INSTRUCTION MANUAL

VIBRATING WIRE LOAD CELL

Model VH

Tel.: 1.450.465.1113 • 1.877.ROCTEST (Canada, USA) • 33 (1) 64.06.40.80 (Europe) • www.roctest.com • www.telemac.fr

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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 gage load cells are not favoured. The vibrating wire strain gage elements in that cell provide the necessary ruggedness, reliability, stability and ease of remote monitoring.

1.1 GENERAL DESCRIPTION

The VH load cells are available in two configurations. To monitor a tensile load, a hollow center cell enables the passage of an anchor through the cell. To monitor a compressive load, a solid center cell is used.

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

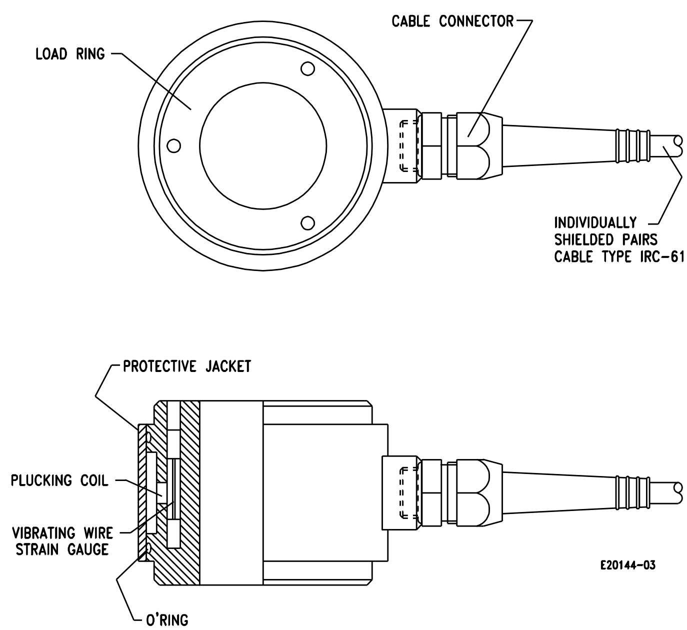

Figure 1: VH Load Cell, model with 3 strain gages and a center hole

1.2 OPERATION PRINCIPLE

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

The sensing element of a strain gage 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 = gage constant, specific for each type of gage

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.

Note: If a temperature correction has to be applied for specific applications, a special calibration can be done in factory for each cell. Please refer to the temperature correction paragraph for more details.

2 INSTALLATION PROCEDURE

2.1 PRE-INSTALLATION ACCEPTANCE READING

Readings of all gages 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 with the cell completely unloaded. Then compare them with the factory readings shown on the calibration sheet. The differences should not exceed 20 LINEAR units.

2.2 INITIAL READING

Before installing the cell, it is necessary to take an initial reading to correctly convert measurements in LINEAR units into load when the load cell is in operation.

Read each strain gage of the cell in LINEAR units. Those readings are called L_{10}, L_{20}, L_{30}, if the cell is fitted with 3 strain gages.

This initial reading process can be done efficiently during the cell acceptance test described before. However, measurements have to be the most accurate as possible because all subsequent readings are referenced to them. Therefore, it is advisable to take each reading several times to check the repeatability of each gage.

For details about how to take readings or how to convert frequency into LINEAR units, please refer to next chapter (Reading procedure).

2.3 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 gages 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 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.

Please refer to last section at the end of this manual for more information about the potential effects of the installation over the readings.

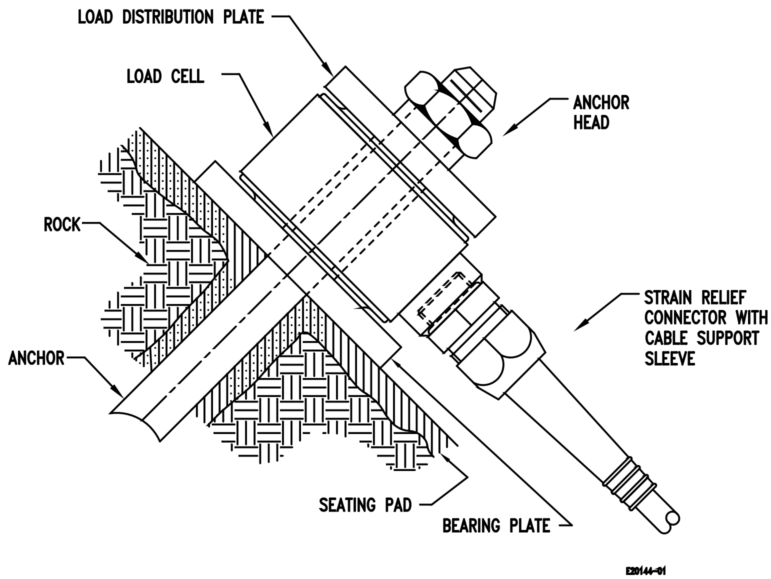

Figure 2: VH typical installation on a tie-back

2.4 CABLE INSTALLATION

2.4.1 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.

