# INSTRUCTION MANUAL

## VIBRATING WIRE TYPE DISPLACEMENT SENSOR MODEL SME - 2120


**SENSORS & MEASUREMENTS ENTERPRISES**

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## 1. Introduction

The SME model-2120 linear displacement transducer incorporates a vibrating wire sensor. It converts mechanical displacement to an electrical frequency output. This frequency output can be read or logged by SME model 2460-P remote digital readout unit or SME model-2500 data acquisition system.

The SME model-2120 vibrating wire displacement transducer is used in geotechnical and structural engineering applications where either it is difficult to take direct mechanical readings due to inaccessibility or online data needs to be logged at a remote location. Some uses are:

- To monitor rock mass or concrete displacement in single or multipoint borehole extensometers.
- To monitor soil displacement in soil extensometers.
- To monitor surface cracks in structures and rock mass (use SME model- 2120 vibrating wire crack/joint meter).
- To monitor two or three axis displacement in joints of mass concrete (for uniaxial displacement use SME model- 2120 vibrating wire joint meter).

Vibrating wire displacement sensors have an advantage over conventional transducers like LVDT as the former gives frequency, rather than a voltage, as output signal. The frequency signal can be transmitted over long distances without any change in value caused by variations in cable resistance which can arise from water penetration, temperature fluctuations, contact resistance or leakage to ground.

This factor, coupled with excellent zero stability and rugged design makes the SME model displacement transducer preferable for long-term measurements in adverse environments.

### 1.1. Type manufactured

SME manufactures vibrating wire displacement sensor in this configuration:

- Model SME-2120: It has M6 threads centrally on both ends of the sensor and so has a cable coming out eccentrically from the back The sensor is suitable for applications upto a water pressure upto 0.4 MPa. It is mostly used in crack meters and biaxial/ triaxial joint meters.

### 1.2. How to use this manual

The users' manual is intended to provide sufficient information for making optimum use of vibrating wire displacement sensor for 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 this manual.

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

A lot of effort has gone in preparing this instruction manual. However the best of instruction manuals cannot provide for each and every condition in the field, which may affect performance of the instrument. 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.

**NOTE:** This sensor is normally used to monitor site conditions and will record any change, even though minor that may affect behavior of the structure being monitored. Some of these factors amongst others, are, seasonal weather changes, temperature, rain, barometric pressure, earthquakes, nearby landslides, 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 containing a specific type of information. The list given below tells you where to look for in this manual if you need some specific information. It is however recommended that you read the manual from the beginning to the end to get a thorough grasp of the subject. You will find a lot of unexpected information in the sections you feel you may skip.

## 2. Vibrating wire displacement sensor

### 2.1. Operating principle

Vibrating wire displacement sensor basically consists of a magnetic, high tensile strength stretched wire, one end of which is anchored and other end fixed to a shaft through a precision coil spring that deflects in some proportion to displacement. Any change in position of shaft, deflects the spring proportionally and this in turn affects tension in the stretched wire. Thus any change in displacement, directly affects tension in the wire and thus frequency of vibration.

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

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

where $\sigma$ = tension of wire in $kg/cm^2$

$g$ = 980 $cm/sec^2$

$\rho$ = density of wire in $kg/cm^3$

$l$ = length of wire in cm

The length of the wire in the displacement sensor is 5.5 cm. Consequently the formula can be reduced to:

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

The resonant frequency, with which the wire vibrates, induces an alternating current in the coil magnet. The displacement is proportional to square of frequency and the readout unit is able to display this directly in engineering units.

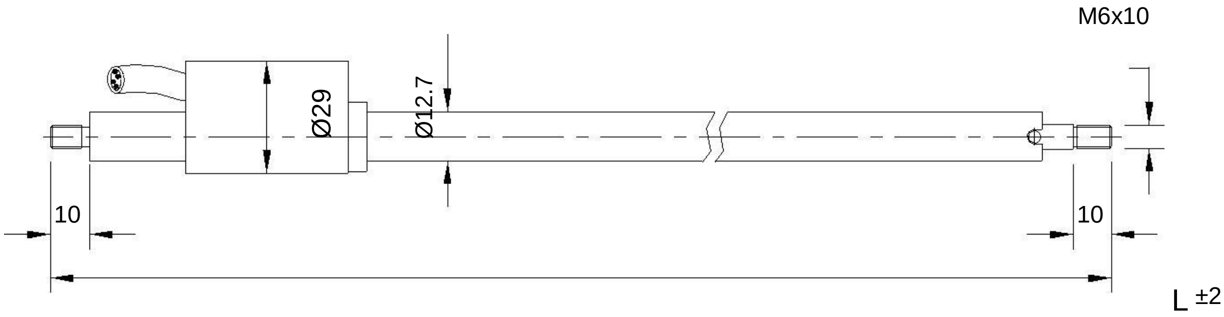
### 2.2. General Description

The sensor body is of stainless steel construction. It has a shaft with M6 x 10 threads at the exposed end. For monitoring displacement in any application, the shaft slides inside the sensor body with respect to the latter. The shaft should never be rotated inside the sensor body as this will damage the transducer.

