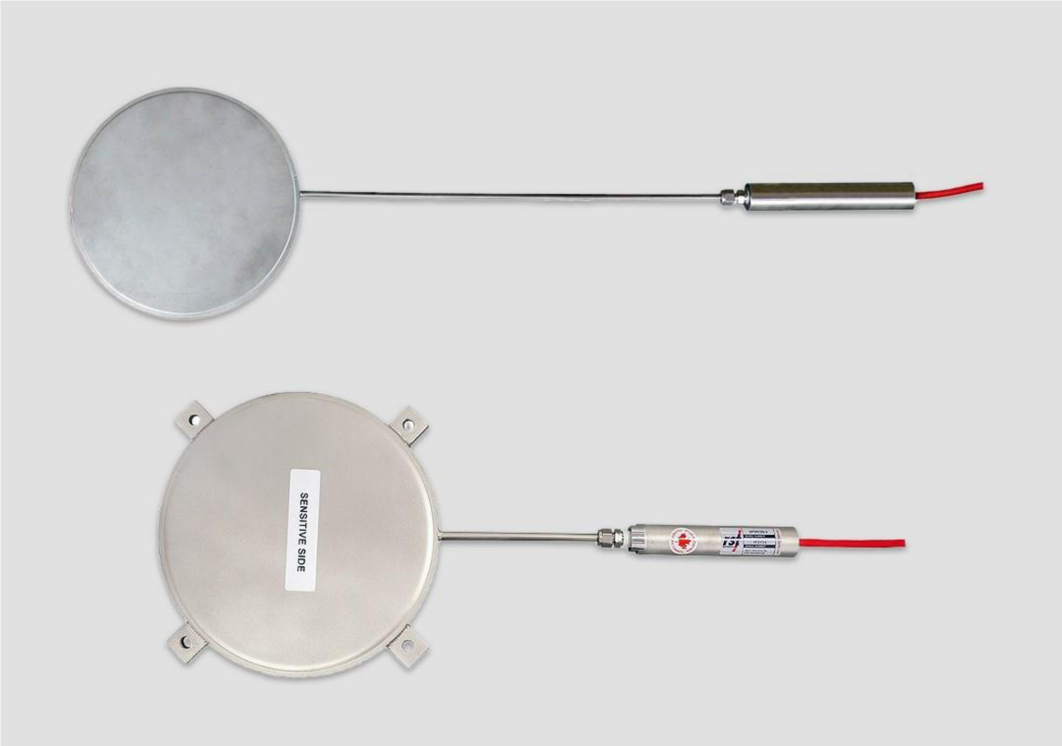

Total Earth Pressure Cell Installation and User Manual

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REVISION HISTORY

Rev.	Revision History	Date	Prepared By	Approved By
B		November 21, 2016		
C	Manual rewrite	March 18, 2024	SM	CA, JP

1 INTENDED AUDIENCE

This guide is for the personnel responsible for installing or using RST's Total Earth Pressure Cell. This manual provides steps for installing the Total Earth Pressure Cell, how to take readings and interpret them.

2 ICONS AND CONVENTIONS USED IN THIS GUIDE

This guide uses the following icons to call attention to important information.

🛑	**WARNING:** This icon appears when an operating procedure or practice, if not correctly followed, could result in personal injury or loss of life.
⚠	**CAUTION**: This icon appears when an operating procedure or practice, if not strictly observed, could result in damage to or destruction of equipment.
→|	**NOTE**: This icon appears to highlight specific non-safety related information.

3 ABBREVIATIONS AND ACRONYMS

Abbreviation or acronym	Definition
TEPC	Total Earth Pressure Cell
VW	Vibrating Wire
SG	Strain Gauge
SS	Stainless Steel
MPa	Megapascal
kPa	Kilopascal
mbar	millibar
Hz	Hertz
in.	Inch
mm	millimeter
ft.	Feet
mA	milliampere
psi	Pounds per square inch
F.S.	Full Scale

4 SAFETY

WARNING: Always follow safety precautions and use proper personal protective equipment (PPE) including safety glasses and high-visibility clothing when working in the field with this equipment.

It is important to obtain the correct permissions to access the installation location.

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5 OVERVIEW

5.1 THEORY OF OPERATION

RST's Total Earth Pressure Cells are designed to measure total pressure (i.e. combined effect of effective soil pressure and pore water pressure).

NOTE: To measure effective soil pressure only, the following method is used:

1. Measure pore water pressure with a piezometer at the same elevation.

2. Calculate soil pressure using Terzaghi's principle of effective stress:

$\sigma ' = \sigma - \mu$

Where:

$\sigma '$ = effective soil pressure

σ = total pressure

μ = pore water pressure

The pressure cells are of the hydraulic variety—two circular stainless-steel plates are welded together around their periphery and the gap between the plates is filled with the hydraulic fluid, deaired glycol. The cell is connected via a stainless-steel stem to a transducer, forming a closed hydraulic system.
The soil pressure acts to push the plates together, building pressure in the fluid contained between them. The fluid pressure is then converted to a signal by the transducer unit, which can be remotely read on readout units or data loggers.

Fundamental conformance issues arise due to the differences in the Elastic Modulus of the cell and the surrounding fill, which alters the stress fields in the fill. However, having a large diameter to thickness ratio minimizes this effect. RST's Total Earth Pressure Cells have an ideal 20:1 thickness to width ratio, which minimizes the effects of stress distribution on the mean plane.

NOTE: RST recommends using enough cell locations to obtain soil pressure readings that are representative of the area being surveyed.

There is inherent variability in soil properties across an area of soil, causing varying soil pressures at different places in the soil. Using limited cell locations will hence not provide a good sample of the mean pressure.

5.1.1 Vibrating Wire Pressure Transducer Principle

VW Pressure Transducer converts total pressure to a frequency signal via a patented* arrangement of a diaphragm, a tensioned steel wire, and an electromagnetic coil. The pressure transducer is designed so that a change in pressure on the diaphragm causes a change in the tension of the wire. An electromagnetic coil is used to excite the wire, which then vibrates at its natural frequency. The vibration of the wire in the proximity of the coil generates a frequency signal that is transmitted to the readout device. The readout or data logger stores the reading in Hz. Calibration factors are then applied to the reading to arrive at a pressure in engineering units.

5.1.2 Strain Gauge Pressure Transducer Principle

Pressure transducers utilize strain gauges to measure the force operating on them. The strain gauges withstand deformation, and this deformation produces a variation in voltage generated by it. The pressure measurement is based on the degree of variation detected in the voltage.

5.2 TOTAL EARTH PRESSURE CELL DESIGN

The Total Earth Pressure Cells are constructed from two circular stainless-steel plates welded together around their periphery, leaving a small gap between them that is filled with the hydraulic fluid (deaired glycol). The annular gap is connected via a stainless-steel stem (length varies according to customer specifications) to a transducer where the fluid pressure is converted to a signal that is transmitted through an instrument cable to the readout unit. The instrument cable is comprised of four separately insulated pairs of cable.

