BOART LONGYEAR INTERFELS

PRODUCT NO. 331.0000

STRESS MONITORING STATIONS

This equipment should be installed, maintained, and operated by technically qualified personnel. Any errors or omissions in data, or the interpretation of data, are not the responsibility of Boart Longyear Interfels GmbH. The information herein is subject to change without notification

Boart Longyear Interfels GmbH
Deilmannstr. 5
D-48455 Bad Bentheim

Tel: +49-5922-9898-0
Fax: +49-5922-9898-98
Interfels@boartlongyear-eu.com

Content

PRINTED IN GERMANY- 19/4/05

1 Stress Cell Design and Construction

The basic total pressure cell (TPC) is comprised of two stainless steel plates which are laser-welded together around the periphery, leaving a thin space between the plates which is filled with a special de-aired oil (see Fig. 1). For environmental reasons INTERFELS is avoiding the use of mercury as a TPC fluid. This approach is made possible by particular design features of the INTERFELS TPC such as:

- The steel plates are always rounded thus minimizing errors from stiff boundary sections of the TPC to the stress readings.
- The two steel plates which make up the TPC are of unequal thickness. There is a thicker base plate which gives the TPC a solid shape and which also provides the connections for the pressure tube and the pinch tubes; and there is a significantly thinner cover plate which is bent at its periphery to minimize the stiffness of the TPC in its outer section. This thinner side is the most sensitive side of the TPC.
- The height to width ratio of the INTERFELS TPC is very small, actually smaller than any other commercially available TPC. This gives superior TPC performance even in stiff media such as concrete.

The oil-filled space of the TPC is connected via a pressure tube to a membrane switch pressure sensor. Stresses applied normal to the plates of the TPC which shall be monitored are balanced by a corresponding built-up of internal fluid pressure which is then measured by the membrane switch using a manual compensation pump.

Mounting eyes are provided at the edges of the tangential TPC to allow for easy positioning of the cell prior to embedment in the shotcrete or concrete.

One design aspect of the TPC should be particularly noted to secure proper TPC functioning in stiff media: This is the pinch tube which, like the TPC body, is completely filled with de-aired oil. The tube is connected at one end to the fluid-filled space between the TPC plates whilst the other end is entirely squeezed (blind tube). The purpose of this pinch tube is to slightly inflate the cell when the concrete around it has fully cured and has cooled off to the ambient temperature. During concrete curing, temperatures rise and will cause the cell fluid to expand. After curing the cell fluid shrinks thus leaving a small gap between the pressure cell plates and the now hardened concrete. For reliable measurements the pressure cell plates have to be brought back into direct contact with the surrounding concrete. This is done by squeezing of the pinch tube by heavy-duty pliers thus injecting some additional fluid into the body of the TPC. Very often only a very small amount of pinching, typically by some 10 to 20 mm, will do to re-establish the full contact between TPC plates. This is typically indicated by a significant increase of the cell pressure.

Repressurization is also recommended when the TPC is placed in a pre-formed bed (e. g. by a mould inserted in the concrete and later on replaced by the TPC). This is particularly relevant when using TPCs for precast tunnel concrete segments.

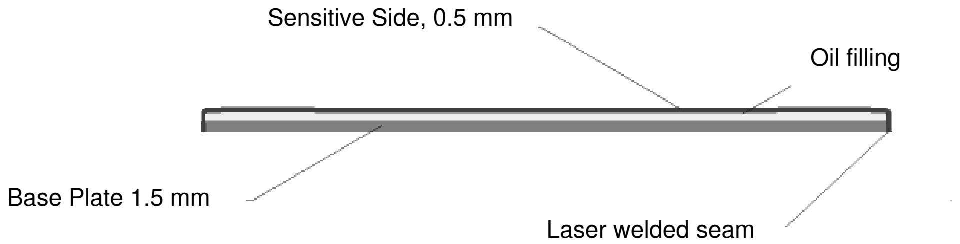


Fig. 1 Cross Section of an INTERFELS TPC

PRINTED IN GERMANY- 19/4/05

2 Specifications

2.1 Radial TPC

Radial-TPC:	
Length	283 mm
Width	151 mm
Thickness	3,5 mm
Effective area	375 cm^2
Material	stainless steel (1.4571)
Weld Seam	Laser
Pressure fluid	Hydraulic oil, de-aired