**CAUTION:** Never rotate shaft inside sensor body as this will damage the transducer. The shaft end is provided with an alignment pin that sits inside an alignment slot on sensor body. Always displace shaft axially while checking or installing sensor.

Each sensor is provided with a thermistor for monitoring temperature. Normally, no correction due to temperature induced frequency changes is required. However, if it is necessary to make these corrections, refer to data on zero shift due to temperature changes provided in test report.

### 2.3. SME model




### 2.4. Wiring

The sensor is provided with an integral 1 m long φ 4 mm four core PVC sheathed cable with cores in red, black (Optional). Red and black cores are for frequency signal while green and white are for temperature monitoring through a thermistor (Optional). In case specially ordered, PU sheathed cable can be provided.

### 2.5. Taking readings with model SMEMODEL-2460-P vibrating wire indicator/logger

Model SMEMODEL-2460-P is a microprocessor based readout unit for use with SME 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.

SMEMODEL-2460-P indicator/logger can store calibration coefficients of up to 500 vibrating wire sensors so that value of measured parameter from these transducers 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 of the 500 programmed transducers in any combination. 4,500 sets of readings can be stored either from any one transducer or 9 sets stored from all 500 transducers. 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 SMEMODEL-2460-P instruction manual for entering the transducer calibration coefficients. The gage factor given in the test certificate and the zero reading in frequency (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 SMEMODEL-2460-P can also display and record the temperature of the transducer directly in degree Centigrade. Any SME 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/logger 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 SMEMODEL-2460-P indicator to charge the internal battery from 230 V AC mains.

The SMEMODEL-2460-P 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.

## 3. Checking of sensor and installation

### 3.1. Checking sensor before installation

The cable from the sensor is two wired 1 m long. Red and black cores are for frequency signal while green and white (Optional) are for temperature monitoring through a thermistor.

Check the working of the sensor as follows:

- The coil resistance measured by the digital millimeter should lie between 120-140 Ohm. Determine resistance at the room temperature from thermistor temperature resistance chart. This resistance should be equal to that between the green and white wires. For example, in case the room temperature is 25$^{o}$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 SME model SME MODEL-2460-P portable readout unit and switch it on. The display will show something like: Freq: 2230.8 Hz where the actual figure will vary depending on the transducer connected to the indicator. This initial reading on the portable readout unit should be stable.
- A crude but a simple and very effective method of checking whether the displacement sensor is responding to changes in displacement is as follows:

  Shift the read-out unit display to the engineering unit mode. Using a scale, extend the displacement sensor by about 5 mm. The reading in the digital readout unit should change by around 5 mm. The change in reading ensures that the deformation produced by the displacement is transmitted to the vibrating wire sensing element.

**CAUTION:** The displacement sensor is a delicate and sensitive instrument. It should be handled with care. Twisting or applying too much force on the shaft with respect to the sensor body may result in a zero shift or even permanent damage. Always displace shaft axially while checking or installing sensor.

The shaft end is provided with an alignment pin that sits inside an alignment slot on sensor body. When not in use or while tightening sensor against a shaft mounting object, keep the pin engaged inside the slot to prevent any damage to the sensor by rotation of sensor against shaft body.

- If the vibrating wire displacement sensor is mounted close to a junction box or a multiplexer, the surge arrestor component can be mounted in the junction box or the multiplexer box itself. SME can provide junction boxes and multiplexers with lightning protection installed as an option (specify while ordering).
- Lightning arrestor boards and enclosures are available from SME, which can be installed at the exit point of the structure being monitored. Consult the factory for additional information on these or alternate lightning protection schemes.

### 3.2. General precautions in cable installation

Unless otherwise specified, each sensor is provided with 1 m cable attached. Cable may be extended without affecting sensor reading or its long term performance. Always ensure a waterproof joint of appropriate strength.

The procedure for laying of cables differs with individual installations. The cable should be routed in such a way so as to minimize the possibility of damage due to moving equipment, debris or other causes. In general:

- Protect cable from damage by angular and sharp particles of material in which it is embedded.
- In earth/rock embankments and backfill, cable must be protected from stretching due to differential compaction of embankment. Cable must also be protected from damage by compaction equipment.

The 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 the cables is generally taken most casually. Care should be taken to put an identification tag at the point where the cable comes out of the structure such that cable identity is not lost if the cable gets cut or damaged. Route the cable properly to the location where readings have to be taken, taking care that it is suitably protected. Gage and lead wires must be protected from mechanical damage and from water.