Depending upon the output, the pressure transducer can be either strain gauge type (model LPTPC-S) or vibrating wire type (model LPTPC-V).

Different signal outputs are available:

- 4-20 mA (most common), RS-485, and 0-5 V for strain gauge sensors.
- 1200 – 3550 Hz for vibrating wire sensors.

The type of sensor used depends upon the application of the cell and the customer requirements, which will vary between projects.

Vibrating wire sensors are usually specific to the geotechnical industry, while the strain gauge sensor is more widely used in industrial applications.

For example, a bridge monitoring project might use strain gauge sensors in other areas, so would benefit from utilizing strain gauge pressure cells as well. Whereas a hydroelectric dam using vibrating wire piezometers could benefit from vibrating wire pressure cells.

The vibrating wire model has a standard thermistor included inside the transducer for temperature measurement at the cell location. The thermistor for the strain gauge model is optional and can be ordered separately.

The thinner, sensitive side of the pressure cell is positioned flush with the structure’s surface and reacts to soil pressure. Whereas the thicker side bears against the external surface of the structure. The optional mounting ears are used to secure and drill the cell onto a concrete structure if being used vertically.

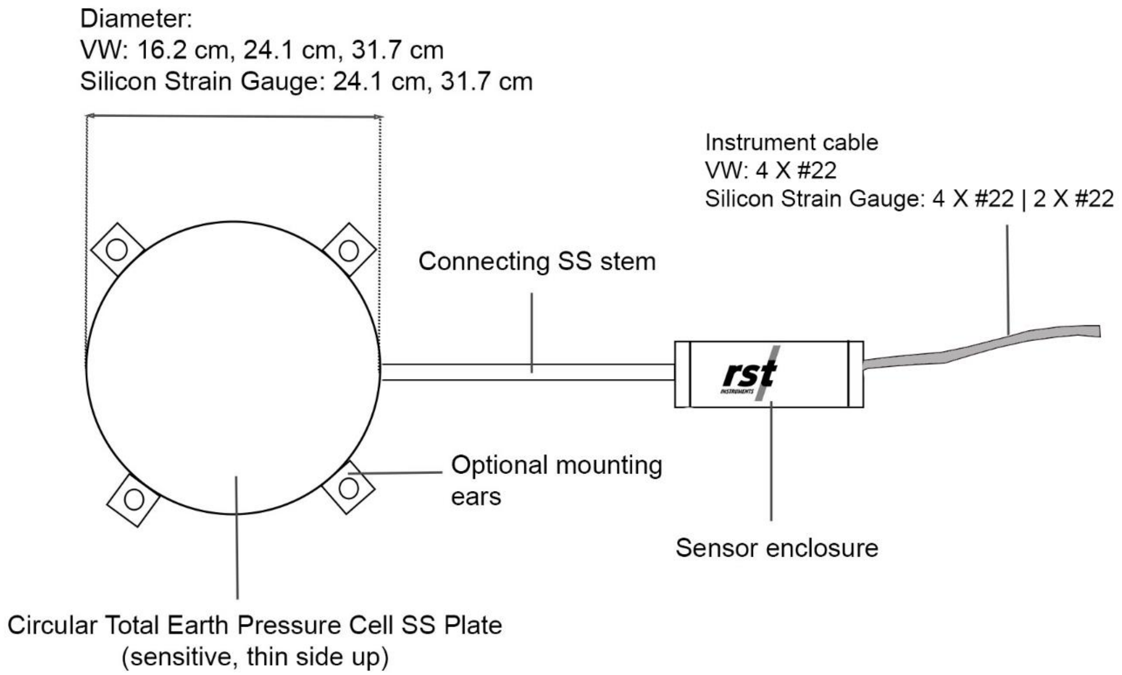

Figure 1: Total Earth Pressure Cell Diagrammatic View

5.3 FEATURES

- Long-term stability
- High accuracy and sensitivity
- Constant monitoring capability
- Ease of data logging
- Strain gauge or vibrating wire transducer, located 46 cm (18 in.) away from the cell to avoid any influence from the transducer
- Stainless-steel construction

5.4 APPLICATIONS

The TEPCs are generally used in 2 kinds of applications:

- Measuring pressure in a mass material such as earth embankments and mine backfill.
- Measuring pressure at the interface between soil mass and a structure such as tunnel lining, foundation, and culvert.

Examples of applications:

- Earth embankments
- Dams
- Foundations, retaining walls, and piles
- Against pipelines and culverts
- In railroad bases
- Beneath raft foundations
- Tunnel linings
- Mine backfill monitoring

6 INSTALLATION GUIDELINES

These installation instructions are general and may require alteration to suit specific site conditions and the required configuration of the instrument. The user is encouraged to read these installation instructions carefully prior to attempting the installation and to anticipate any steps or procedures which may require modifications. Please consult and seek appropriate approval from site engineer / consultant for final installation procedures.

NOTE: The cell's response to its immediate surroundings depends on how closely the soil immediately surrounding the cell has the same degree of compaction as the undisturbed soil mass.

The following general guidelines are recommended:

- Pressure readings should be taken regularly and at the completion of each installation state to ensure overpressure does not occur and the cell is functioning properly.
- The installation location depends on the specific project requirements and objectives.
- Each pressure cell installation location should be in soil mass that is undisturbed and whose composition is representative of the surrounding material.
- Cells may be installed either individually, in pairs or in a cluster arrangement for pressure measurement in different planes in the same survey area. Adjacent cells should be separated by at least 1 m or 5 cell diameters to prevent readings being affected.
- The cell must be uniform and in full contact with the surrounding material. Soil or rock adjacent to the cell should be free from large, sharp or unrepresentative material that may cause stress irregularities on the pressure pad providing inaccurate measurements.

NOTE: The storage and installation location of cells must be free from rapid temperature changes, such as in direct sunlight or exposure to cold, windy conditions. RST recommends the use of insulation to maintain proper conditions.

6.1 REQUIRED EQUIPMENT

Before installing the Total Earth Pressure Cell, make sure to have the following equipment:

- Portable readout instruments
- Single-channel data acquisition systems
- Multi-channel data acquisition systems
- Readout terminal stations

NOTE: RST provides the following data loggers:

- RSTAR Affinity (RS-485 and vibrating wire options)
- DT2055B (5/10 channel data logger for vibrating wire/thermistor sensors)
- DT2011B (single channel data logger for vibrating wire/thermistor sensors)
- FlexDAQ (both vibrating wire and strain gauge)
- NavStar SIO800
- VWL600 (for vibrating wire option)
- ADC800 (for strain gauge option)

6.2 PRELIMINARY TESTING

Prior to beginning the installation, the cells must be checked for proper functioning.

