NATM STRESS CELLS

VWNPC-3000

INSTRUCTION MANUAL

CE

GEOSENSE

CONTENTS

1.0 INTRODUCTION

This manual is intended for all users of **Geosense® NPC-3000 NATM Cells** and provides information on their installation, operation and maintenance**.**

It is VITAL that personnel responsible for the installation and use of the NATM Cells READ and UNDERSTAND the manual, prior to working with the equipment.

1.1 General Description

The primary uses for NATM Cells are :-

The measurement of stress in concrete

Particular features of **Geosense®** Vibrating wire are:-

Reliable long term performance.
Rugged; suitable for demanding environments.
High accuracy.
Insensitive to long cable lengths.

The Pressure sensor is based upon 'industry standard' Vibrating Wire technology. When electronically excited, the sensor produces an output signal in the form of an alternating current. The frequency of the alternating current can then be readily converted to a fluid pressure by applying individual calibration factors.

Frequency signals are particularly suitable for the demanding environment of civil engineering applications, since the signals are capable of long transmission distances without degradation. They are also somewhat tolerant of damp wiring conditions and resistant to interference from external electrical noise.

Geosense® NPC-3000 NATM Cells are supplied in various configurations to suit varying installation environments and techniques. Each cells is fitted with a length of connecting cable, an internal temperature sensor and a surge arrestor.

1.2 How it works
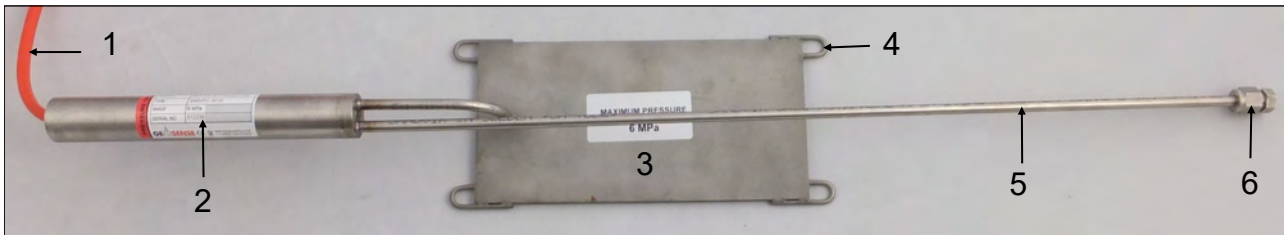
1 - **Sensor cable**

2 - **VW sensor** (no elasticity)

3 - **Stress cell body** - comprises of two stainless steel rectangular plates welded together around their periphery, leaving a thin space between the plates which is then filled with an relatively incompressible de-aired fluid. Pressure applied normal to the plate is balanced by a corresponding build up of internal fluid pressure which is measured by the sensor.

4 - **Mounting lug** - provided at each corners of the cell body to fix the cells in place while the shotcrete is applied.

5 - **Pressure (pinch) tube** - this is filled with a relatively incompressible de-aired fluid and is connected at one end to the fluid filled space between the plates and the other end is capped. The purpose of this tube is to inflate the cell once the concrete is cured.

6 - **End cap**

1.3 Application

The "New Austrian Tunnelling Method", or NATM, calls for the support of a tunnel by the rapid application of shotcrete to the freshly exposed ground. The theory behind this method of support, particularly useful in weaker ground, is that if the inherent strength of the ground can be preserved, it will be almost self-supporting and will require much less artificial support in the form of concrete or steel. To preserve the inherent cohesion of the ground it is necessary to prevent it from breaking up in the first place and, hence, the need for a rapidly applied layer of shotcrete.

The graph below shows the ground reaction curve which is the amount of support needed versus the amount of inherent support and ground deformation. In order to prevent any support deformation it requires a support pressure exerted onto the tunnel wall to be equal to the original in-situ ground stress.
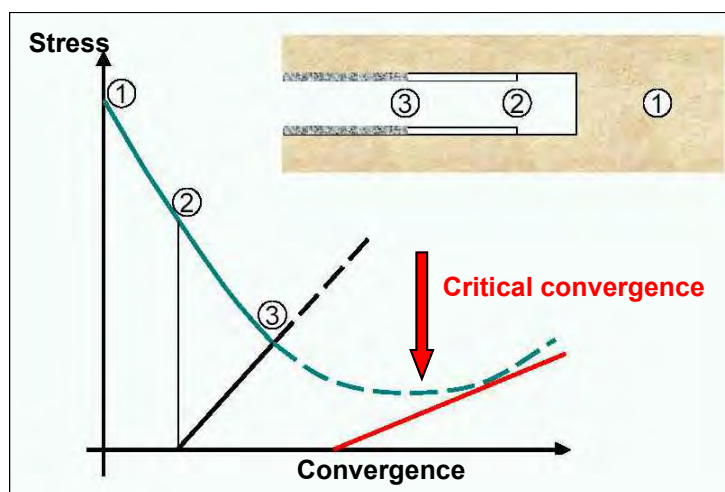
NATM cells are used to monitor and thus calculate the support pressure and in combination with other monitoring devices such as a tape extensometer allows an assessment as to how much shotcrete lining is required and can be used to alter the amount as construction progresses.

