INSTRUCTION MANUAL

VIBRATING WIRE LOAD CELL

Model VH

This product should be installed and operated only by qualified personnel. Its misuse is potentially dangerous. The Company makes no warranty as to the information furnished in this manual and assumes no liability for damages resulting from the installation or use of this product. The information herein is subject to change without notification.

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1 PRODUCT

Load cells are basically used in rock bolting or in tie-back systems, where tensile loads apply. They are also used for pile testing or under the supports of bridges to monitor a compressive load.

The Model VH load cell has been designed primarily to be used under adverse environmental conditions where electrical resistance strain gauge load cells are not favoured. The vibrating wire strain gauge elements in that cell provide the necessary ruggedness, reliability, stability and ease of remote monitoring.

1.1 GENERAL DESCRIPTION

The VH load cells are designed with a hollow center enables the passage of an anchor through the cell.

The VH load cell body is constructed of heat-treated steel and has three to six vibrating wire strain gauges located around the circumference. The load on the cell is sensed by these strain gauges. Several of them are useful to avoid significant distortion under load. They are needed to account for the effects of off-center or eccentric loading. The average strain is an average of all output readings. Lead wires from the coils are brought out and connected to the external cable.

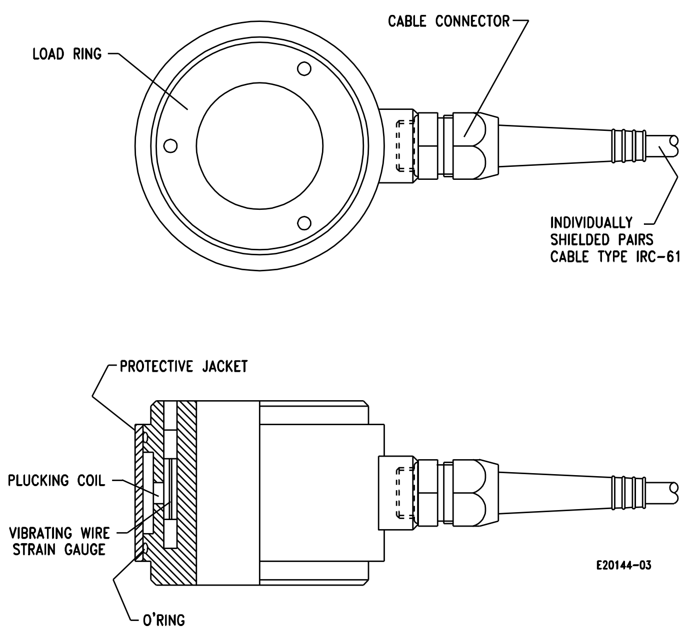

Figure 1: VH Load Cell, model with 3 strain gauges and a hollow center

1.2 OPERATION PRINCIPLE

When the cell is loaded, the load ring and, therefore, the gauges are strained.

The sensing element of a strain gauge is a piano wire, which tension is affected by the tensile or compressive load. The tension is directly proportional to the square of the resonant or natural frequency of the wire.

In operation, plucking voltages are applied to a coil and a magnet located near the wire in a spectrum of frequencies, spanning the natural wire frequency, thus forcing the wire into vibration. The oscillation of the wire generates a voltage in the coil. This signal is amplified by the readout unit, which also discriminates against harmonic frequencies, to determine the resonant frequency of the wire.

The relationship between the period N and the strain ε in the vibrating wire is expressed by the following equation:

$$\varepsilon = K \cdot \frac{10^9}{N^2}$$

where ε = strain in micro-strain

N = vibration period in microseconds

K = gauge constant, specific for each type of gauge

The vibrating wire technology offers the unique advantage of a frequency output signal virtually unaffected by line impedance, or contact resistance.

Cable length of several kilometres can be used without signal deterioration.

Portable units as the MB-3TL are available to read the vibrating wire sensor (excitation, signal conditioning, display of different readings). Contact Roctest for further information.

1.3 CALIBRATION

A calibration data sheet is supplied with each cell. It enables conversion of gross readings into load values.