6.2.1 Zero Reading Check

1. Connect the cell's electrical leads to a readout device (see Table 1).
2. Each cell is provided with a no-load zero reading. Compare the current zero reading with the zero-reading given on the provided calibration report.

NOTE: RST Total Earth Pressure Cells are calibrated as a complete assembly (rather than just the sensor) to capture the calibration of the complete cell for highest quality of data. The calibration process is performed after the hydraulic fluid is deaired to ensure there is no error due to compressibility effects.

3. For a successful preliminary test, the two readings must not differ by more than 1% F.S. after corrections made for temperature, barometric pressure, height above sea level and cell position (vertical, horizontal or at an angle).

6.2.2 Functionality Check

1. Connect the cell's electrical leads to a readout device (see Table 1).
2. Press on the cell, causing changes to the readout digits. Ensure that as pressure is increased or decreased, the reading increases or decreases respectively.

6.2.3 Insulation Check

A Multimeter can be used to carry out insulation checks.

For proper insulation, the resistance between any conductor and the shield must not exceed 50 MΩ.

6.2.4 Optional Thermistor Check

A Multimeter can be used to carry out thermistor checks.

NOTE: The integrated thermistor is a Negative Temperature Coefficient (NTC) thermistor, i.e. its resistance decreases as the temperature it is exposed to is increased.

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1. Confirm the thermistor's rated value (3k Ω).
2. Without applying any heat to the thermistor, check the resistance value. It should be very close to the rated value.

NOTE: Depending upon the ambient temperature, the resistance value may be slightly higher or lower than 3 kΩ.

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3. Next, apply heat to the thermistor using a heating device such as a heater or blow dryer. If the thermistor is functioning properly, the resistance should start steadily declining within seconds once heat is applied.

6.2.5 Field Calibration Check for VW and SG sensor

1. Connect the cell's electrical leads to a readout device (see Table 1).
2. Incrementally place a series of known weights or use a hydraulic jack to gradually increase applied pressure on the pressure cell plate.
3. Record the corresponding outputs and compare to the values in the supplied calibration sheet.
4. Readings should be within 1% of each other.

6.3 INSTALLATION IN EMBANKMENT OR FILL

For pressure cell installations in soil, RST recommends the following guidelines:

- Ensure close contact between the pressure cell and the fill material. Make sure the fill is compacted uniformly and has a similar density as the surrounding fill/soil.
- To prevent point loading of the cell, install the cell in a lens of select (300-400 mm thick) hand compacted fill that is free from large aggregates or stones (bigger than 2% of pressure cell plate diameter).
- Try to avoid disturbance of the surrounding material.

6.3.1 Single Cell Typical Installation

When preparing the site for installation, create an excavation 0.5-0.75 m (1.6 – 2.5 ft.) deep. Backfill and compact the excavation by hand or with light mechanical equipment before allowing large vehicles to pass over. Use low angled side slopes (not steeper than 45°) to avoid stress concentrations and arching. Dig a trench for the cables, entering the excavation halfway along its length. Carefully compact and level the disturbed base of the excavation. This leveling is crucial for accurate stress analysis, as all cells will be assumed to be at the same level.

6.3.2 Multiple Cell Typical Installation in Array

Referring to Figure 2, follow the procedure to install an array of 5 cells:

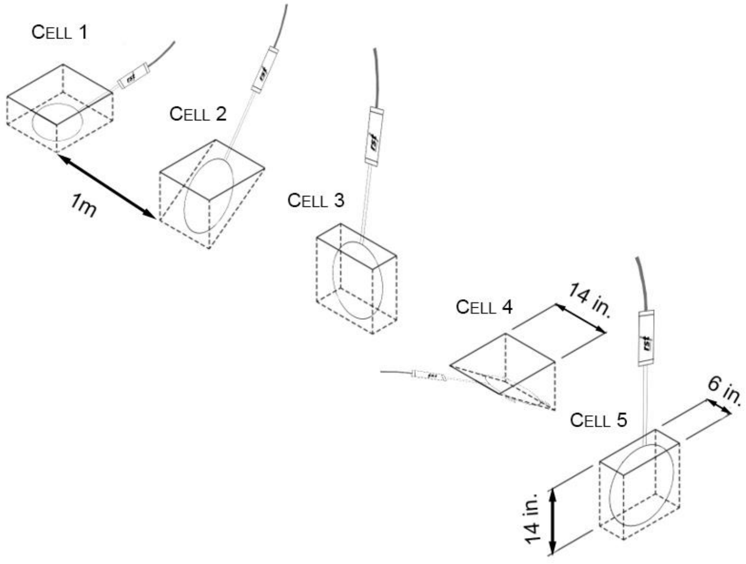


Figure 2: TEPC Array Installation Cell Orientation

1. Mark out the area for each cell with centers at a minimum distance of one meter.

2. Align the cells on or parallel to the embankment center line.

3. Carefully excavate a hole at each cell position, removing any protruding stones and filling the void with graded material smaller than 5mm. Compact the material thoroughly.

4. Set up shade or monitor temperature, if possible, to maintain a constant temperature during installation. Alternatively, place the cells in a water-filled container and monitor the adjacent temperature.

5. Ensure enough space for the cell and transducer in the base of each excavation.

6. Place a little graded material at the position of the underside of the cell and compact thoroughly.

7. Place Cell 1 into its hole, add a thin layer of graded material over its surface, and compact thoroughly.

8. Take readings and check alignment at intervals during the installation process.

9. Properly compact the material around the cell, especially in hot climates where the material should be kept at its natural moisture content.

10. For Cell 2, place it on a 45° surface filled with graded material. Use a 45° square and level to check the angle. Compact with graded material on top of the cell in horizontal layers, keeping the cell against the 45° face.

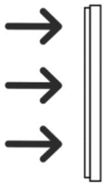
11. For Cell 3, place materials around the cell and compact as before. Keep the cell hard against the prepared face and continue compacting material around it, gradually squeezing inward and over the top of the cell. Use more force in compacting at the center after adding 30 to 40mm of fill.

12. Install Cells 4 and 5 in the same manner as Cells 2 and 1, respectively, but with the cells turned 90°. Continuously check levels, orientation, and readings during their placement.

13. Create a shallow lead-in channel at least 100mm deep for the steel tube, pressure transducer, and armoured cable in all cell holes. Carefully compact the fill by hand, especially where the steel tube is welded to the cell.

14. Backfill the excavated area to formation level using a pneumatic or petrol-driven hand-operated compactor. Avoid using large machines, bulldozers, or rollers until the area is back to formation level.

Pressure cells are usually installed with the flat surface horizontal, measuring vertical pressure. However, to measure pressures in different directions, the cells can be oriented accordingly. For example, a cell placed at 90 degrees vertically will measure the horizontal stress perpendicular to the cell plates.