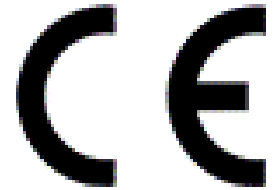This therefore provides the most cost effective lining to be installed.

2.0 CONFORMITY

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Rougham Industrial Estate
Rougham, Bury St Edmunds
Suffolk , IP30 9ND
United Kingdom

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Declaration of Conformity

We Geosense Ltd at above address declare under our sole responsibility that the
Geosense products detailed below to which this declaration relates complies with protection requirements
of the following harmonized EU Directives,

The Electromagnetic Compatibility Directive 2014/30/EU
Restriction on the use of certain Hazardous Substances RoHS2 2017/2102/EU
Waste electrical & electronic equipment WEEE 2012/19/EU

Equipment description	**Vibrating Wire NATM Stress Cells**
Make/Brand	**Geosense**
Model Numbers	VWNPC-3000, VWNPC-3010

This equipment has been designed and manufactured with reference to the following standards:

All mechanical drawings used in the production of this equipment are based upon BS 8888
Electrical/electronic drawings are based upon BS 3939.

A technical file for this equipment is retained at the above address
This Declaration of Conformity was prepared according to EN ISO/IEC 17050-1:2004.

Martin Clegg December 2020
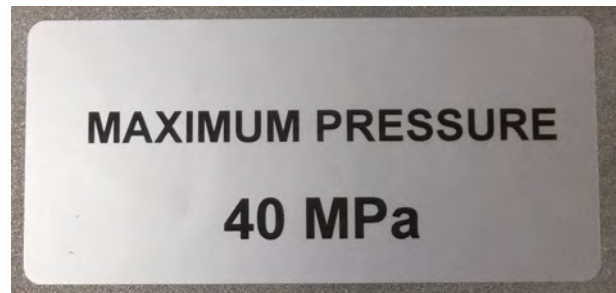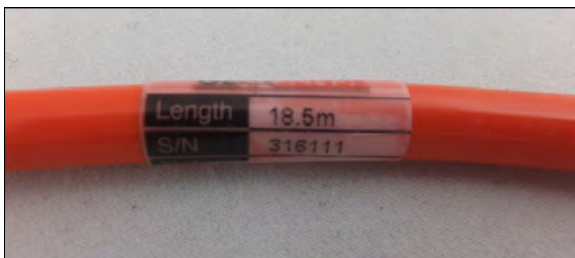*Director*

3.0 MARKINGS

Geosense® NPC-3000 NATM Cells are labelled with the following information:-

Manufacturers website & telephone number

Product type

Pressure range

Model

Serial number

Cable length

CE mark

Maximum pressure

4.0 DELIVERY

This section should be read by all users of **Geosense® NPC-3000 NATM Cells**.

4.1 Packaging

Geosense® NPC-3000 NATM Cells are packed for transportation to site. Packaging is suitably robust to allow normal handling by transportation companies. Inappropriate handling techniques may cause damage to the packaging and the enclosed equipment. The packaging should be carefully inspected upon delivery and any damage MUST be reported to both the transportation company **Geosense®**.

4.2 Handling

Whilst they are a robust devices, **Geosense® NPC-3000 NATM Cells** are precision measuring instruments. They and their associated equipment should always be handled with care during transportation, storage and installation.

Once the shipment has been inspected (see below), it is recommended that cells remain in their original packaging for storage or transportation.

Cable should also be handled with care. Do not allow it to be damaged by sharp edges, rocks for example, and do not exert force on the cable as this my damage the internal conductors and could render the installation useless.

4.3 Inspection

It is important to check all the equipment in the shipment as soon as possible after taking delivery and well before installation is to be carried out. Check that all the components detailed on the documents are included in the shipment. Check that the equipment has not been physically damaged.

ALL **Geosense® NPC-3000 NATM Cells** carry a **unique** identification serial number which is located on the cable close to the pressure sensor body and at the free end of the cable. All are supplied with individual calibration sheets that include their serial numbers and these will shipped with the cells.

Calibration Sheets contain VITAL information about the NATM Cell. They MUST be stored in a safe place. Only copies should be taken to site.

4.4 Functionality test & zero readings

CHECK the Cells 'Zero Readings' against the factory 'Zero Readings' on arrival to ensure they have not changed due to damage during transportation. To do this, connect a Vibrating Wire readout to the bare cable ends (Black and Red conductors). – See readout manual for connection guidance.