All the sensors are individually calibrated over their working range before shipment. The calibration factors are established by running the calibration data points through a linear regression formula.

Load cells, due to their design, are inherently sensitive to varying end load conditions. Thus, the output and calibration of a hollow load cell can be affected by various factors as warping of the bearing plates, friction between the bearing plate and the load cell, eccentric loading of load cells, excessive load applied, temperature effects. Note that all of these effects can be cumulative and can vary the sensitivity of the cell by up to ± 20%, unless special care is taken.

Thickness of the distribution plate should be at least 25 mm. This thickness should be more important when load range increases and when surfaces of the load cell and the loading element (hydraulic ram) differ. For better results, it is important to calibrate the load cell in the laboratory under the same loading conditions as will be used in the field.

2 INSTALLATION PROCEDURE

2.1 PRE-INSTALLATION ACCEPTANCE READING

Readings of all gauges for each instrument should be taken as the VH load cells are received to ensure they have not been damaged during shipment or handling on site.

Take the readings in LINEAR units (LU) with the cell completely unloaded. Then compare them with the factory readings shown on the calibration sheet. The differences should not exceed +/-30 LINEAR units.

2.2 LOAD CELL INSTALLATION

Load cells are accurate instruments and should be treated with care. They should under no circumstances be picked up by the cable. Even if the cells have been designed to be watertight and robust, they can be damaged by misuse, particularly with respect to the cable.

Load cells have to be installed with a special care to their installation. From the design arrangements comes the quality of the measurements.

Although model VH load cells have from three to six gauges for averaging the readings, the installation design should minimize the eccentric loading and the misalignment of load, whatever the context of measurement (tie-backs, pile test …)

Therefore, cells have to be set between two very flat, smooth and stiff plates. The wall where the tie-back applies or the top of the pile during a load test should be plane as well. If necessary, make it so with cement or concrete.

If the cells are installed on tie-backs, bushings are often useful to center the hollow cylinder.

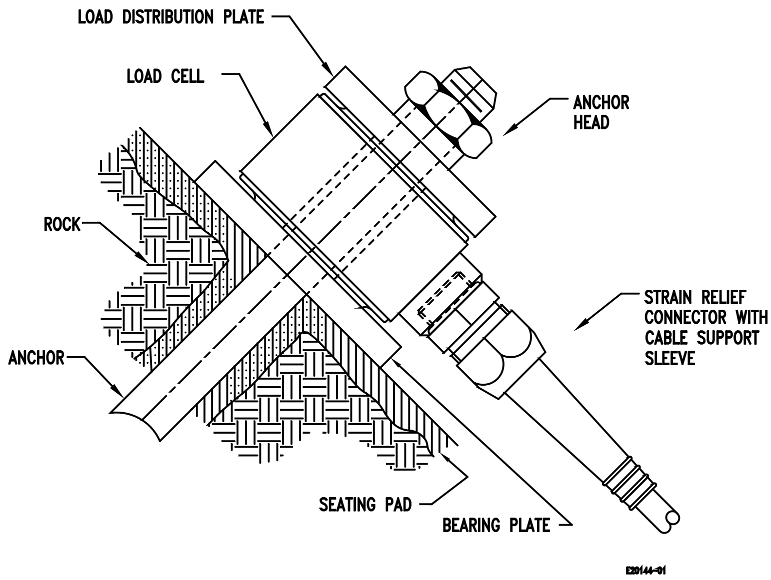

Figure 2: VH typical installation on a tie-back

2.3 CABLE INSTALLATION

2.3.1 CABLE IDENTIFICATION

The electrical signal coming from the sensor is transmitted through an electrical cable. This cable is generally supplied in rolls.

Cables are identified with the serial number that is labelled on the sensor housing. The serial number is stamped on a tag that is fastened to the readout end of the cable.

In the case where the sensor cable has to be cut or if the cable end is inaccessible, make sure to be able to identify it (by marking its serial number for instance with an indelible marker or using a color code). It is very important to clearly identify the instrument for reading or wiring purposes.