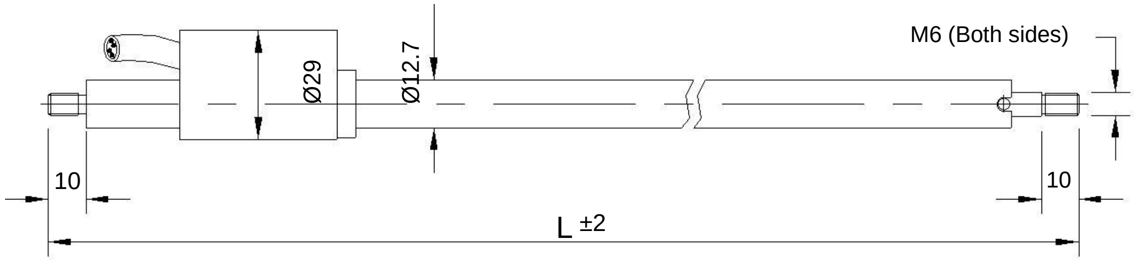
Take care to keep cables as far away as possible from sources of electrical interference such as power lines, welding equipment, motors, generators and transformers etc. To avoid picking up noise, cables should never be buried or run along with AC power lines as this will cause problems in obtaining stable data.

### 3.3. Initial reading

Always carefully record initial displacement reading along with temperature at time of installation to serve as a reference for determining subsequent deformation.

### 3.4. SME model- 2120 vibrating wire crack/joint meter

Displacement sensor for Crack meter




Mounting details for Crack meter

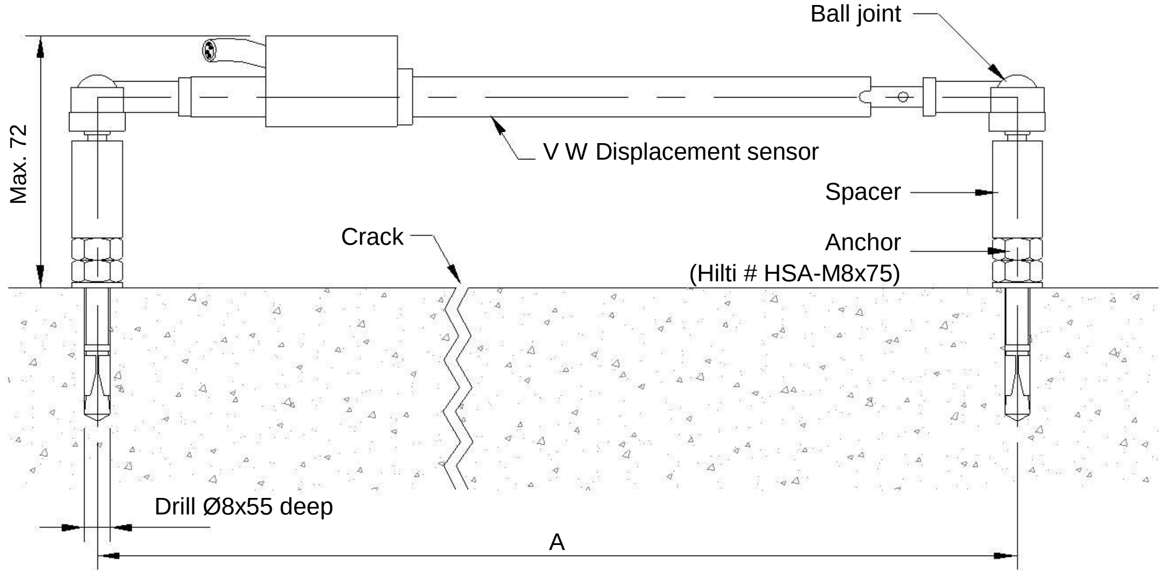



**Figure 4.1** – Crack/joint meter mounting details

| Range mm | L mm | A mm (half open position) |
|---|---|---|
| 15 | 207 | ~ 255 |
| 25 | 222 | ~ 275 |
| 50 | 292 | ~ 357 |

## 4. Thermistor - temperature resistance correlation

**Thermistor type** Dale 1C3001-B3

**Temperature resistance equation**

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

where T = temperature in $^oC$

LnR = Natural log of thermistor resistance

A = $1.4051 \times 10^{-3}$

B = $2.369 \times 10^{-4}$

C = $1.019 \times 10^{-7}$

| 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 |

### 4.1. Measurement of temperature

Thermistor for temperature measurement is incorporated in each displacement 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 Ohm meter. The cable resistance may be subtracted from the Ohm meter reading to get the correct thermistor resistance. However the effect is small and is usually ignored.

The SME model SMEMODEL-2460-P read-out unit gives the temperature from the thermistor reading directly in engineering units.

### 4.2. Temperature correction

Each vibrating wire displacement sensor is relatively insensitive to temperature variations within certain limits and often the effect of temperature can be ignored. However in case a ‘displacement - temperature variation’ correlation is required, correction for the temperature effect on the sensor can be made by making use of the temperature zero shift factor (K) provided in the test certificate and substituting it in the following equation:

$d_{correction}$ = (current temperature - initial temperature) x K

The temperature correction value is subtracted from the displacement reading from the SMEMODEL-2460-P read-out.

## 5. Trouble shooting

The displacement sensor is installed during construction of the structure. 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 to the following list of problems and possible solutions should problems arise. For any additional help, consult the factory.

### 5.1. Symptom: displacement 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 displacement sensor? 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.

### 5.2. Symptom: displacement sensor 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 130 - 180 Ohm. The correct value is given in the test certificate. Please add the cable resistance when checking. 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 displacement sensor? 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.

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