> *NB   If the readout display is in 'Period' units (eg 0.03612) a calculation must be performed to convert to $Hz^2/1000$ (Linear Digits) units, since the calibration sheet is presented in $Hz^2/1000$ units. The Geosense Readout model **VW200** displays the readings in 'Period'. The RST readout / logger unit Model Number **VW2106** displays the readings in Linear digits. See Section 6 of this manual for more information on units and conversion routines.*

Prior to carrying out a 'Zero Reading' CHECK, ensure that the NATM Cells have been stored in a reasonably stable temperature for at least 30– 60 minutes.

Record the values displayed on the readout (and units) against the NATM Cell serial numbers. If these 'out of the box' CHECK readings show significant differences (+/- 40 digits) to the zero pressure values on the calibration sheets, contact Geosense for assistance. (It should be noted that the 'CHECK Readings WILL be affected by the atmospheric pressure & altitude).

If components are missing or damaged, contact the delivery company, the supplier and / or **Geosense™**.
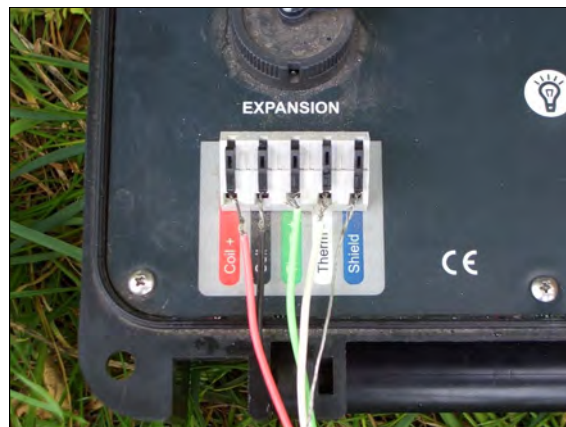
4.4 Storage

Whilst **Geosense® NPC-3000 NATM Cells** are relatively robust they are a precision instrument and if they need to be stored care should be taken to protect them against any impact or weight.

Ideally they should be stored in their original packaging but if not do not stack units on top of each other or any other item that could damage the sensor or connecting pipework from the cell body.

It is recommended that they be stored in a dry environment to prevent moisture migrating along the cables and storage areas should be free from rodents as they have been known to damage connecting cables.

5.0 INSTALLATION

This section of the manual is intended for all users of **Geosense® NPC-3000 NATM Cells** and is intended to provide <u>guidance</u> with respect to their installation.

It must be remembered that no two installations will be the same and it is inevitable that some 'fine tuning' of the following procedures will be required to suit specific site conditions.

⚠️ **It is VITAL that personnel responsible for the installation and use of the NATM cells READ and UNDERSTAND the manual, prior to working with the equipment.** ⚠️

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As stated before, it is vital to check all the equipment in the shipment soon after taking delivery and well before installation is to be carried out. Check that all components that are detailed on the shipping documents are included.

5.1 Cell Installation

Cells are positioned on the wall of the tunnel in two ways, one way to monitor **tangential** stresses and the other to measure **radial** stresses.

5.1.2 Tangential cell (VWNPC-3000)

⚠️ **CELL MUST BE INSTALLED PERPENDICULAR TO TUNNEL LINING**

Typical installation is by using short pieces of steel rebar grouted inside short boreholes and protruding into the area where the lining will be placed.

STEP 1 - place a **VWNPC-3000** tangential stress cell onto two horizontal re-bar mountings.

STEP 2 - carefully bend the pressure tube 90 degrees away from the tunnel wall so that it protrudes through the shotcrete lining and can be accessed for re-pressurising.

STEP 3 - tie to the re-bars using soft iron wire connected to the lugs at the corners of the cell.

5.1.2 Tangential cell (VWNPC-3000) contd..

STEP 4 - fix the cable firmly to other pieces of rebar or to the reinforcing mesh (if one is used) and feed out to the readout location which typically is a junction box.

The cable is terminated inside this box. Sufficient cable should be coiled inside the box to allow it to be pulled out and connected to a portable readout box.

It is very important that the concrete makes intimate contact with the stress cell. Therefore the concrete should be sprayed evenly around the cell ensuring no voids exist.

5.1.3 Radial cell (VWNPC-3010)

STEP 5 - Install re-bar sections or nails adjacent to the cell location so that the radial cell can be attached to them.

STEP 6 - make a pad of quick setting mortar onto the surface of the tunnel wall.

STEP 7 - place the **VWNPC-3010** radial stress cell onto the pad and press firmly so that mortar is displaced from underneath it to eliminate any air bubbles or spaces between the cell and the ground.

STEP 8 - carefully bend the pressure tube so that it will protrude out of the shotcrete lining.

STEP 9 - tie to the re-bars using soft iron wire connected to the lugs at the corners of the cell.

STEP 10 - fix the cable firmly to other pieces of rebar or to the reinforcing mesh (if one is used) and feed out to the readout location which typically is within a junction box.