2.4.2 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.

2.5 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, 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.

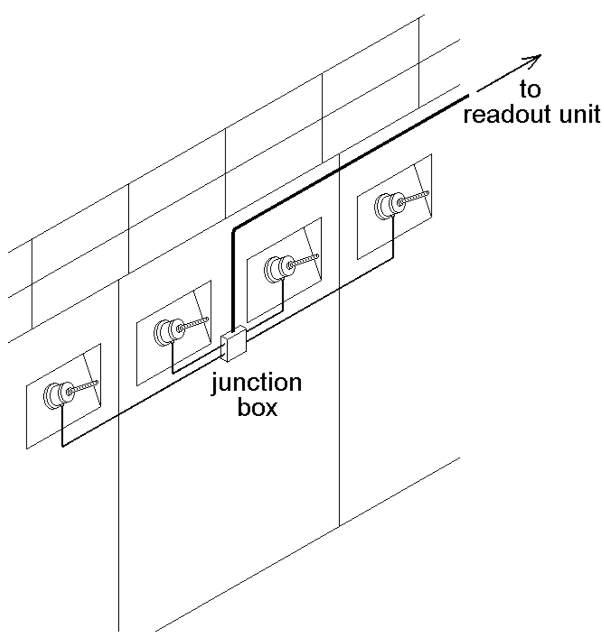

Figure 3: Example of junction box use

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

2.6 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.

2.7 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-3T(L), 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 gages, the lead wires from each individual gage can be connected to a switching panel. The wiring instructions for connecting the gages 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 gage lead wire according to the table below.

	Connections				
Cable	Wire High	Wire Low	Temp. High	Temp. Low / Shield	
IRC-41A(P)	red	black	white	green	shield

Table 1: Wiring code for electrical cables

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

Vibrating wire gages and thermistors are not usually affected by polarity changes (High and Low reversal). However, if problems occur during gage 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 L (Linear Units 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

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

The following equations applies using LINEAR units displayed by the MB-3TL :

- for a cell fitted with 3 gages:

$$Y = C_f \cdot \left[\frac{(L_1 - L_{10}) + (L_2 - L_{20}) + (L_3 - L_{30})}{3} \right]$$

- for a cell fitted with 6 gages:

$$Y = C_f \cdot \left[\frac{(L_1 - L_{10}) + (L_2 - L_{20}) + (L_3 - L_{30}) + (L_4 - L_{40}) + (L_5 - L_{50}) + (L_6 - L_{60})}{6} \right]$$

where Y = applied load in kilo-Newton
L_n = reading in LINEAR units (LU) of gage n
L_{n0} = initial reading in LINEAR units (LU) of gage n
C_f = calibration factor (see calibration sheet), in kN/LU

Example with a cell fitted with 3 gages:

Initial reading : L_{10} = 2 901.0 LU
L_{20} = 2 782.9 LU
L_{30} = 2 857.8 LU
Actual reading : L_1 = 2 695.9 LU
L_2 = 2 585.6 LU
L_3 = 2 647.4 LU

With C_f = -0.46186 kN/LU,

We get:

$$Y = -0.46186 \times \left[\frac{(2695.9 - 2901.0) + (2585.6 - 2782.9) + (2647.4 - 2857.8)}{3} \right] = 94.3 \text{ kN}$$

Note that decreasing readings in LINEAR units indicate increasing load.

If the frequency is measured, convert it into LINEAR units using the following equation:

$$L = K \frac{F^2}{1000}$$

where L = reading in LINEAR units
K = gage constant for VH load cell = 1.0000
F = frequency in Hz

Example:
With F = 1 739 Hz,

We get: $L = 1.0 \times \frac{1739^2}{1000} =$ 3 024.1 LU

Note: The above is correct only for VH load cells that were built after to February 1st 2005.

3.5 TEMPERATURE CORRECTION

Material used in the vibrating wire sensors are specially chosen to minimize the temperature effects on the measurements. The thermal coefficient of expansion of the sensor body is very close to the wire’s one, so that most of temperature effects are self-compensated.

As temperature goes up, readings in kN will go up by approximately 0.03% full scale per °C. If maximum accuracy is desired or if huge temperature variations are suspected, correction factors specific to each cell can be determined on demand at our factory.

To apply a temperature correction, use the following relation:

$$Y_T = C_T\left(T - T_0\right)$$

where Y_T = load increment due to temperature variations, in kilo-Newton

C_T = calibration factor for temperature, in kN/°C

T = current temperature reading, in Celsius degrees

T_0 = initial temperature reading, in Celsius degrees

Then the corrected load is get with the relation:

$$Y_c = Y - Y_T$$

where Y_c = corrected load, in kN

Y = load read, in kN

Y_T = load increment due to temperature effects, in kN

Example:

If temperature increases by 5°C and that range of the cell is 1000 kN, load read *Y* should be reduced by $Y_T = C_T\,(T - T_0)$ i.e. 0.03% full scale per °C x 1000 KN (15°C -10°C) i.e. 1.5 KN

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.

