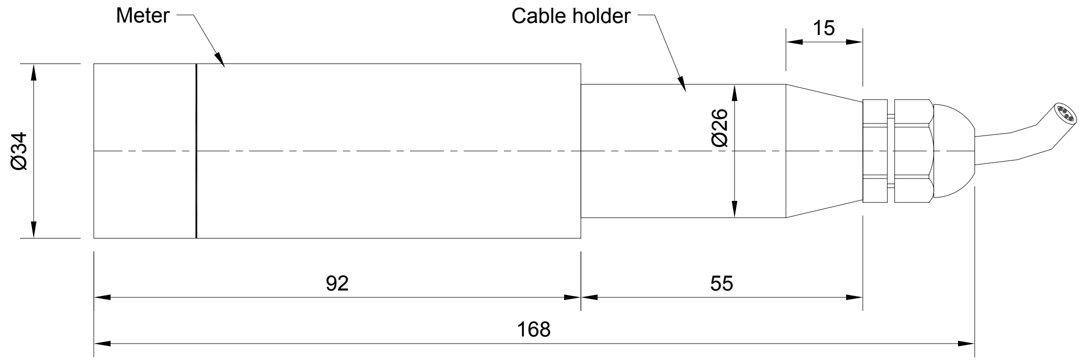


Figure 2.1

2.1.2 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 temperature meter. The two pins marked red and black are connected to the coil magnet. The other two pins are free. A cable joint housing and cable gland is provided for the cable connection. For cable jointing, refer to User's Manual 6002.11/6002.11E.

2.1.3 Operating principle

Vibrating wire temperature meter is designed on principle that dissimilar metals have different linear coefficient of expansion with temperature variation. Temperature meter basically consists of a magnetic, high tensile strength stretched wire, two ends of which are fixed to any dissimilar metal in a manner that any change in temperature directly affects tension in wire and thus its natural frequency of vibration. The dissimilar metal, in the case of Encardio-rite temperature meter, is aluminium. As temperature signals is converted into frequency by the vibrating wire, the same read-out unit as is used for other vibrating wire sensors, can also be used for monitoring of the temperature.

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

Length of the wire in temperature meter being 5.5 cm, the formula can be reduced to:

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

For calibration, frequency is measured at 0°C and 70°C and sensitivity determined. The resonant frequency with which the wire vibrates, induces an alternating current in the coil magnet. The temperature is proportional to the square of the frequency and the EDI-51V is able to display this directly in engineering units.

2.2 Specifications

Accuracy	± 0.5 % fs
Temperature limit	-20 to 70°C
Insulation Resistance	> 500 m Ohm at 12 V
Coil resistance	120 - 150 Ohm
Enclosure	Hermetically sealed; stainless steel construction

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

Model EDI-51V is a microprocessor based indicator for use with Encardio-rite's range of vibrating wire sensors. It can display measured frequency in terms of time period, frequency, frequency squared or value of measured parameter directly in proper engineering units. For sensors with a built-in interchangeable thermistor, it can also display temperature of transducer directly in degree Centigrade. Pressing the 'TEMP' key will display temperature of the sensor directly in degree Centigrade with a resolution of '1'.

The EDI-51V indicator can store calibration coefficients of up to 250 vibrating wire transducers so that the value of the measured parameter from these transducers can be shown directly in proper engineering units by selecting the channel number and pressing the 'UNITS' key.

The vibrating wire transducers indicator has an internal non-volatile memory with sufficient capacity to store about 3200 readings with temperature from any of the 250 programmed transducers in any combination. You can store either 3200 readings from any one transducer or 12 sets of readings from all 250 transducers. Each reading is stamped with the date and time the measurement was taken.

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

An internal 6V rechargeable sealed maintenance free battery is used to provide power to the indicator. A fully charged new battery provides nearly 60 hours of operation on a single charge. A separate battery charger is provided with the EDI-51V indicator to charge the internal battery from 230 V AC mains. A fully discharged battery takes around 16 hours to charge.