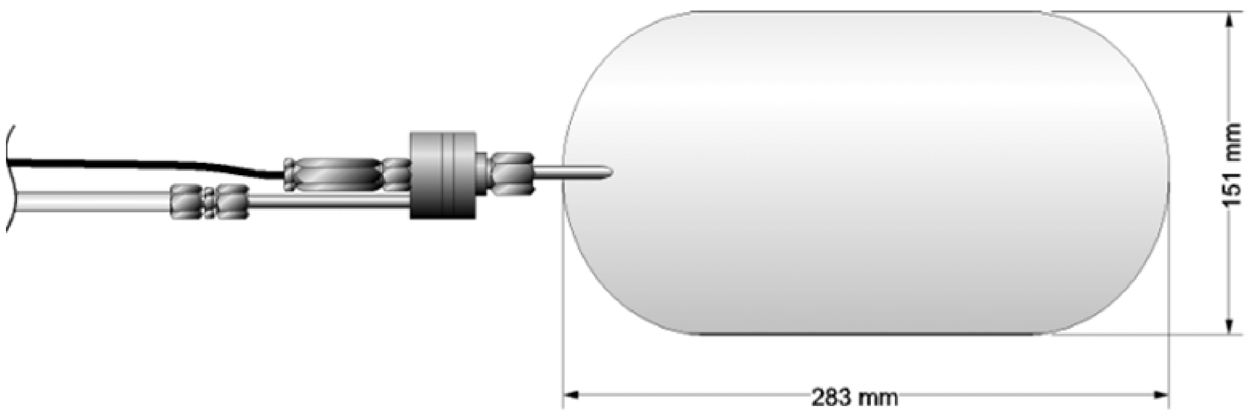


Fig. 2 INTERFELS Radial Pressure Cell with Membrane Switch (also available: VW Pressure Transducer)

PRINTED IN GERMANY- 19/4/05

2.2 Tangential TPC

Tangential-TPC:	
Length	222.5 mm
Width	101 mm
Thickness	3,5 mm
Effective area	200 cm^2
Length Post-Tensioning Tube	app. 450 mm
Material	stainless steel (1.4571)
Weld Seam	Laser
Pressure fluid	Hydraulic oil, de-aired

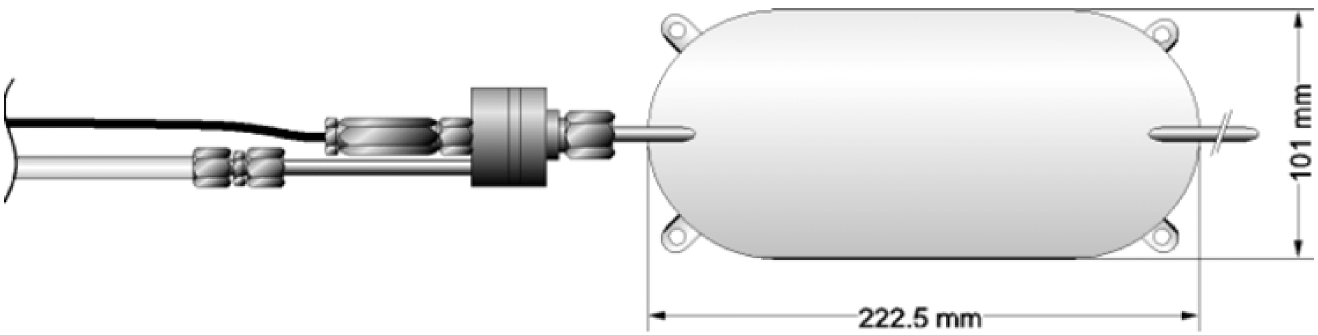


Fig. 3 INTERFELS Tangential Total Pressure Cell with Membrane Switch, Mounting Eyes and Post-Tensioning Tube ((also available: VW Pressure Transducer)