The cable is terminated inside this box. Sufficient cable should be coiled inside the box to allow it to be pulled out and connected to a portable readout box.

5.1.4 Initial readings

⚠️ **BEFORE SHOTCRETING TAKE INITIAL PRESSURE & TEMPERATURE READINGS**

5.2 Re-Pressurising the Cell

During concrete curing, temperatures very often rise and will cause the cell to expand in the still green concrete. On cooling, the cell contracts leaving a space between it and the surrounding concrete which, if allowed to remain, would prevent the transmission of pressures from the concrete to the cell. Therefore the cell will require to be re-pressurised in order to measure this pressure.

⚠️ **ONCE TEMPERATURE HAS STABILISED TAKE INITIAL PRESSURE & TEMPERATURE BEFORE RE-PRESSURISING**

STEP 1 - connect the sensor cable to the readout (for full details see page 9)

STEP 2 - start crimping the re-pressurisation tube from the end cap end with the special crimping tool.

Check the readings on the readout as the tube is crimped. If there is a relatively large gap between the cell and the surrounding concrete each crimp will result in a small value increase in pressure. If the cell is already in good contact with the concrete then a large value will be seen.

⚠️ **DO NOT START CRIMPING THE TUBE CLOSER THAN 25MM FROM THE END CAP**

STEP 3 - plot a graph of pressure against the number of crimps.

If the gap between the cell and the concrete is relatively large then the curve will be as graph 1 on page 15.

If the gap between the cell and the concrete is small the curve on the graph will be as graph 2 on page 15.

5.2 Re-Pressurising the Cell contd...

It is recommended that results are graphed so that site characterisation can be obtained.
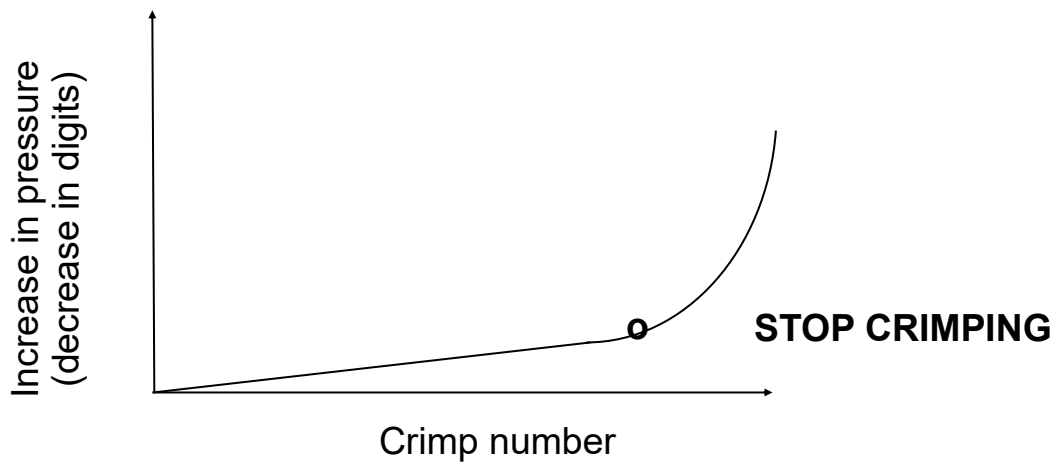
GRAPH 1 - a gradual increase in pressure occurs showing that there is initially little contact between the cell and the concrete. As the cell starts to become in contact with the concrete the pressure starts to build up quickly. Once this occurs stop crimping.
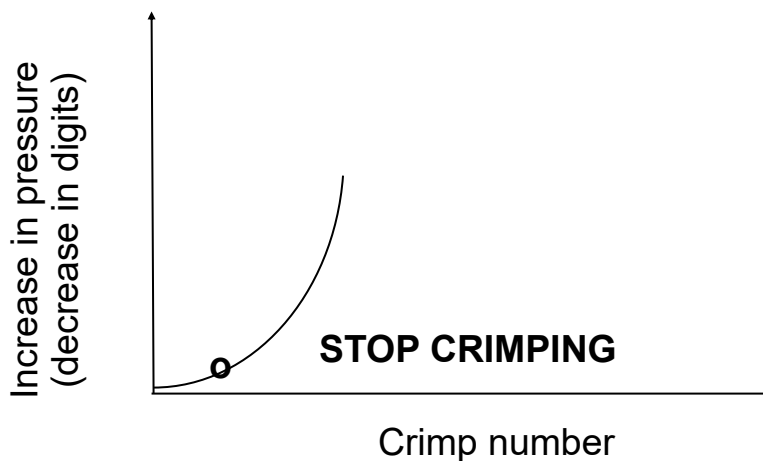
GRAPH 2 - a quick increase in pressure occurs showing that the cell is already in good contact with the concrete. Once this occurs stop crimping.

5.2 Re-Pressurising the Cell contd..

However, it is also possible that the cell is already in good contact with the concrete, so that crimping will immediately cause a pressure rise in the cell. If this is the case then cease crimping immediately.