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

3 TOOLS & ACCESSORIES REQUIRED FOR INSTALLATION

The following tools and accessories are required for proper cable jointing and installation of temperature meter (also refer users manual on cable jointing - 6002.11/6002.11E):

- Soldering iron 25 watt
- Rosin 63/37 solder wire RF-3C, 30 swg
- Thread sealant (Loctite 577 or equivalent)
- Cable jointing compound (Please refer to Encardio-rite user's manual "cable jointing of sensors" 6002.11/6002.11E for options that can be used)
- Acetone (commercial)
- Spanner 27/32
- Hacksaw with 150 mm blade
- Cable Cutter
- Surgical blade with holder
- Wire Stripper
- Pliers 160 mm
- Pouring funnel
- Stainless steel rod 2 mm ϕ 150 mm length
- Spatula
- Rotary tin cutter
- Fixture for jointing upto six temperature meters (refer figure below)
- Tooth brush
- Cloth for cleaning (lintless)
- Digital multimeter
- Portable read-out (EDI-51V)

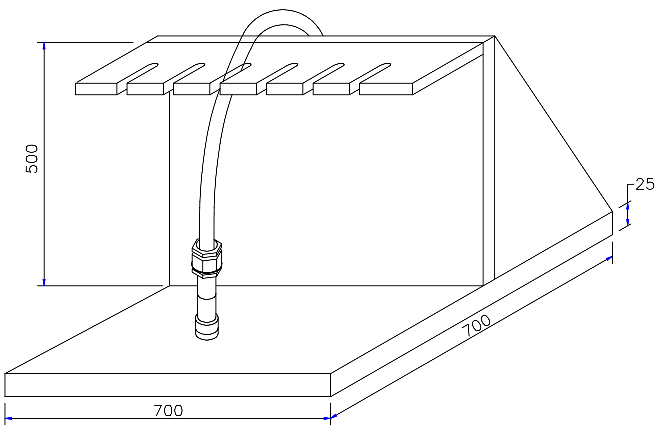


Figure 3.1

4 INSTALLATION PROCEDURE

4.1 Preparation of sensor before installation

- Remove cable joint housing. This gives access to the four-pin terminal. The two active terminals are marked red and black. Clean terminals with tooth brush.

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

- Check working of sensor as follows:
    - Coil resistance measured by digital multimeter between red and black pins should lie between 120 - 150 Ohm.
    - Resistance between any lead and the outside casing should be > 500 M Ohm.
    - Connect sensor to EDI-51V read-out unit. Initial reading on portable indicator should be stable. Read room temperature with temperature sensor. It should approximately match the room temperature obtained with an ordinary thermometer.
    - Connect required length of cable to sensor as suggested in operating manual on cable jointing - 6002.11/6002.11E.

NOTE: The cable should always be unreeled by turning the cable drum so that the cable is laid out on the flooring. Cables should never by unreeled by pulling on the 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 working of the sensor again following the procedure described above.
- The cable should be marked with permanent markers every 5 m by the use of stainless steel tags tied by stainless steel wire stamped with the appropriate temperature meter numbers. Alternatively plastic tabs are also available. Temporary identification can be done by writing the serial number of the meter, 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 cable 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.

4.2 Installing temperature meter

Installing of the temperature meter in the embankment of concrete dams and other structures is a fairly simple operation. No special orientation of the temperature meter is necessary. It can be directly placed on the concrete surface. The only care necessary is that any sharp points on the concrete surface do not damage the connecting cable.

- Place some sand/gravel to form a plain surface in the concrete dam or the structure.
- In case of a concrete dam or structure, pour concrete by a hand shovel to embed the sensor to a depth of around 0.5 m before commencing normal operation.

4.3 Cable laying in concrete dams and structures

Very careful and skilled cabling is required in installation of the temperature meter 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 readout 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