CAUTION: Contact with large rocks during installation could deform the pressure cell plates, causing damage to the instrument and error in readings.

Ensure that the fill directly surrounding the cell is clear of all rock masses larger than 5 mm.

NOTE: The desired cell placement can be maintained during installation through plywood backing or steel cages. These aids do not need to be removed after installation is performed.

RST recommends using the same material as the fill to surround the pressure cell.

In areas with considerable coarse material, place fine material in transitional layers, from less coarse to coarser.

Hand place all fine material in the fill and compact with tampers.

6.4 INSTALLATION ON STRUCTURES

For load measurements in structures like retaining walls and culverts, the cells can be installed in three ways: attached to the structures before concreting, attached to the structure after concreting but before backfilling, or embedded in the backfill near the structure. In all three methods, ensure that the cell is in contact with the backfill using stone-free selected material.

In the first method, when installing the cell in the structure, securely hold it against the structure during concreting. Secure the cable to the structure at intervals of 0.5 m (1.6 ft.) or less.

To attach the cell to an existing structure before backfilling, apply a pad of cement mortar on the structure's surface and place the cell against it, squeezing out excess mortar until a layer of 5-10 mm (approx. ¼ in. – ½ in.) thickness stays underneath the pad. Avoid trapping air bubbles. Secure the cell in place to withstand backfilling, and label and fix the cable along the structure or excavation wall to the terminal unit or junction box.

After installation, verify the proper functioning of each cell.

6.5 INSTALLATION ON TUNNEL LINING

If shotcrete is used: Prepare a flat surface, apply a pad of cement mortar, place the cell against the pad, and coat the instrument with another layer of mortar.

For cells used to measure tangential pressures, fix the cells to short re-bars inserted into the rock or to the rebar cage. Mounting ears around the cells aid fixing. Route the cables along the structure to the terminal unit or junction box.

If precast concrete lining is used, it is recommended to fix the cells to the rebar cage using the mounting ears before pouring the concrete. For cells measuring normal pressures, position them close to the outer surface of the lining. Take note of the distance between the pad and the outer surface of the lining, as it helps in understanding pressure variations between cells.

6.6 CABLE INSTALLATION

→ **NOTE**: Specific cable installation instructions will depend upon the Total Earth Pressure Cell installation, on a case-by-case basis.

Contact RST for support and additional information.

In general, all installations must adhere to the following guidelines:

- Protect the cable from possible damage by sharp pieces of surrounding material.
- Protect the cable from possible damage by compaction equipment
- In earth/rock embankments and backfills, protect the cable from stretching
- In concrete structures, protect the cable from damage during placement and vibration of the concrete.

6.7 CABLE SPLICING

If the vibrating wire cable is cut and needs to be repaired, or the cable must be lengthened with a cable splice, RST recommends the use of an RST ELSPLICE4 Electrical Cable Splice Kit for Vibrating Wire Cable. Any cable splice that will be exposed to any moisture should be protected in this manner to eliminate the potential of water egress, short circuiting, and conductor corrosion.

⚠ **CAUTION**: If the cables are damaged or not spliced properly, the pressure cell may not function.

6.8 ELECTRICAL INTERFERENCE

If installed near sources of electrical interference (power lines, generators, motors, transformers, arc welders, AC lines, etc.), the instrument cables will intercept frequency noise from them causing issues obtaining a stable reading.

Ensure that instrument cables are installed as far as possible from sources of electrical interference and never buried or run alongside AC power lines.

6.9 INITIAL READINGS

Initial readings at zero load MUST be recorded along with the barometric pressure and temperature at the time of installation.

Record the initial readings while the cell is in position, just prior to it being covered by fill or pouring of concrete.

7 READOUT PROCEDURES

→| **NOTE**: For information on operating a specific data logger, refer to the logger's instruction manual.

Referring to the following wiring chart, make the appropriate connections to the readout unit and record readings:

Table 1: Total Earth Pressure Cell Wiring Chart

	Sensor Wiring	**Thermistor Wiring**
VW TEPC	Red: + Input Black: - Output (Interchangeable)	Green: + Input White: - Output (Interchangeable)
*4-20 mA + RS485 Strain Gauge	Black (Red): + VCC White (Black): Out/GND Blue (Green): RS485A (optional) Yellow (White): RS485B (optional) **_*Alternate color code is provided in red_**	N/A
Voltage + RS485 Strain Gauge	Black: + VCC White: GND Red: + Output Blue: RS485A (optional) Yellow: RS485B (optional)	N/A

NOTE: The VW2106 Readout Unit displays vibrating wire readings in frequency units called B-Units, which equal Frequency^2 x 10^{-3}, where frequency is in Hertz. The B-Unit values represent absolute pressure and must be corrected for changes in temperature and barometric pressure.

NOTE: RST's readout units are set up to use either formula to calculate the pressure cell output in engineering units.

7.1 PRESSURE CALCULATION

Pressure is calculated with the following equations, which can also be found on the sample calibration sheets in Appendix A.

NOTE: Appendix A contains sample calibration sheets for both VW sensor and strain gauge pressure sensor. Please ensure to refer to the correct sheet for each calculation.

1 mbar = 0.1kPa.

7.1.1 Pressure Calculation for VW Sensor

7.1.1.1 Linear equation

$$P\ (MPa) = CF\ (L_I - L_C) + [0.0001\ (B_I - B_C)]$$

Where:

P = Pressure in Mpa
CF = Calibration factor in MPa/B-unit (calibration sheet)
L_I, L_C = Initial & Current B-unit reading (Frequency^2 x 10^{-3})
0.0001 = Constant for MPa/millibar
B_I, B_C = Initial & Current Barometric pressure (millibar)

7.1.1.2 Polynomial equation

$$P\ (Mpa) = A\ (L_C)^2 + B(L_C) + C - [0.0001\ (B_C - B_I)]$$

Where:

P = Pressure in MPa
A, B, C = Polynomial gauge factors (calibration sheet)
L_C = Current B-unit reading (Frequency^2 x 10^{-3})
B_I, B_C = Initial & Current Barometric pressure (millibar)

7.1.2 Pressure Calculation for Strain Gauge Sensor (Volt)

7.1.2.1 Linear equation

$$P\ (Mpa) = CF\ (L_I - L_C) + [0.0001\ (B_I - B_C)]$$

Where:

P = Pressure in MPa
CF = Calibration factor in MPa/mV (calibration sheet)
L_I, L_C = Initial & Current mV reading
0.0001 = Constant for MPa/millibar
B_I, B_C = Initial & Current Barometric pressure (millibar)

7.1.2.2 Polynomial equation

$$P\ (Mpa) = A\ (L_C)^2 + B(L_C) + C - [0.0001\ (B_C - B_I)]$$

Where:

P = Pressure in MPa
A, B, C = Polynomial gauge factors (calibration sheet)
L_C = Current mV reading
B_I, B_C = Initial & Current Barometric pressure (millibar)