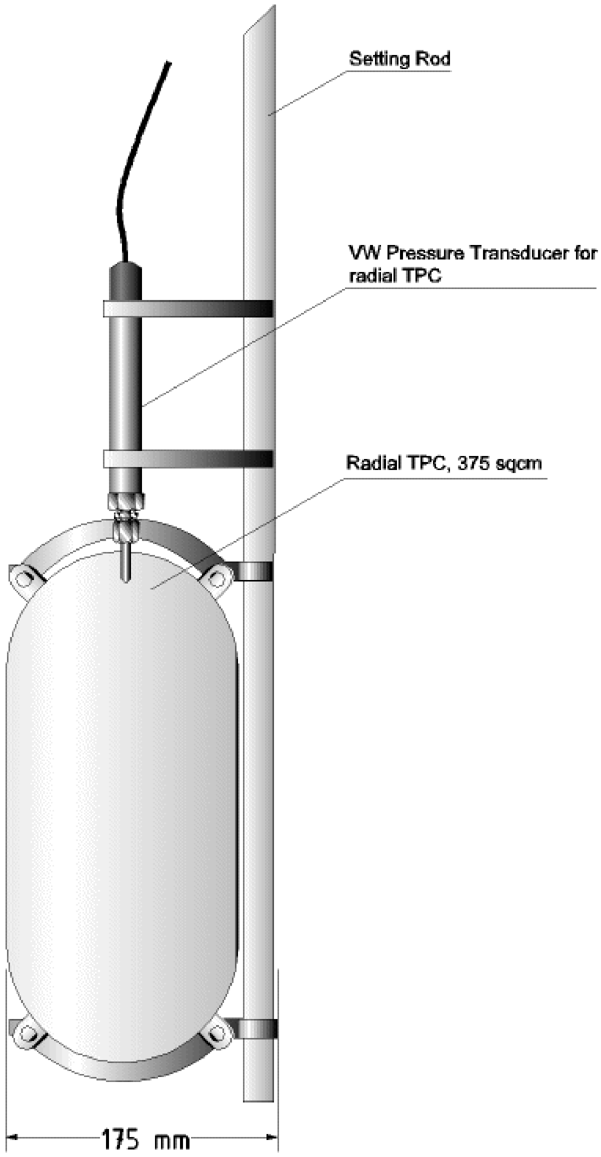
PRINTED IN GERMANY- 19/4/05

3 Types of Stress Monitoring Stations

Different Types of Stress Monitoring Stations are available for a large number of bore hole applications and stress directions.

3.1 1D Version

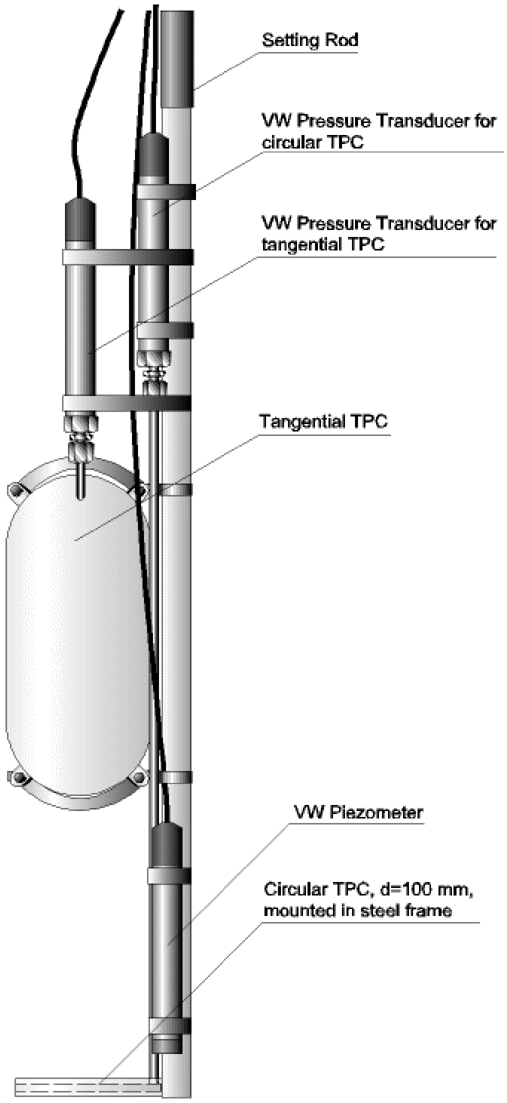
Typically used for monitoring stresses in one direction perpendicular to the bore hole axis.