Continued crimping after the cell has made good contact could cause the concrete around the cell to split open which is not desirable and could lead to erroneous readings. A slight relaxation of the cell after the re-pressurization procedure is normal and should drop the cell pressure to a value roughly equal to the concrete stress. From this point on, the cell pressure should then be equal to the absolute concrete stress. Record the new initial pressure after the cell has stabilized.

While the concrete is curing it will be a good idea to take simultaneous readings of temperature and pressure for the purpose of developing a temperature correction factor. See section 6.

5.3 Cable
5.3.1 Cable Installation
The cable should be protected from accidental damage caused by moving equipment. This is best done by putting the excess cable inside a junction box (Cables may be spliced to lengthen them, without affecting gauge readings. Waterproof splice kits are available from **Geosense**®.

5.3.2 Cable marking.

Cables should be marked with unique identification. Markings should be repeated at regular intervals along the cable where multiple cables are to be grouped together, so that in the event of cable damage, there may be a chance that the identification could be exposed and the cables re-joined. Multiple cable marks are particularly important close to the end of the cable. The spacing of markings can vary according to specific site requirements but a guide of 5m to 10m is commonly applied (available on request).

5.4 Tools.
5.4.1 Tools list
Obtain any tools necessary to carry out the installation. The following is a brief list of tools typically used during the installation of **Geosense**® **NPC-3000 NATM Cells**:-

- **NATM Crimper -** to re-pressurise the cell.
- **Wire cutters and strippers**
- **Vibrating Wire Readout unit** for checking the NATM cell function
- **Cable Marking** system / equipment (eg coloured PVC Tapes)
- **Tie wire/ Cable ties** - for installing NATM cells and cable.

6.0   DATA HANDLING

The function of an instrument is to provide useful and reliable data. Accurate recording and handling of the data is essential if it is to be of any value.

6.1   Monitoring the NATM cell readings

Geosense® **NPC-3000 NATM Cells** include both pressure and temperature sensors. NATM cells are installed in a zone where the temperature is likely to fluctuate significantly and therefore records of both pressure and temperature data should be recorded. They can then be used to assess any temperature effects on the pressure readings.

6.1.1 Portable Readouts

Geosense® offer a range of readout and data logging options. Specific operation manuals are supplied with each readout device.

Below is a brief, step-by-step procedure for use with the **RST VW2106** portable readout.

1. Connect signal cable from the sensor to the readout following the wiring colour code. Conductor colours may vary depending upon the extension cable used. Commonly these are:

    RED   =   VW +
    BLACK   =   VW -
    GREEN   =   Temp
    WHITE   =   Temp

2. Switch on the unit and, where necessary, select range B

3. The readout displays the Vibrating Wire reading (in Hz^2/1000 - Linear Digits) and a temperature reading in degrees C.

Whilst it is not critical that the polarity be observed for most Vibrating Wire instruments, a better signal may be obtained if the correct polarity is adopted. Since the temperature sensor is a Thermistor, its connection polarity is not important.

6.1.2 Data Loggers

A number of data loggers are available to automatically excite, interrogate and record the reading from Vibrating Wire instruments. These include devices manufactured by **Geosense®** / RST in both single and multi-channel configurations, as well as equipment manufactured by independent suppliers.

Geosense® configure and supply equipment manufactured by both Campbell Scientific Ltd and DataTaker Ltd. These are the most commonly adopted third party manufacturers of data loggers that can be used with Vibrating Wire Instruments.

Specific configuration and programming advice can be obtained from Geosense.

6.2 Data Reduction

Overview

The tension of a sensor wire can be measured by detecting the frequency (note) at which it naturally vibrates. The following is a description of the units commonly used by the instrumentation industry.

Frequency Units (Hz). If the wire is 'excited' electronically the frequency at which it vibrates can be measured. The units used to express frequency are Hertz (Hz) or Kilohertz (kHz).

The disadvantage of these units is that there is no 'linear' conversion from 'change in Hertz' to 'change in wire tension'.

Linear Digits (B). In order to overcome the problem of a linear conversion described above, the frequency value can be squared, thereby rendering it linear, but quite large. To reduce its size, it is often divided by 1000 (or multiplied by 10^{-3}). The expression $Hz^2/1000$ (or $Hz^2 \times 10^{-3}$) is the most commonly adopted as a 'linear' digital output.

Period Units (P). Some readout devices utilise the 'counter' function available in many common integrated circuits.

Period Units represent the time taken for the wire to vibrate over one full oscillation, expressed in seconds. Due to the very small size of the number generated most equipment manufacturers display the unit multiplied by either 1000 (10^3) or 10000000 (10^7).