2.3.2 CABLE ROUTING

Some of the more important considerations that must be given to cable runs are:

- Avoid traversing transition zones where large differential settlements could create excessive strain in the cable.
- Avoid cable splices. If necessary, refer to the special paragraph below.
- Do not lay cables one on top of the other.

- Use horizontal snaking or vertical snaking of the cable within the trenches. For most materials, a pitch of 2 m with amplitude of 0.4 m is suitable. In very wet clays increase the pitch to 1 m.
- Use a combination of horizontal and vertical snaking at transition zones.

Once a cell is installed, route its cable towards the junction or switching panel. Make sure that the cable is protected from cuts or abrasion, potential damage caused by angular material, compacting equipment or stretching due to subsequent deformations during construction or fill placement.

If necessary, run the cable through rigid or flexible conduit to the terminal location. To provide protection for cable running over concrete lifts, hand placed concrete is sometimes used, depending on site conditions.

Check that the cable does not cross over itself or other cables in the same area.

Surface installations require continuous surveillance and protection from the earth moving equipment circulating on the field.

During the cable routing, read the instruments at regular intervals to ensure continued proper functioning.

Record the cable routing with care and transfer this routing to the drawings.

2.4 SPLICES

Generally, cable splices are to be avoided. If necessary, use only the manufacturer's approved standard or high-pressure splice kit. Splicing instructions are included with the splice kit.

Should the cable be cut, we recommend the use of our high pressure cable splice kits, especially if the splice is located underwater.

Because of the vibrating wire technology the sensor uses, the output signal is a frequency, not affected by the impedance of the cable. Therefore, splices have no effect on the quality of the readings.

Furthermore, in special cases on site (large distance between sensors and readout position for example), splices are useful to limit the number of cables to lay. Individual sensor cables can be merged into a multi-conductor cable using a splice or a junction box.

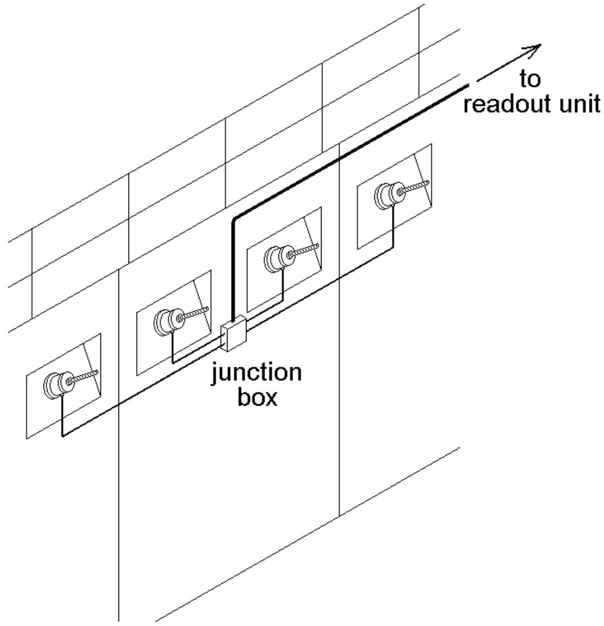

Figure 3: Example of junction box use

Please contact Roctest for additional information about junction boxes and splice kits.

2.5 CABLE WIRING

Before cutting a cable, make sure of its identification. Strip back the conductor insulation by about 1cm. If possible, tin the exposed conductors with a solder.

2.6 LIGHTNING PROTECTION

At all times during the installation, any cable that is exposed to potential damage by lightning must be protected.

A large grounded metal cage placed over the cable bundle, combined with direct grounding of all leads and shields is an effective way to prevent lightning damage to the instruments and cables during the installation process.

Please contact Roctest for additional information on protecting instruments, junction boxes and data logging systems against power surges, transients and electromagnetic pulses.

All junction boxes and data logging systems furnished by Roctest are available with lightning protection.

3 READING PROCEDURE

3.1 GENERALITIES

Readings can be taken manually with a portable readout unit model MB-3TL or automatically when connected to a SENSLOG data acquisition system.

When a 3kΩ thermistor (temperature sensor) is provided in the load cell, temperature can then be read using a MB-3TL, a SENSLOG data acquisition system or an ohmmeter as well.