PRINTED IN GERMANY- 19/4/05

3.2 2D Version

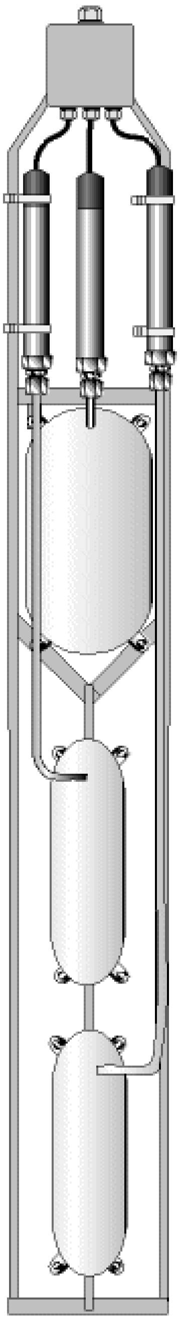
In a 2D Version stresses perpendicular to the bore hole axis as well as parallel to the bore hole axis can be obtained.



PRINTED IN GERMANY- 19/4/05

3.3 3D Version

The preferred layout for 3D versions are three radial or tangential cells positioned 120° to each other for monitoring stress fields perpendicular to the bore hole axis.



PRINTED IN GERMANY- 19/4/05

4 Installation

Adequate installation is imperative for proper stress monitoring. According to the rock or soil conditions the backfill material must be chosen carefully and be adapted to the stiffness of the rock or soil.

Two installation procedures are feasible, one being the Soft inclusion method the other one the hard inclusion.

4.1 Soft Inclusion

When installing stress monitoring stations into soft rock such as shale or clay it is advisable to backfill the bore hole using cement-bentonite-grout mixes which should be adjusted to the modulus of the surounding material as described below. For installation insert the stress monitoring station into the borehole using the guiding rod and position the TPCs according to the assumed stress field. For easier backfilling also attach a tremie pipe.

You will need a mixer, a grout pump and a pipe or hose for delivering the grout. We recommend that you do not mix the grout by hand. We also recommend that you do not use a water pump to place the grout, since pumping grout would damage it. Properly mixed grout should be free of lumps. It has to be thin enough to pump but thick enough to set in a reasonable length of time. If the mixture is too watery, it will shrink excessively, leaving the upper portion of the borehole ungrouted. Also, avoid the use of admixtures and grouts that cure at high temperature since these may damage the instruments.

Mix cement with water first. Then mix in the bentonite. Adjust the amount of bentonite to produce a grout within the consistency of heavy cream. If the grout is too thin, the solids and the water will separate. If the grout is too thick, it will be difficult to pump.