The relationship between Period units and Frequency units is expressed as

$$P = \frac{1}{Frequency}$$

Period units are convenient to measure but to convert the readings to units of pressure, calibration factors must be applied to the recorded values. For most Vibrating Wire sensors, these factors are unique and are detailed on the sensor calibration sheet. A unique calibration sheet is supplied with all **Geosense® NPC-3000 NATM Cells** (see page 21).

If the readout display is in Period units (e.g. 0.03612 or 3612 - depending upon the readout used) the first step to producing an engineering value is to convert the reading to Linear Digits ($Hz^2/1000$) . Two examples of this calculation can be seen below. The first (1) where the readout includes a decimal point and displays the Period in **Seconds^{-2}** and the second (2) where the readout displays the Period in **Seconds^{-7}**

(1)	Readout Display	=	0.03612
	Linear Digits ($Hz^2/1000$)	=	(1 / 0.03612 x 10 $^{-2}$) ^{2} / 1000

$$= \quad 7664.8$$

(2)   Readout Display $= \quad 3612$
            Linear Digits $(Hz^2/1000)$ $= \quad (\,1\,/\,3612 \times 10^{-7}\,)^2\,/\,1000$
                                          $= \quad 7664.8$

If the readout displays 'Frequency' values, (e.g. 2768.5 Hz) only a simple calculation is required to convert the readings to Linear Digits.

            Linear Digits $(Hz^2/1000)$ $= \quad (\,2768.5\,)^2\,/\,1000$
                                          $= \quad 7664.6$

Certain data loggers store their Vibrating Wire data in Linear Digits but further divided by 1000. In this case the data would have to be multiplied by a further 1000 to maintain the standard Linear Digits $(Hz^2/1000)$ format for standard calculations.

There are many ways to achieve the conversion from recorded data to useful engineering values. The following are included as a guide only and as a basis for alternative approaches.

Linear Calculation

This is the most simple calculation to convert 'raw' data to engineering units. It can be easily carried out using a simple calculator. It assumes that the reading is in Linear Digits ($Hz^2/1000$). Where this is not the case, the reading should be converted to these units prior to application of the calibration factors. For most applications this equation is perfectly adequate and is carried out as follows:

Pressure (KPa) = Linear Factor for KPa (k) x (Current Reading - Base Reading)

Polynomial Calculation

The polynomial calculation can be more precise as it accommodates any slight deviation from a perfect linear correlation. However to use the polynomial equation the "C" Constant for the environment must be calculated using a "Site Zero" Reading at atmospheric pressure.

Once the Site "C" Constant is established the polynomial formula can be used to convert Raw Data to Engineering Units.

$$Site\ C = (-A \times Site\ Zero\ Reading^2) - (B \times Site\ Zero\ Reading)$$

The above formula essentially gives the relative change in the variable being measured

$$Engineering\ Unit = (A \times Reading^2) + (B \times Reading) + Site\ C$$

Where the Pressure is required in an alternative format, mH_2O for example, a simple conversion using standard conversion factors can be applied to each factor or at the end of the equation. (1 psi = 0.7031 mH_2O for example).

$$Eng\ Unit = (A \times Reading^2) + (B \times Reading) + (-A \times Site\ Zero\ Reading^2) \\ - (B \times Site\ Zero\ Reading)$$

$$Eng\ Unit = A \times (Reading^2 - Site\ Zero\ Reading^2) + B \times (Reading - Site\ Zero\ Reading)$$

An instrument calibration sheet similar to the example on page 21 includes the following information:

Model	This refers to the **Geosense**® model number.
Serial Number	This is a unique sensor identification number that can be found on the cable just behind the NATM cell body and, for long cables, at the end of the cable.
Works ID	Unique works batch and range code
Cal Date	Date the calibration was performed
Baro	Barometric Pressure at the time of calibration
Temp °C	Temperature at which the NATM cell was calibrated
DPI No.	Serial number of the Digital Pressure Indicator used in conjunction with the pressure generator
Readout No.	Serial Number of the readout used to display the transducer output
R/O Cal Date	The date on which the Readout was calibrated to a traceable standard
Applied Pressure	Pressure applied to the transducer as part of the calibration cycle in both psi and kPa
Readings [digit]	Readings from the transducer as pressure is applied and as pressure is reduced, in steps. The average is calculated.
Calculated Pressure	Calculation of the applied pressure using the calculated Linear and Polynomial for comparison with the actual Applied Pressure.
Non Lin. % FSO	Non Linearity expressed as a percentage of the transducers Full Scale.
Calibration Factors	'Linear' and 'Polynomial' factors are provided for a selection of engineering units (other units can be calculated directly from the kPa values). Examples of calculated values are detailed on the next page.