To convert the output to other engineering units, multiply the calibration factor by the conversion multiplier listed in the following table:

Table 2: Conversion Table for Engineering Units

From → To ↓	**psi**	**“H2O**	**‘H2O**	**mm H20**	**m H20**	**“HG**	**mm HG**	**atm**	**mbar**	**bar**	**kPa**	**Mpa**
psi	1	.036127	.43275	.0014223	1.4223	.49116	.019337	14.696	.014503	14.5039	.14503	145.03
“H2O	27.730	1	12	.039372	39.372	13.596	.53525	406.78	.40147	401.47	4.0147	4016.1
‘H2O	2.3108	.08333	1	.003281	3.281	1.133	.044604	33.8983	.033456	33.4558	.3346	334.6
mm H20	704.32	25.399	304.788	1	1000	345.32	13.595	10332	10.197	10197	101.97	101970
m H20	.70432	.025399	.304788	.001	1	.34532	.013595	10.332	.010197	10.197	.10197	101.97
“HG	2.036	.073552	.882624	.0028959	2.8959	1	.03937	29.920	.029529	29.529	.2953	295.3
mm HG	51.706	1.8683	22.4196	.073558	73.558	25.4	1	760	.75008	750.08	7.5008	7500.8
atm	.06805	.0024583	.0294996	.0000968	.0968	.03342	.0013158	1	.0009869	.98692	.009869	9.869
mbar	68.947	2.4908	29.8896	.098068	98.068	33.863	1.3332	1013.2	1	1000	10	10000
bar	.068947	.0024908	.0298896	.0000981	.098068	.033863	.001333	1.0132	.001	1	.01	10
kPa	6.8947	.24908	2.98896	.0098068	9.8068	3.3863	.13332	101.320	.1	100	1	1000
Mpa	.006895	.000249	.002988	.00000981	.009807	.003386	.000133	.101320	.0001	.1	.001	1

8 TROUBLESHOOTING

→ **NOTE**: This section details commonly encountered scenarios and steps for troubleshooting them. This is not an exhaustive list.

Contact RST for additional support and troubleshooting help.

8.1 VIBRATING WIRE SENSOR TROUBLESHOOTING

8.1.1 VW Sensor Fails to Give a Reading

1. Check the resistance of the vibrating wire coils by connecting a multimeter across the gauge terminals (red and black wires). Nominal resistance is approximately 180Ω (±5%), plus cable resistance at approximately 15Ω per 300 m of 22 AWG wire. Ensure to account for the two lengths of 22 AWG wire (i.e., red wire AND black wire) in this calculation. If the resistance is extremely high or infinite, the cable is possibly broken or cut. If the resistance is exceptionally low, the gauge conductors may be shorted.

2. Check the VW2106 Readout Unit with another vibrating wire sensor to confirm that the VW2106 Readout Unit is working.

3. The vibrating wire sensor may have been over-ranged or physically damaged. Inspect the instrument for any obvious damage. Contact RST Instruments if necessary.

8.1.2 VW Sensor Reading Unstable

1. Connect the blue/bare shield wire on the vibrating wire readout to the shield wire of the vibrating wire instrument. In the absence of a shield wire on the vibrating wire instrument, the blue/bare shield wire can be connected to the black or green wires from the vibrating wire instrument. If this does not result in more stable readings, proceed to step 2 below.

2. Isolate the vibrating wire readout from ground sources by placing it on a piece of wood or similar non-conductive material. If this does not result in more stable readings, proceed to step 3 below.

3. Check for sources of nearby electrical noise such as motors, generators, antennas, or electrical cables. Move the vibrating wire sensor cables as far as possible away from any sources of electrical noise. Filtering and shielding equipment are likely required if the noise cannot be eliminated. Contact RST for technical advice.

4. The vibrating wire sensor housing may be shorted to the shield. Check the resistance between the shield drain wire and sensor housing. The resistance should be extremely high.

5. The vibrating wire sensor may have been over-ranged or physically damaged. Inspect the instrument for any obvious damage. Contact RST Instruments if necessary.

8.1.3 Thermistor Reading is Too Low

1. If the calculated temperature from the thermistor resistance reading is unrealistically low, it is highly likely that there is an open circuit or poor connection in the thermistor wiring which is resulting in excessive resistance.

2. Check all connections, terminals, and plugs for any damage or corrosion that could cause excessive in-line resistance.

3. If cable damage or a cut is located, a splice must be performed to return the function of the wire connection to normal. It is recommended that an RST ELSPLICE4 Electrical Cable Splice Kit for Vibrating Wire Cables be used to ensure a strong and waterproof splice.

8.1.4 Thermistor Reading is Too High

1. If the calculated temperature from the thermistor resistance reading is unrealistically high, it is highly likely that there is a short circuit in the thermistor wiring which is resulting in a lower resistance reading.

2. Check all connections, terminals and plugs for any damage or current leakage that could explain a partial short that could result in a reduced circuit resistance. If a short or partial short is in the cable, the cable must be repaired with a splice. It is recommended that an RST ELSPLICE4 Electrical Cable Splice Kit for Vibrating Wire Cables be used to ensure a strong and waterproof splice.

3. If no obvious sources of shorting are found, it is possible that water may have penetrated the interior of the piezometer. There are no remedial actions available if this is concluded to be the case.

8.2 STRAIN GAUGE SENSOR TROUBLESHOOTING

8.2.1 Strain Gauge Sensor Fails to Provide Reading

1. Determine if the fault is with the transducer, power supply or readout.

2. If it can be determined that the transducer is no longer operable, remove it from service for further analysis. If the transducer output falls within the limits described above, the fault lies somewhere else in your system.

8.2.2 Strain Gauge Sensor has Failed

1. Inspect the cable for physical damage. Cuts in the cable jacket can result in water ingress into the transducer housing, which can cause permanent damage.

2. To determine if the transducer has been damaged, dry the transducer and cable and test for proper operation. If operational, the cable should be repaired or replaced. The cable can be repaired using a splice kit supplied by RST Instruments or can be replaced at the factory.

3. Inspect the transducer housing. It should be intact and free of corrosion. If the outer surface of the transducer is pitted, this could be an indication of galvanic corrosion caused by stray ground currents. If this is the case, the transducer will probably require replacement.

⚠ **CAUTION**: The TEPCs are vacuum filled during manufacturing. RST advises against removing the strain gauge sensor for cleaning/inspection as this will affect subsequent reading accuracy.

8.2.3 Vented Transducer Develops a Negative Offset and Gets Worse Over Time (Actual Level Exceeds Specified Level)

→| **NOTE**: This section only applies to vented transducers. Not all transducers are vented. Verify if your transducer is vented before proceeding with the following troubleshoot.