Manual readings can be taken either directly on the cable end or through a switching panel using a readout unit.

To facilitate reading a cluster of gauges, the lead wires from each individual gauge can be connected to a switching panel. The wiring instructions for connecting the gauges to the wiring block with the junction box are included in the junction/switchbox manual.

3.2 TAKING MEASUREMENTS

The readout unit MB-3TL with the four-pin, male, panel-mounted electrical connector is supplied with one multi-core cable fitted with a mating female connector at one end and a set of four color coded alligator clips at the other. The conductor's insulation is color coded to match that of the alligator clips and the instrument cable conductors' insulation jacket.

Connect the alligator clips to the gauge lead wire according to the table below for the standard load cell with three gauges using our standard IRC-82A cable.

Gauge 1	Gauge 2	Gage 3	Thermistor
Red	Blue	Yellow	White
Black	Brown	Orange	Green

Table 1: Wiring code for electrical cables IRC-82A with 3 gauges

The color code corresponding to the gauges depends of course on the number of gauges incorporated in the cell. Please refer to the calibration sheet for that information.

Vibrating wire gauges and thermistors are not usually affected by polarity changes (High and Low reversal). However, if problems occur during gauge readings, check the polarity.

Switch on the MB-3TL and press Enter. At the Type prompt, choose the appropriate frequency and temperature settings. Press Change to display a different combination. Press Enter to select the option that is displayed.

Select Type: *'Hz^2 + Thermistor'* = Displays values in Hz^2/1000 and Celsius degrees for 3K thermistor.

The MB-3TL displays readings converted into linear unit (LU) (or $Hz^2/1000$).

Note: If you use a model VH load cell that was built prior to February 1st 2005, select Type:
VWSG: uStrain + THRM for spotweld SM-2

Choose frequency sweep B or C.

Record these numbers as they appear on the display.

Please consult the MB-3TL instruction manual for more details.

The jumper cables should never be short-circuited when they are connected to the readout unit front panel.

3.3 QUICK VERIFICATION OF MEASUREMENTS

On site, even before converting raw readings into engineer values, several checks can be done to prevent a bad measurement.

- Compare readings to previous ones. Are they in the same range? Are they moving slowly of abruptly? Consider external factors that can affect the measurements like construction activities, excavations or fills…
- In any case, it is advised to take several readings to confirm the measurement. Then, repeatability can be appreciated and dummy readings erased.

3.4 LOAD VALUE (DATA REDUCTION)

The basic units utilized for measurement and reduction of data of the vibrating wire load cells are the "linear unit" or identified LU on the calibration data sheet. Calculation of linear unit (LU) versus the wire frequency (F) is based on the following equation:

$$LU = F^2/1000$$

For the load measurement, the calculation principle is to average all readings of the strain gauges in LINEAR units and then apply the calibration factors.

To convert the linear unit to load, the gauge readings for each cell must be averaged. For better accuracy a polynomial regression is done through all data, and then following equation must be applied.

$$Y = (Ax^2 + Bx + C) - CT\ (T_1 - T_0)$$

for a cell fitted with 3 gauges

$$x = \left[\frac{(L_1) + (L_2) + (L_3)}{3}\right]$$

Where

- Y: Applied load in kN
- x: Average reading in linear unit
- L_n: Current linear reading for gauge n with load applied

- A,B,C: Calibration factors
- T_0: Initial temperature at installation in degree Celsius
- T_1: Current temperature in degree Celsius
- CT: Thermal coefficient in kN/°C

Note that decreasing readings in LINEAR units indicate increasing load.

As temperature goes up, for an unconfined load cell inside an environmental chamber, readings in kN will go down. A thermal coefficient (CT) is provided to compensate the cell for temperature variations. In all situations, it is advised to protect the cell from direct sunlight and wait for the temperature to stabilize before taking readings and attempting any correction for temperature.

Also be aware that it is impossible to say what the real effect of temperature will be on a load cell installed on a tensioned rebar or a stretched cable. It depends on the length of the bar or cable and the properties of the surrounding soil. The real effect of temperature can only be obtained empirically by simultaneous measurements of load and temperature over a short period of time.