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6.3 Calibration certificate

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MGS QUALITY FORM
Form No MGS /QF/123
ISS. 5
DATE : 10/8/12
SIG SKH

VIBRATING WIRE NATM STRESS CELL

Model	VWNPC-3010	Cal date	16-Jul-12	DPI No.	52001702
Serial	312236	Baro	1014.0	Readout No.	VR0601
Works ID	50 6 65	Temp °C	22	R/O Cal. date	12/07/2012

Applied pressure		Readings [digit]			Calculated Pressure		Error % fso	
psi	kPa	1 up	1 down	avg.[digit]	lin.[kPa]	polyn.[kPa]	linear	polynomial
0.000	0.000	9499	9499	9499.0	-11.95	-1.26	-0.17%	-0.02%
200.145	1380.000	8747	8747	8747.0	1385.45	1383.26	0.08%	0.05%
400.290	2760.000	8004	8004	8004.0	2766.13	2757.63	0.09%	-0.03%
600.435	4140.000	7260	7260	7260.0	4148.66	4140.25	0.13%	0.00%
800.580	5520.000	6521	6521	6521.0	5521.90	5519.90	0.03%	0.00%
1000.725	6900.000	5785	5785	5785.0	6889.56	6900.23	-0.15%	0.00%

Calibration of master DPI valid from 16 sept 2010. UKAS Certificate of Calibration 08568 issued by Chamois Metrology (UKAS Accredited Calibration Laboratory 0822)

CALIBRATION FACTORS

Linear factor (k)

kPa per digit	psi per digit
-1.858241923	-0.269506

Polynomial factors

	kPa	psi
A	5.77774E-06	8.37961E-07
B	-1.946542977	-0.282312
C	17967.61713	2605.890809

Note: Digits are $Hz^2 \times 10^{-3}$ units.
(please consult the User Manuals for conversion of alternative reading units)
Polynomial calculation [kPa] = A * (Reading)2 + B * (Reading) + C

Linear calculation [kPa] = k (kPa) * (Current Reading - Site Zero Reading)

THIS CERTIFICATE IS VALID ONLY WHEN CARRYING THE
OFFICIAL ORIGINAL STAMP OF MGS-GEOSENSE BELOW

6.3 Pressure calculation

Readings from **Geosense**[®] vibrating wire sensors can be in various different formats depending on what readout is used. Typical examples are:-

Readout   **Format**

RST VW2106   Digits

Campbell data logger   Frequency

Calculation of the pressure is as follows:-

STEP 1 -   Confirm what format the data is in i.e. digits, frequency or period

STEP 2 -   Convert the readings as follows:-

A - **Digits**

Δ **Digits x K = pressure**

Where

Δ Digits   = (Current digit reading - base digit reading)
                        (Hz^2 x 10^{-3} - Hz^2 x 10^{-3})

K   = Linear calibration factor (obtained from calibration certificate)
                        KPa / Hz^2 x 10^{-3}

B - Frequency

Frequency should be converted into digits as follows:-

(frequency x frequency) x 10^{-3} = Digits

Calculate pressure from equation in A

6.4 Stress value

In practice as soon as the cell and the concrete are in contact the pressure reached inside the cell relates directly to the absolute concrete stress.

6.5 Temperature correction

All monitoring instrumentation is influenced by temperature. Whilst instruments and sensors can be calibrated in a laboratory environment it is advisable that site characterisation is carried out to allow any temperature compensation to be made.

It is recommended that a control cell or cells, depending on the size of the project are installed in a non stressed environment so that the effects of temperature can be monitored and the site specific compensation carried out on the data from the in-situ cells.

Geosense® NPC-3000 NATM Cells are fitted with internal thermistors which allow temperature to be monitored.

6.3 Temperature compensation

USING STEINHART & HART LOG

Thermistor Type. YSI 44005, Dale 1C 3001 B3, Alpha 13A3001-B3

Resistance/ temperature equation:-

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

Where:-

T = Temperature in degrees Centigrade
LnR= Natural log of Thermistor resistance.
A= $1.4051 * 10^{-3}$
B= $2.369 * 10^{-4}$
C= $1.019 * 10^{-7}$

(Applicable to the range –50 to + 150 Centigrade only)

Resistance versus temperature table

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	141.1	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
77.66K	-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	-34	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	292.4	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	5692	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	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	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

7.0   MAINTENANCE

Geosense® **NPC-3000 NATM Cells** are a maintenance free device for most applications. This is because it is intended for sub-surface installation and would normally be irretrievably sealed into concrete.

Maintenance of wiring connections between the NATM cell and any terminal panels / or loggers should involve occasional tightening of any screw terminals to prevent loose connections or cleaning to prevent the build up of corrosion.

8.0   TROUBLESHOOTING

It is generally accepted that when a Vibrating Wire instrument is producing a stable reading on a suitable readout, the value will be correct. Only on <u>very</u> rare occasions will this be untrue.

In almost all cases, a fluctuating reading is a sign of a faulty signal from the sensor. The fault could be in either the sensor, the connecting cable, any switch boxes or the readout. The best way to fault find an instrument is to isolate it from all other instruments and connections. Where possible begin fault finding from the sensor itself.