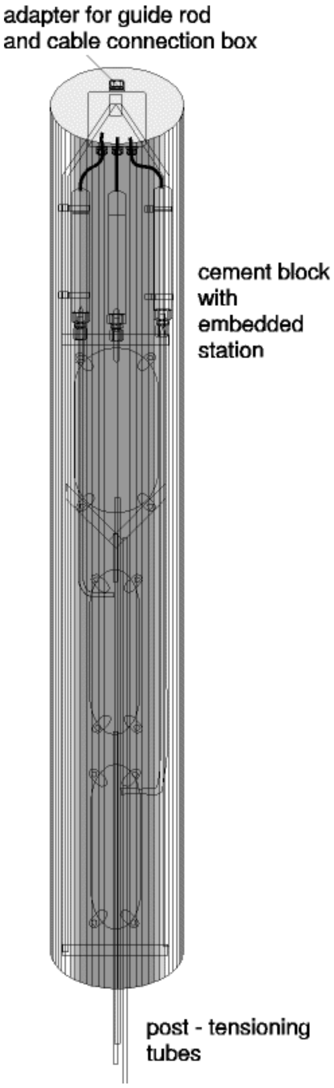
Cement-Bentonite Grout Mixes				
Application	**Grout for Medium to Hard Soils**		**Grout for Soft Soils**	
Materials	Weight	Ratio by weight	Weight	Ratio by weight
Water	110 L	2.5	280 L	6.6
Portland Cement	40 kg (1 sack)	1	40 kg (1 sack)	1
Bentonite	10 kg (as required)	0.3	18 kg	0.4
Notes	The 28-day compressive strength of this mix is about 0.35 MPa, similar to very stiff to hard clay. The modulus is about 70 MPa		The 28-day strength of this mix is about 0.03 MPa, similar to very soft clay.	

Grouting is always done from the bottom of the bore hole upwards. In upwards dipping bore holes it is import to insert a deairing tube to the end of the hole. To prepare a polyethylene hose for grouting, cut a wedge-shaped end and several additional holes.

PRINTED IN GERMANY- 19/4/05

4.2 Hard Inclusion

When installing a stress monitoring station in hard rock the preferred method would be to prepare a hard inclusion. For hard inclusions only tangential pressure cells with post tensioning tubes can be used.



Prepare an appropriate cast such as a PVC tube with an outer diameter that easily fits into the prepared bore hole whereas the inner diameter should accommodate the complete stress station. The minimum recommended casing size is 5'' (127 mm). Slightly greasing the inside of the casing facilitates the removal of the concrete core.

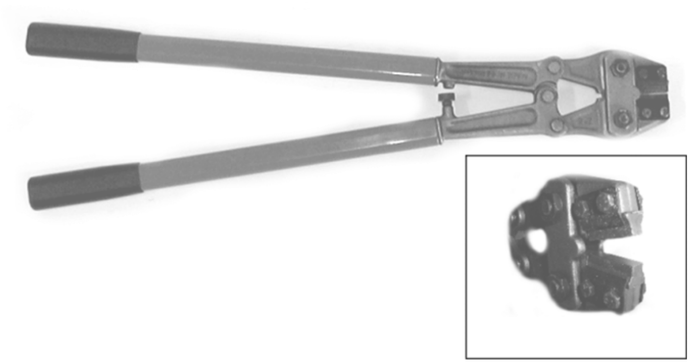
Choose a length of casing appropriate to the design of the stress monitoring station. The connection box for the cables as well as the adapter for the rods should be accessible at the top; the post tensioning tubes should be accessible for at least 100 mm at the bottom.

Use a type of concrete with a modulus comparable to the surrounding rock.

Insert the station into the casing and close the lower end. Remember to allow the post tensioning tubes to stick out at least 100 to 150 mm. Mark tubes with tape for identification of the cells.

Pour concrete mix into cast and wait until set. Remove core from casing.

Carefully post tension the cells by pinching the tubes with the pliers (see picture below) starting at the end.



IMPORTANT: While pinching it is imperative to monitor the internal pressure in the cells. As soon as a significant increase in pressure is noticeable stop the post tensioning procedure. Increase of pressure indicates that the cell is now in contact with the cement, further post tensioning could crack the concrete core.