This may be a sign that moisture has entered the reference (vent) tube in the cable and is inside the transducer housing. This is usually the result of not maintaining the desiccant vent filter or of operating the transducer without a desiccant filter or aneroid bellows. If caught early enough, the transducer can be saved by coiling the cable and transducer in a pan and baking it in an oven at 50^{o}C (122 F) for a minimum of 2 hours. Be careful that the oven temperature does not exceed 50^{o}C (122 F) or both the transducer and the cable can be damaged. Alternatively, suspend both the cable and transducer in a vertical position (with vent tube down) overnight to allow water to drain from the transducer and vent tube.

8.2.4 Transducer Suddenly Fails During or Just After a Nearby Lightning Event

This failure is usually caused by over-voltage due to ground transients resulting from a direct or indirect lightning event. These transients can travel distances of a mile or more. The transducer may be returned to the factory for repair and optional retrofit of our lightning protection system.

8.2.5 Transducer Response to Pressure/Level Input Changes Becomes Slow

This is usually a sign that the pressure sensing end of the transducer has become fouled with residue. The transducer must be removed from service and the pressure sensing diaphragm cleaned as described with warm, soapy water. If fouling persists, the transducer may be replaced with a wide mouth transducer, which is specifically designed for trouble-free operation is a high residue environment.

8.2.6 No Electrical Output From the Transducer

Check all electrical connections to ensure they are correct and secure. Double check your power supply or use a battery to ensure the transducer is getting power. If all checks OK, the problem could be a circuit board or the sensor in your transducer. The unit must be returned to the factory for evaluation. The most probable cause of this type of failure is damage to the submersible cable jacket allowing water to leak down the cable and into the transducer housing or lightning damage.

9 PRODUCT SPECIFICATIONS

<table>
<tr><th>Item</th><th colspan="3">Specification</th></tr>
<tr><td>Model</td><td>LPTPC-V</td><td colspan="2">LPTPC-S</td></tr>
<tr><td>Transducer type</td><td>Vibrating Wire (VW)</td><td colspan="2">Silicon Strain Gauge*</td></tr>
<tr><td>Range – Standard Calibration</td><td>Up to 2.0 MPa (300 psi)</td><td colspan="2">Up to 2.0 MPa (300 psi)</td></tr>
<tr><td>Range – Maximum Available</td><td>20 MPa
(3000 psi)</td><td colspan="2">20 MPa
(3000 psi)</td></tr>
<tr><td>Calibrated Accuracy</td><td>0.15% F.S.</td><td colspan="2">0.15% F.S.</td></tr>
<tr><td>Resolution</td><td>0.025% F.S. minimum</td><td colspan="2">Infinite</td></tr>
<tr><td>Excitation Voltage</td><td>5 V sq. wave</td><td colspan="2">Dependent on sensor</td></tr>
<tr><td>Signal Output</td><td>1200 – 3550 Hz</td><td colspan="2">4 – 20 mA, 0-5 V</td></tr>
<tr><td>Thermistor</td><td>Yes (standard)</td><td colspan="2">Optional</td></tr>
<tr><td>Conductor</td><td>4 X #22 (2 for VW, 2 for Thermistor)</td><td>4 X #22</td><td>2 X #22</td></tr>
<tr><td rowspan="2">Operating Temperature</td><td colspan="3">VW: -20 to +80°C</td></tr>
<tr><td colspan="3">SG: -10 to +80°C (compensated range)</td></tr>
</table>

*_RST provides various types of strain gauge transducers. Contact RST for more information (contact information provided in Section 5: Service, Repair and Contact Information)._

10 ORDERING INFORMATION

Transducer	Standard Cell Diameter	Standard Pressures (0.35 MPa – 3 MPa)	High Pressures (>3 MPa – 20MPa)	Low Pressures (<0.35 MPa)
Vibrating Wire	24.1 cm (9.5 in.)	LPTPC09-V	LPTPC09-V-HP	LPTPC09-V-LP
Vibrating Wire	31.7 cm (12.5 in.)	LPTPC12-V	LPTPC12-V-HP	LPTPC12-V-LP
Silicon Strain Gauge	24.1 cm (9.5 in.)	LPTPC09-S	LPTPC09-S-HP	LPTPC09-S-LP
Silicon Strain Gauge	31.7 cm (12.5 in.)	LPTPC12-S	LPTPC12-S-HP	LPTPC12-S-LP

OPTIONAL

Item	Part Number
Vibrating Wire Cable	EL380004
Mounting Ears (4 Tabs)	LPTPC-EARS4

OTHER ORDERING INFORMATION

- Part number
- Pressure range requirements
- Cable length

11 SERVICE, REPAIR AND CONTACT INFORMATION

This product does not contain any user-serviceable parts. Contact RST for product services or repairs.

- For sales information: sales@rstinstruments.com
- For technical support: support@rstinstruments.com
- Website: www.rstinstruments.com
- Toll free: 1-800-665-5599

RST Canada Office (Head Quarters)