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 gages 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 gages 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 gage 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 FAILS

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

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

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

For example, if a VH load cell is fitted with 6 gages and one of them fails (number 2 for instance), use the following relation to reach the load value anyway:

$$Y = C_f \cdot \left[\frac{(L_1 - L_{10}) + (L_3 - L_{30}) + (L_4 - L_{40}) + (L_5 - L_{50}) + (L_6 - L_{60})}{5} \right]$$

where Y = applied load in kilo-Newton

L_n = reading in LINEAR units (LU) of gage n

L_{n0} = initial reading in LINEAR units (LU) of gage n

C_f = calibration factor (see calibration sheet), in kN/LU

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

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Table 2: Conversion factors

5.3 EXAMPLE OF CALIBRATION SHEET

EXAMPLE OF CALIBRATION SHEET (page 1 / 2)

ROCTEST TELEMAC

CALIBRATION DATA SHEET

VIBRATING WIRE LOAD CELL

Model: VH-500
Serial number: 1440457
Capacity: 500 kN
Temperature: 21 °C
Cable model: IRC-61
Cable length: 3 m.

Color code:

	Gage 1	Gage 2	Gage 3
	Red	White	Green
	Black	Black	Black

Calibration data:

First pass				Second pass			
Load kN	Gage 1 LU	Gage 2 LU	Gage 3 LU	Load kN	Gage 1 LU	Gage 2 LU	Gage 3 LU
-0,1	2879,5	2867,5	2764,9	0,0	2878,6	2866,2	2763,6
48,8	2781,2	2763,4	2668,8	50,1	2780,9	2761,9	2663,3
99,5	2672,9	2649,5	2567,4	101,1	2672,0	2647,8	2561,2
150,3	2560,9	2535,1	2464,4	150,0	2563,0	2536,3	2462,3
199,8	2448,7	2423,3	2364,1	200,7	2449,4	2422,8	2358,8
250,3	2332,0	2309,1	2261,3	249,2	2337,9	2314,1	2262,5
300,7	2218,7	2196,1	2158,5	300,4	2219,0	2196,6	2155,6
349,2	2105,2	2084,9	2059,1	351,9	2102,4	2081,2	2051,1
398,4	1990,0	1972,3	1959,4	400,0	1990,0	1970,8	1952,9
450,5	1869,8	1853,5	1852,8	449,7	1873,8	1857,9	1851,2
499,9	1755,3	1741,1	1751,6	500,8	1755,9	1741,3	1747,1

Traceability no: TR-03-07
Certificate no: 1440457-60.xls Page: 1 of 2

Calibrated by: Bruno Lessard Date: 04/11/05

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EXAMPLE OF CALIBRATION SHEET (page 2 / 2)

ROCTEST TELEMAC

CALIBRATION DATA SHEET
VIBRATING WIRE LOAD CELL

Model: VH-500
Serial number: 1440457
Capacity: 500 kN
Temperature: 21 °C
Cable model: IRC-61
Cable length: 3 m.

Color code:

Gage 1	Gage 2	Gage 3
Red	White	Green
Black	Black	Black

Calibration data:

Average		Linear Regression	
Load kN	Gages LU	Load kN	Error % F.S.
49,4	2736,6	51,2	-0,35
100,3	2628,5	100,4	-0,02
150,2	2520,3	149,7	0,09
200,3	2411,2	199,4	0,17
249,7	2302,8	248,8	0,19
300,5	2190,8	299,9	0,13
350,5	2080,7	350,0	0,10
399,2	1972,6	399,3	-0,02
450,1	1859,8	450,6	-0,11
500,3	1748,7	501,2	-0,19

Calibration factor C.F.: -0,45559 kN/LU

Load is calculated with the following equation:

$$Y = C.F.\left[\frac{(L_1 - L_{10}) + (L_2 - L_{20}) + (L_3 - L_{30})}{3}\right]$$

Y: Applied load in kN
L_{n0}: Initial linear reading at installation for gage n with no load applied
L_n: Current linear reading for gage n with load applied

Traceability no: TR-03-07
Certificate no: 1440457-60.xls Page: 2 of 2

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5.4 POTENTIAL EFFECTS OF INSTALLATION OVER READINGS

Hollow-center load cells are susceptible to varying conditions of end loading. Eccentric loading, warping of the distribution plate, and friction between the distribution plate and the load cell can significantly affect readings. Special precautions must be taken to minimize these effects.

The fact that the load cell is fitted with at least three sensors at its periphery reduces the effect of eccentric loading. However, the user must employ every means to reduce eccentric loading. Spherical distribution plates can be used.

Furthermore, cells have to be set between two flat and stiff plates. 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. Also, the user may consider asking for a doing a calibration using the same distribution and bearing plates he intends to use in the field. Please contact Roctest for more information about distribution plates and calibration.

Finally, different friction conditions between the distribution plate and the cell will also affect readings. We suggest using flat, smooth, non-lubricated, plates in the field as we do during calibration. Friction losses within the hydraulic jack can also affect readings.