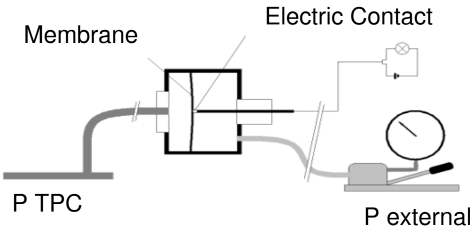
PRINTED IN GERMANY- 19/4/05

5 Taking Readings

5.1 INTERFELS Membrane Switch

5.1.1 Measuring Principle of the Membrane Switch

The pressure reading is performed by using the compensation method. The membrane switch is attached to the TPC. When the cell is installed and stressed, the pressure inside it causes the membrane to touch the contact pin. The switch is closed. An external compensation pump is connected to the cell using the quick connect coupling inside the connection box. By pumping oil into the hydraulic line, pressure is applied to the stainless steel membrane inside the switch. When the pressure on the pump side slightly exceeds the pressure on the cell side the membrane will bend and open the switch (see below). An LED Unit with an internal battery attached to the electric connector inside the connection box indicates closed and open switch position (LED on or off). The compensation pressure is directly read from the pressure gauge on the compensation pump. To receive the correct pressure reading the procedure should be repeated at least once.



Measuring Principle of INTERFELS Membrane Switch

5.1.2 Obtaining Pressure Readings in the Field

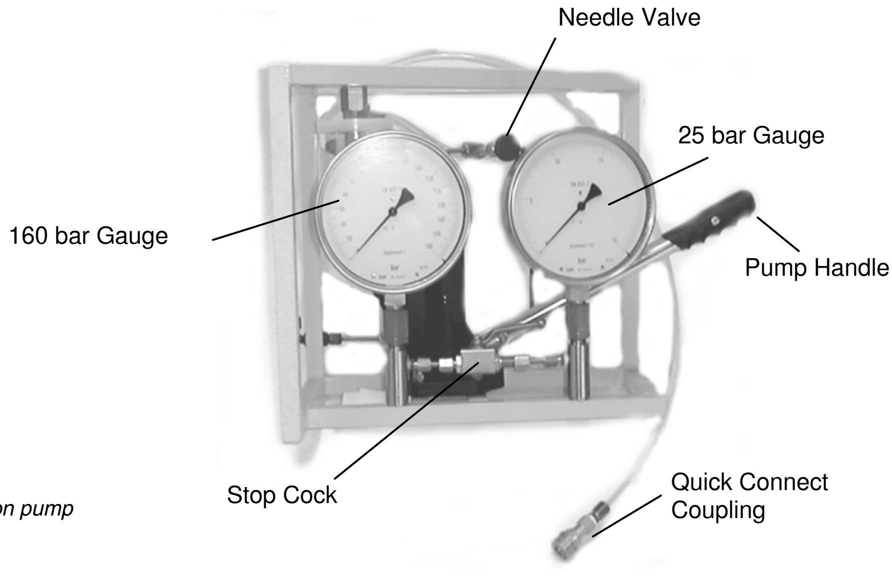
When on site open connection box and insert LED Unit into the electric connector of the TPC to be monitored. Since there should be pressure in the cell the LED should be ON.

Attach the compensation pump with the quick connect coupling to the corresponding hydraulic line(see below).

Now close the needle valve on the pump by turning it clockwise and start pumping. Observe pressure gauge reading and LED unit. When the LED goes out, compensation pressure is reached. Opening the needle valve releases pressure and will cause the LED to light again. This way the reading can be obtained starting below and above the actual compensation pressure.

Pressure readings smaller than 25 bar (app. 360 PSI) should be performed using the gauge on the right, whereas readings above 25 bar up to 160 bar (app. App. 2300 PSI) must be obtained using the gauge on the left.

NOTE: To avoid damaging the 25 bar gauge, make sure to close the stop cock between the pressure gauges when reading higher pressure.



INTERFELS compensation pump

PRINTED IN GERMANY- 19/4/05

Always perform pressure readings before and after installation of TPCs to check for proper system function. This will also indicate leaks and cable breaks.

NOTE: Unstressed cells usually show a load of app. 0.8 bar. This is normal and due to technical reasons by prestressing the membrane switch for proper functioning.