Address: 11545 Kingston Street, Maple Ridge, BC, Canada V2X 0Z5

Telephone: 604-540-1100

Fax: 604-540-1005

Business hours: 7:30 a.m. to 5:00 p.m. (PST) Monday to Friday, except holidays

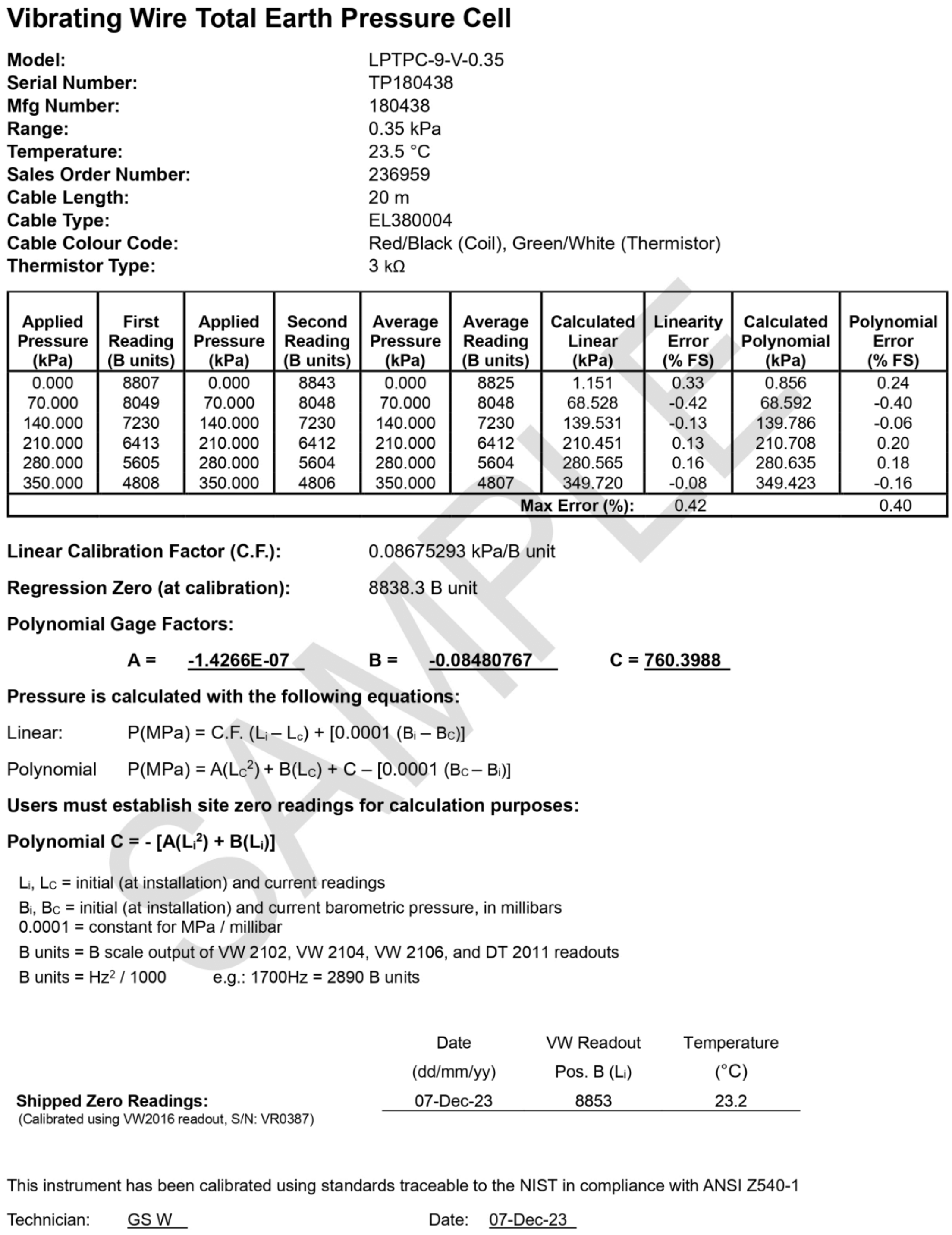
RST UK Office

Address: Unit 4 Charles Industrial Estate Stowupland Road, Stowmarket
Suffolk, UK, IP14 5AH

Telephone: +44 1449 706680

Business hours: 9:00 a.m. to 6:30 p.m. (GMT) Monday to Friday except holidays

APPENDIX A: SAMPLE CALIBRATION RECORD SHEETS



Vibrating Wire Total Earth Pressure Cell

Model:	LPTPC-9-V-0.35
Serial Number:	TP180438
Mfg Number:	180438
Range:	0.35 kPa
Temperature:	23.5 °C
Sales Order Number:	236959
Cable Length:	20 m
Cable Type:	EL380004
Cable Colour Code:	Red/Black (Coil), Green/White (Thermistor)
Thermistor Type:	3 kΩ

Applied Pressure (kPa)	First Reading (B units)	Applied Pressure (kPa)	Second Reading (B units)	Average Pressure (kPa)	Average Reading (B units)	Calculated Linear (kPa)	Linearity Error (% FS)	Calculated Polynomial (kPa)	Polynomial Error (% FS)
0.000	8807	0.000	8843	0.000	8825	1.151	0.33	0.856	0.24
70.000	8049	70.000	8048	70.000	8048	68.528	-0.42	68.592	-0.40
140.000	7230	140.000	7230	140.000	7230	139.531	-0.13	139.786	-0.06
210.000	6413	210.000	6412	210.000	6412	210.451	0.13	210.708	0.20
280.000	5605	280.000	5604	280.000	5604	280.565	0.16	280.635	0.18
350.000	4808	350.000	4806	350.000	4807	349.720	-0.08	349.423	-0.16
						Max Error (%):	0.42		0.40

Linear Calibration Factor (C.F.): 0.08675293 kPa/B unit

Regression Zero (at calibration): 8838.3 B unit

Polynomial Gage Factors:

A = -1.4266E-07 **B = -0.08480767** **C = 760.3988**

Pressure is calculated with the following equations:

Linear: $P(MPa) = C.F.\,(L_i - L_c) + [0.0001\,(B_i - B_C)]$

Polynomial $P(MPa) = A(L_C^2) + B(L_C) + C - [0.0001\,(B_C - B_i)]$

Users must establish site zero readings for calculation purposes:

Polynomial $C = -[A(L_i^2) + B(L_i)]$

L_i, L_C = initial (at installation) and current readings

B_i, B_C = initial (at installation) and current barometric pressure, in millibars
0.0001 = constant for MPa / millibar

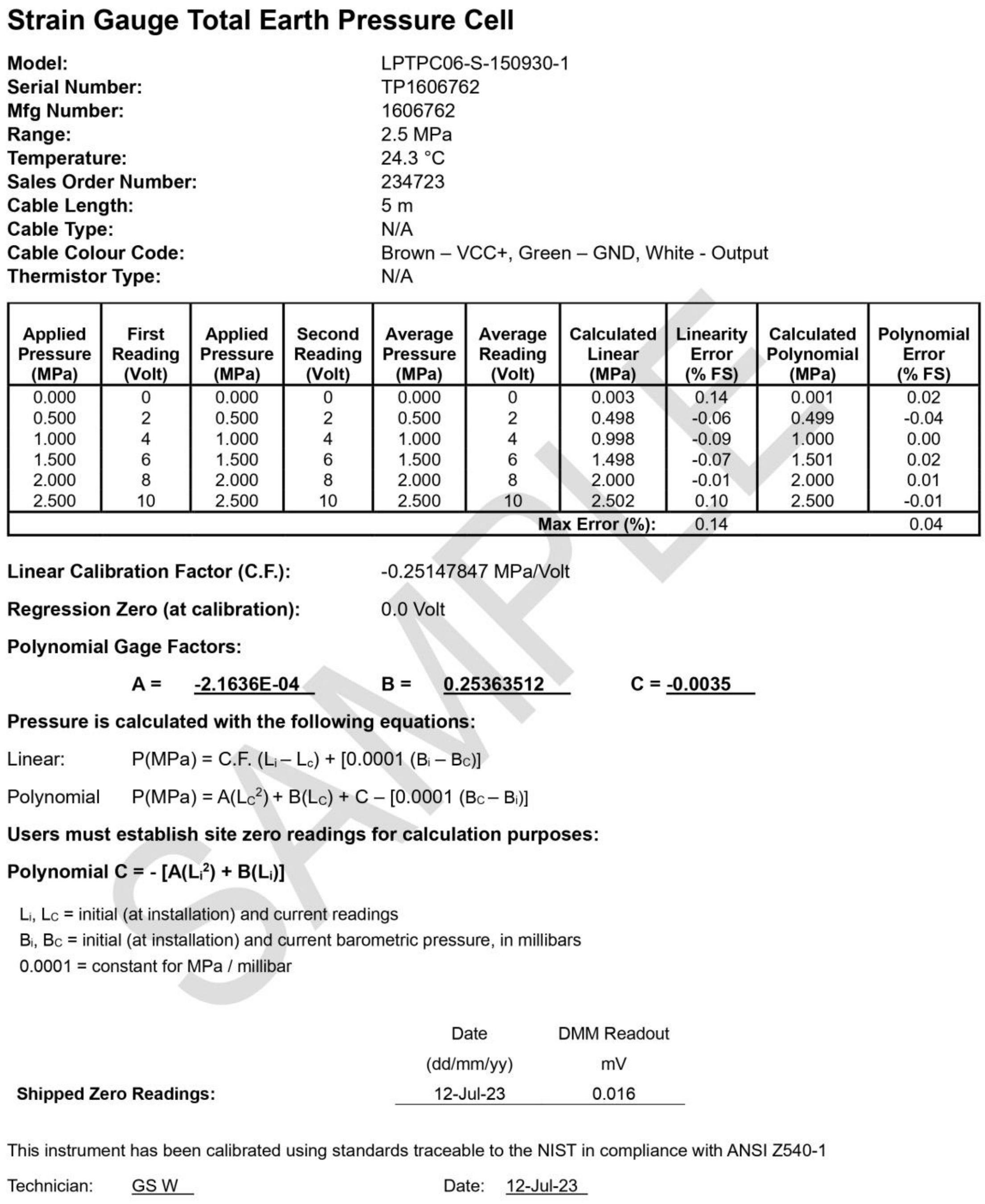
B units = B scale output of VW 2102, VW 2104, VW 2106, and DT 2011 readouts