4 TROUBLESHOOTING

Maintenance and troubleshooting of vibrating wire transducers are required. Periodically check cable connections and terminals. The transducers themselves are sealed and cannot be opened for inspection.

4.1 UNSTABLE READING

- Check if the same troubles occur with the other gauges of the same cell. If so, check the integrity of the cable.

- Check if the same troubles occur with other instruments. If so, compare cable routes or check the readout unit.

- Is the shield drain wire correctly connected to the readout unit?

- Isolate the readout unit from the ground by placing it on a piece of wood or similar non-conductive material.

- Check the battery of the readout unit.

- Check for nearby sources of electrical noise such as motors, generators, electrical cables or antennas. If noise sources are nearby, shield the cable of move it.

- If a data logger is used to take the readings, are the swept frequency excitation settings well adjusted?

- The sensor may have gone outside its range. See previous records.

- The sensor body may be shorted to the shield. Check the resistance between the shield drain and the sensor housing.

- Check the integrity of the cable.

- The sensor may have been damaged by shocks.

4.2 NO READING

- Check the battery of the readout unit.

- Check if the same troubles occur with the other gauges of the same cell. If so, check the integrity of the cable.

- Check if the same troubles occur with other instruments. If so, the readout unit may be suspected and the factory should be consulted.

- If a data logger is used to take the readings, are the swept frequency excitation settings well adjusted?

- The sensor may have gone outside its range. See previous records.

- Check the coil resistance. Nominal coil resistance is 90Ω ± 10Ω, plus cable resistance (22 gauge copper = approximately 0.07Ω/m).

  - If the resistance is high or infinite, a cut cable must be suspected.

- If the resistance is low or near zero, a short must be suspected.
- If resistances are within the nominal range and no reading is obtained, the transducer is suspect and the factory should be consulted.

- Cuts or shorts are located, the cable may be spliced in accordance with recommended procedures.

- The sensor may have been damaged by shocks or water may have penetrated inside its body. There is no remedial action.

4.3 THE CASE WHERE ONLY ONE SENSOR FAIL

A load cell fitted with several strain gauges has two advantages:

- it allows to minimize the eccentricity of the load by an average on readings
- if one or several gauges failed to read the strain, there still may be one or several gauges alive to allow continuing the measurements.

In the case where one or several gauges fail to give valid readings, average reading in LINEAR units can be done with the remaining strain gauges without significant lost of accuracy, provided installation of the cell is adequate and load is uniformly distributed through the cell.

Or you can contact also Roctest and we can provide a new calibration data sheets and calibration factors based only on the data of the strain gauges that are still in operation.

5 MISCELLANEOUS

5.1 ENVIRONMENTAL FACTORS

Since the purpose of the load cells installation is to monitor site conditions, factors which may affect these conditions should always be observed and recorded. Seemingly minor effects may have a real influence on the behaviour of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to: blasting, rainfall, tidal levels, excavation and fill levels and sequences, traffic, temperature and barometric changes, changes in personnel, nearby construction activities, seasonal changes, etc.

5.2 CONVERSION FACTORS

	To Convert From	To	Multiply By
LENGTH	Microns Millimetres Meters	Inches Inches Feet	3.94E-05 0.0394 3.2808
AREA	Square millimetres Square meters	Square inches Square feet	0.0016 10.7643
VOLUME	Cubic centimetres Cubic meters Litres Litres	Cubic inches Cubic feet U.S. gallon Can–Br gallon	0.06101 35.3357 0.26420 0.21997
MASS	Kilograms Kilograms Kilograms	Pounds Short tons Long tons	2.20459 0.00110 0.00098
FORCE	Newtons Newtons Newtons	Pounds-force Kilograms-force Kips	0.22482 0.10197 0.00023
PRESSURE AND STRESS	Kilopascals Bars Inches head of water* Inches head of Hg Pascal Kilopascals Kilopascals Kilopascals	Psi Psi Psi Psi Newton / square meter Atmospheres Bars Meters head of water*	0.14503 14.4928 0.03606 0.49116 1 0.00987 0.01 0.10199
TEMPERATURE	Temp. in °F = (1.8 x Temp. in °C) + 32 Temp. in °C = (Temp. in °F – 32) / 1.8		