SYMPTOM	REMEDY
No reading from cell	Check for cable damage
No reading from cell	Check readout or data logger functionality
Unstable readings	Check readout setting
Unstable readings	Check data logger frequency settings
Unstable readings	Check for electrical interference
Unstable readings	Check earth

9.0 SPECIFICATION

Model	VWNPC-3000	VWNPC-3010
Type	Tangential	Radial
Range	2,3,5,7,20,35 MPa	2,3,5 MPa
Over range	150% FS (maximum)	150% FS (maximum)
Signal output	2000 - 3500 Hz	2000 - 3500 Hz
Resolution	±0.025% FS	±0.025% FS
Accuracy*	± 0.1% FS	± 0.1% FS
Linearity	<0.5% FS	<0.5% FS
Overall length	450mm	450mm
Cell dimension	100 x 200mm	150 x 250mm
Cell thickness	5mm	5mm
Operating temperature	-20 to + 80 ^{o}C	-20 to + 80 ^{o}C

10.0 SPARE PARTS

Geosense® **NPC-3000 NATM Cells** are sealed units, and there are no replaceable parts.

Civil engineering sites are hazardous environments and instrument cables can be easily damaged if they are not adequately protected. Geosense can therefore provide the following parts that may be required to effect repairs to instrument cables:

- PU coated 4 Core cable with foil shield and copper drain.

- PVC coated, armoured, 4 Core cable suitable for direct burial.

- Epoxy jointing kit for forming a waterproof cable joint.

Please contact Geosense for price and availability of the above components.

11.0 RETURN OF GOODS

11.1 Returns procedure
If goods are to be returned for either service/repair or warranty, the customer should contact **Geosense**® for a **Returns Authorisation Number,** request a **Returned Equipment Report Form QF034** and, where applicable, a **Returned Goods Health and Safety Clearance Form QF038** prior to shipment. Numbers must be clearly marked on the outside of the shipment.

Complete the **Returned Equipment Report Form QF034**, including as much detail as possible, and enclose it with the returned goods.

All returned goods are also to be accompanied by a completed **Returned Goods Health and Safety Clearance Form QF038** attached to the outside of the package (to be accessible without opening the package) and a copy of both forms should be faxed or emailed in advance to the factory.

11.1.1 Chargeable Service or Repairs

Inspection & estimate
It is the policy of **Geosense**® that an estimate is provided to the customer prior to any repair being carried out. A set charge for inspecting the equipment and providing an estimate is also chargeable.

11.1.2 Warranty Claim
(See Limited Warranty Conditions)
This covers defects which arise as a result of a failure in design or manufacturing. It is a condition of the warranty that the **Geosense**® **NPC-3000 NATM Cell** must be installed and used in accordance with the manufacturer's instructions and has not been subject to misuse.

In order to make a warranty claim, contact **Geosense**® and request a **Returned Equipment Report Form QF034.** Tick the warranty claim box and return the form with the goods as above. You will then be contacted and informed whether your warranty claim is valid.

11.2 Packaging and Carriage
All used goods shipped to the factory **must** be sealed inside a clean plastic bag and packed in a suitable carton. If the original packaging is not available, Geosense should be contacted for advice. **Geosense**® will not be responsible for damage resulting from inadequate returns packaging or contamination under any circumstances.

11.3 Transport & Storage
All goods should be adequately packaged to prevent damage in transit or intermediate storage.

12.0 LIMITED WARRANTY

The manufacturer, (Geosense**)**, warrants the **Geosense® NPC-3000 NATM Cell** manufactured by it, under normal use and service, to be free from defects in material and workmanship under the following terms and conditions:-

Sufficient site data has been provided to **Geosense®** by the purchaser as regards the nature of the installation to allow **Geosense®** to select the correct type and range of **Geosense® NPC-3000 NATM Cells** and other component parts.

The **Geosense® NPC-3000 NATM Cells** equipment shall be installed in accordance with the manufacturer's recommendations.

The equipment is warranted for 1 year from the date of shipment from the manufacturer to the purchaser.

The warranty is limited to replacement of part or parts which, are determined to be defective upon inspection at the factory. Shipment of defective part or parts to the factory shall be at the expense of the Purchaser. Return shipment of repaired/replaced part or parts covered by this warranty shall be at the expense of the Manufacturer.

Unauthorised alteration and/or repair by anyone which, causes failure of the unit or associated components will void this **LIMITED WARRANTY** in its entirety.

The Purchaser warrants through the purchase of the Geosense® NPC-3000 NATM Cell that he is familiar with the equipment and its proper use. In no event shall the manufacturer be liable for any injury, loss or damage, direct or consequential, special, incidental, indirect or punitive, arising out of the use of or inability to use the equipment sold to the Purchaser by the Manufacturer.

The Purchaser assumes all risks and liability whatsoever in connection with the NATM cell equipment from the time of delivery to Purchaser.

NOTES:

Geosense Ltd

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