Differences in elevation between position of TPC and compensation pumps must be taken into account. Apply necessary corrections for hydrostatic pressure in the line.

$$P_{TPC} = P_{Gauge} - P_{Preload} + P_{Hydrostatic\ Pressure}$$

When applying all necessary corrections a system accuracy of app. 0.1 bar can be obtained.

5.2 Vibrating Wire (VW) Pressure Transducer

For faster and easier reading of pressure values VW transducers can be installed on the TPCs. They are electrical sensors which are read using a VW readout unit or an appropriate data acquisition system such as the Campbell CR10X data logger.

5.2.1 Connect to the Sensor

The VWP Indicator is typically supplied with either of two jumper cables. Both are have a Lemo connector that plugs into the transducer socket on the front panel of the indicator.

Standard Jumper 52611950

This cable has alligator clips that are connected to wires of the signal cable as shown in the table below:

Clips	Wire Colors		Function
Red	Orange	Red	VW
Red	White & Orange	Black	VW
Black	Blue	White	RTD
Black	White & Blue	Green	RTD

5.2.2 Select a Sweep

Range Press the SWEEP key to select the sweep range that is suitable for the transducer. Each press of the key displays a different range:

- •0.45 - 1.2 kHz
- •0.80 - 2.0 kHz
- •1.40 - 3.5 kHz
- •2.40 - 6.0 kHz

See the next page for suggested settings for specific sensors. In general, you should select a sweep range that matches the range of frequencies reported on the sensor calibration sheet. When the indicator plucks the sensor, it displays an exclamation mark (!). If an incorrect sweep frequency range is selected, the display blinks or displays a zero.

5.2.3 Select a Data Type

Press the DATA key to select the type of data you require. The displayed reading and its label changes with each press of the key. Data types appear in the following order:

- •Hz (Use with any vibrating wire sensor).
- •µstrain VW (microstrain - use only with Slope Indicator’s VW spot-weldable strain gauge).
- •µstrain VS (microstrain - use only with Slope Indicator’s retired arc-weldable or embedment strain gauge. Do not use with Slope
- Indicator’s current arc-weldable or embedment strain gauge).
- •Hz 2
- •µSec
- •°C (for RTD temperature sensors)
- •Batt (battery test)

PRINTED IN GERMANY- 19/4/05

5.2.4 Data Reduction

Overview
Readings from the VW pressure transducer are typically in Hz, rather than in units of pressure. To convert the Hz reading to units of pressure, you must apply factors listed on the sensor calibration record.

Sensor Calibration Record
Each VW transducer has a unique calibration. Use the sensor serial number to match the sensor with its calibration record.

Conversion Factors
ABC Factors: Your calibration record may list these as "manual" ABC factors. They are used to convert Hz readings to various engineering units. They can be used in programmable readouts, such as the DataMate MP, or they can be used in spreadsheets. Keep in mind that it is always a good idea to record unprocessed readings (Hz and °C). Processing on your PC is almost always preferable to processing in the readout or data logger.

Correction Factors
These two factors can be used to correct the pressure reading for temperature effects. These factors are applied to the temperature reading that you obtain from the sensor's built-in thermistor or RTD. Older calibration records list a temperature coefficient.

Temperature Offset
The temperature offset shows the difference between a reading taken with the transducer's built-in thermistor or RTD and a reading taken with an NIST-traceable temperature sensor. If you are interested in more accurate temperature values, add the offset to your temperature readings. However, do not add the offset when you are calculating temperature corrections.

Converting Hz Readings to Units of Pressure

- Choose a unit of pressure from the ABC factors listed on the sensor calibration record.
- Apply the factors as follows:

$$\text{Pressure Reading} = Ax^2 + Bx + C$$

Where x is the Hz reading and A, B, and C are factors listed on the sensor calibration record

Finding Changes in Pressure
Subtract the initial reading from the current reading. A positive value indicates increased pressure. A negative reading indicates decreased pressure.

$$\Delta\text{Pressure} = \text{Pressure current} - \text{Pressure initial}$$

PRINTED IN GERMANY- 19/4/05