* at 4 °C

E6TabConv-990505

Table 2: Conversion factors

5.3 EXAMPLE OF CALIBRATION SHEET

EXAMPLE OF CALIBRATION SHEET (page 1 / 2)

ROCTEST

CALIBRATION DATA SHEET
VIBRATING WIRE LOAD CELL

Model:	VH-500
Serial number:	14402000057
Capacity:	500 kN
Temperature:	23 °C
Cable model:	CA-IRC82A
Cable length:	15 m

Color code:	Gage 1	Gage 2	Gage 3	Thermistor
	Red	Blue	Yellow	White
	Black	Brown	Orange	Green

Calibration data:

First pass				Second pass			
Load	Gage 1	Gage 2	Gage 3	Load	Gage 1	Gage 2	Gage 3
kN	LU	LU	LU	kN	LU	LU	LU
0.1	6678.0	6590.7	6704.4	0.0	6677.0	6589.4	6703.6
51.5	6389.8	6443.0	6579.2	50.9	6395.1	6441.5	6584.8
100.8	6129.5	6286.0	6435.6	100.7	6127.0	6282.7	6442.2
152.0	5855.2	6115.3	6282.6	150.3	5865.5	6118.2	6293.1
200.1	5596.2	5950.5	6144.0	200.7	5596.5	5946.3	6141.7
252.1	5315.8	5767.6	5987.9	249.4	5337.1	5777.2	5994.9
300.2	5068.1	5600.3	5833.0	299.9	5075.7	5599.4	5833.0
350.1	4844.7	5419.1	5644.1	350.8	4847.3	5415.3	5640.6
400.5	4627.2	5236.3	5445.2	400.0	4634.9	5235.9	5445.5
450.7	4414.5	5052.0	5240.6	449.9	4423.2	5052.3	5241.4
499.8	4206.4	4872.1	5042.8	500.0	4211.6	4869.8	5038.0

Initial reading before shipment				
Load	Gage 1	Gage 2	Gage 3	Temp
kN	LU	LU	LU	°C
0.0	6681.0	6595.0	6707.0	26.4

Traceability no: TR-12-07
Certificate no: 14402000057_500kN.xlsx Page: 1 of 2

Calibrated by: F Martel Date: 2020/12/16

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EXAMPLE OF CALIBRATION SHEET (page 2 / 2)

CALIBRATION DATA SHEET
VIBRATING WIRE LOAD CELL

Model: VH-500
Serial number: 14402000057
Capacity: 500 kN
Temperature: 23 °C
Cable model: CA-IRC82A
Cable length: 15 m
Color code:

Gage 1	Gage 2	Gage 3	Thermistor
Red	Blue	Yellow	White
Black	Brown	Orange	Green

Calibration data:

Average Load kN	Average Gages LU	Regression Load kN	Regression Error % F.S.
51.2	6472.2	51.7	-0.11
100.8	6283.8	100.4	0.06
151.1	6088.3	150.8	0.07
200.4	5895.9	200.0	0.08
250.8	5696.8	250.8	-0.01
300.0	5501.6	300.3	-0.05
350.5	5301.8	350.7	-0.05
400.2	5104.2	400.4	-0.03
450.3	4904.0	450.4	-0.04
499.9	4706.8	499.5	0.07

Calibration factors:

A	B	C
-3.0901E-06	-2.1908E-01	1.5991E+03

Thermal coefficient C.T.: -0.25123 ***kN/°C***

Load is calculated with the following equation:

$$Y = (Ax^2 + Bx + C) - CT\,(T_1 - T_0) \qquad x = \left[\frac{(L_1) + (L_2) + (L_3)}{3}\right]$$

Y: Applied load in kN
x: Average reading in linear unit
L_n: Current linear reading for gage n with load applied
L.U.: Linear units, gage factor K=1.000
A,B,C: Calibration factors
T_0: Initial temperature at installation in degree Celsius
T_1: Current temperature in degree Celsius
CT: Thermal coefficient

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