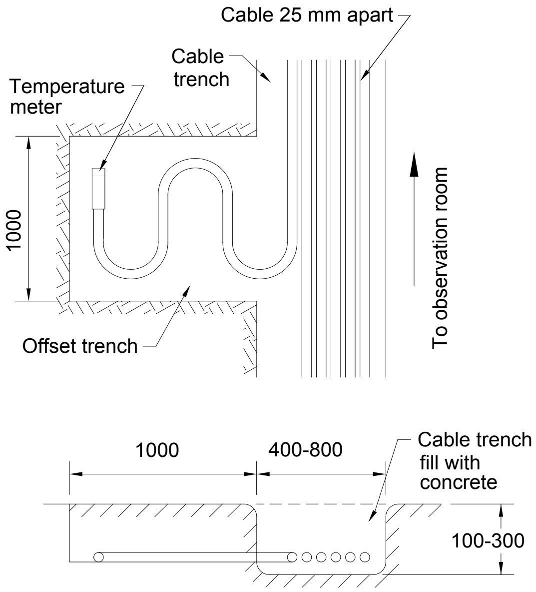
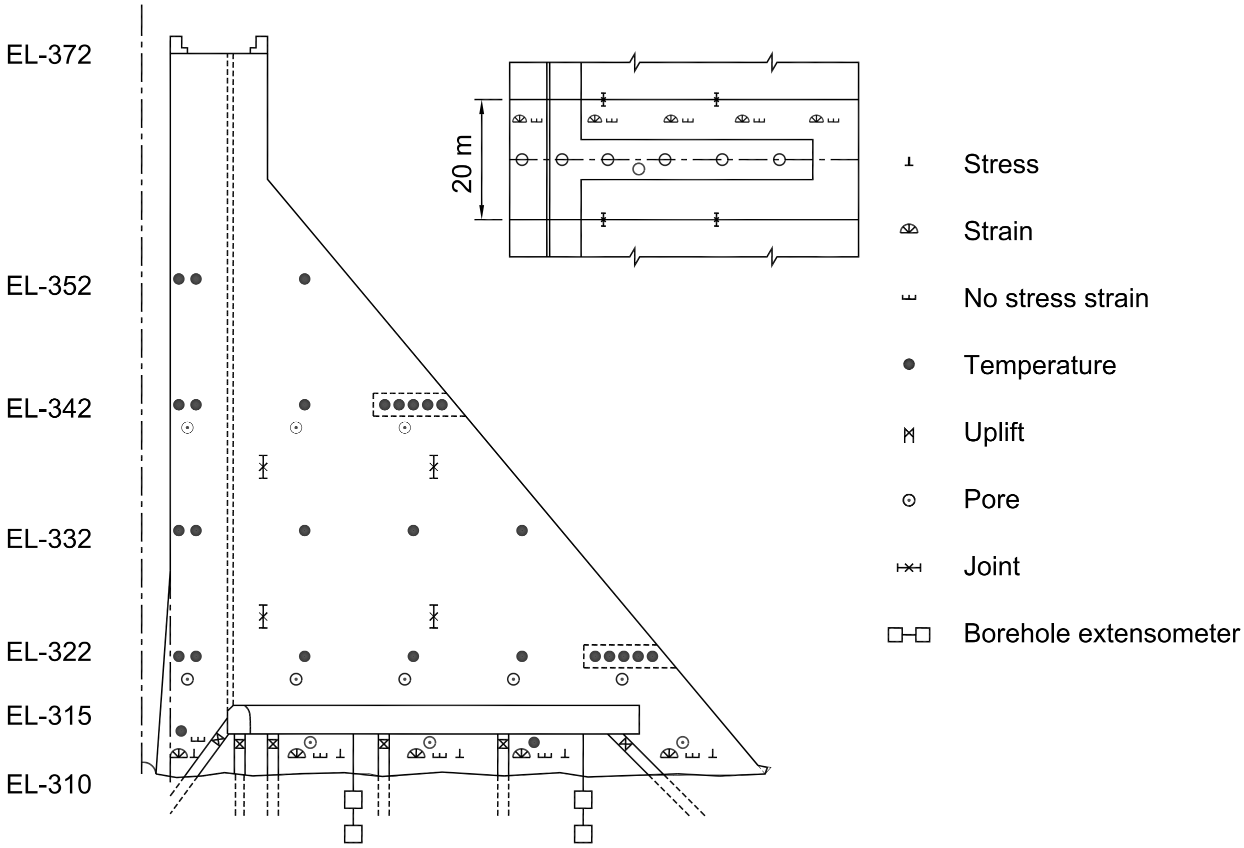


Figure 4.1

In a concrete dam, a number of temperature meters along with other sensors are installed at selected elevations at different cross sections, as illustrated in figure 4.2 on the next page. For example, two temperature meters, three piezometers, five strain rosettes, five no stress strain containers and five stress 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 form sensors at any particular elevation are routed to a vertical shat on the upstream side of the dam. The cables are then lowered or lifted through the vertical shaft tot he gallery.

At any cross section, the filling of the dam is allowed to continue to an elevation of around 25 cm higher than where the sensors are to be mounted, leaving 0.5 m x 0.5 m x 25 cm deep trenches at the positions where the sensors are to be placed. Larger trench may be left in case the temperature meter is to be installed along with other sensors, specially the strain rosette and the no stress strain meter that require more space. In case the latter are to be mounted along with the temperature meter, refer to user manual # WI 6002.16.

The cable from the sensors should be routed through a carefully marked channel trench ending into a vertical shaft and running parallel to the line of the sensors. 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 rock 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.

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.

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.

As an Encardio-rite convention, again, 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.