B units = Hz^2 / 1000 e.g.: 1700Hz = 2890 B units

	Date (dd/mm/yy)	VW Readout Pos. B (L_i)	Temperature (°C)
Shipped Zero Readings: (Calibrated using VW2016 readout, S/N: VR0387)	07-Dec-23	8853	23.2

This instrument has been calibrated using standards traceable to the NIST in compliance with ANSI Z540-1

Technician: GS W Date: 07-Dec-23



Strain Gauge Total Earth Pressure Cell

Model: LPTPC06-S-150930-1
Serial Number: TP1606762
Mfg Number: 1606762
Range: 2.5 MPa
Temperature: 24.3 °C
Sales Order Number: 234723
Cable Length: 5 m
Cable Type: N/A
Cable Colour Code: Brown – VCC+, Green – GND, White - Output
Thermistor Type: N/A

Applied Pressure (MPa)	First Reading (Volt)	Applied Pressure (MPa)	Second Reading (Volt)	Average Pressure (MPa)	Average Reading (Volt)	Calculated Linear (MPa)	Linearity Error (% FS)	Calculated Polynomial (MPa)	Polynomial Error (% FS)
0.000	0	0.000	0	0.000	0	0.003	0.14	0.001	0.02
0.500	2	0.500	2	0.500	2	0.498	-0.06	0.499	-0.04
1.000	4	1.000	4	1.000	4	0.998	-0.09	1.000	0.00
1.500	6	1.500	6	1.500	6	1.498	-0.07	1.501	0.02
2.000	8	2.000	8	2.000	8	2.000	-0.01	2.000	0.01
2.500	10	2.500	10	2.500	10	2.502	0.10	2.500	-0.01
						Max Error (%):	0.14		0.04

Linear Calibration Factor (C.F.): -0.25147847 MPa/Volt

Regression Zero (at calibration): 0.0 Volt

Polynomial Gage Factors:

A = -2.1636E-04 **B = 0.25363512** **C = -0.0035**

Pressure is calculated with the following equations:

Linear: $P(MPa) = C.F. (L_i – L_c) + [0.0001 (B_i – B_C)]$

Polynomial $P(MPa) = A(L_C^2) + B(L_C) + C – [0.0001 (B_C – B_i)]$

Users must establish site zero readings for calculation purposes:

Polynomial $C = - [A(L_i^2) + B(L_i)]$

L_i, L_C = initial (at installation) and current readings
B_i, B_C = initial (at installation) and current barometric pressure, in millibars
0.0001 = constant for MPa / millibar

	Date (dd/mm/yy)	DMM Readout mV
Shipped Zero Readings:	12-Jul-23	0.016

This instrument has been calibrated using standards traceable to the NIST in compliance with ANSI Z540-1

Technician: GS W Date: 12-Jul-23

APPENDIX B: THERMISTOR TEMPERATURE DERIVATION

Resistance to Temperature Equation 1:

$$T = \frac{1}{A + B(LnR) + C(LnR)^3} - 273.2$$

Where:

T	=	temperature in °C
Ln(R)	=	natural log of thermistor resistance
A	=	1.4051×10^{-3} (coefficient calculated over the -50 to +150°C span)
B	=	2.369×10^{-4}
C	=	1.019×10^{-7}

Table 3: Thermistor Resistance Varying With Temperature

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.11	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342..2	83	107.9	123
77.99K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-35	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	282.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	56.92	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.	53	250.9	93	83.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

APPENDIX C: SECOND ORDER POLYNOMIAL TO IMPROVE THE CALCULATED PRESSURE ACCURACY

Most Vibrating Wire Pressure Transducers are sufficiently linear (<0.2% FS) that the use of a Linear Equation and a Linear Calibration Factor will satisfy most normal output requirements. However, it must be noted that the accuracy of the calibration data used to establish the Linear Calibration Factor is dictated by the accuracy of the calibration procedure and apparatus, which is always <0.1 % FS.

The level of accuracy for a VW Pressure Transducer can be improved, especially when the transducer output is non-linear, by using the Second Order Polynomial Expression, which is better suited to the actual pressures than the Linear Equation.

The Second Order Polynomial Expression has the following form:

$$P\ (\text{pressure}) = A(L)^2 + B(L) + C$$

Where,

L = Current VW reading (in B-units)

A, B and C = Polynomial coefficients (from calibration)

Appendix A shows sample calibration sheets for VW pressure transducers with a comparatively low non-linearity. In this case, there will only be a very small difference between the value of pressure calculated by the linear equation and by the second order polynomial expression.

In cases where the VW transducers have a high non-linearity (greater than 0.2% FS), the second order polynomial expression method will provide more accurate pressure values.

The VW calibration sheets contain a column labelled “Linearity Error (% FS)” which displays the calculated linear error percentage for the calibration steps. If the average of these percentages exceeds 0.2%, RST recommends calculating all pressure values using the second order polynomial expression.

The Linearity Error (% FS) is calculated as follows:

$$\text{Linearity Error (\% FS)} = \frac{(\text{Calculated Pressure - Applied Pressure})}{\text{Full Scale Pressure}}\ .\ 100\ \%$$