INSTRUCTION MANUAL

FIBER-OPTIC TOTAL PRESSURE CELL

Models FO-TPC and FO-EPC

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

E1168-000808

TABLE OF CONTENTS

1 PRODUCT

1.1 INTRODUCTION

The FO-TPC and FO-EPC series of fiber optic total pressure cells are designed to measure the total stress acting in embankments, in mine backfill and mass concrete. They are also used to measure the contact pressures on tunnel linings, foundations, slurry and retaining walls, culverts or other embedded structures.

The FO-TPC and FO-EPC are hydraulic cells comprised of oil filled pressure pad connected to a pressure transducer.

Two types are available.

- Model **TPC** with a thin film oil filled pressure pad for cells installed or embedded in contact with soils, concrete or soft medium rock. The model TPC cell has a cross-sectional modulus of rigidity of approximately 35 x 10^6 kPa (5 x 10^6 psi) making it suitable for embedment in concrete where temperature variations are small.

- Model **EPC**, with oil filled pressure pad for cells installed in contact with soils or mine backfill. (cell modulus 17 x 10^6 kPa / 2.5 x 10^6 psi)

The models TPC and EPC pressure cells are fitted with either a FPC pneumatic pad, a vibrating wire pressure transducers, a fiber optic pressure transducers or an electrical 4-20 mA pressure transducers. The EPC can also be fitted with a bourdon pressure gage connected to the pressure pad by the length of pressure tubing required to remotely read the cell.

The TPC model is also available in rectangular shape designed for the measurement of radial and tangential stresses in shotcrete tunnel linings.

The stiffness of the TPC earth pressure cell is very high. This high stiffness is due to the very small quantity of oil used in the cell and the very high stiffness of the vibrating wire pressure transducer used to measure the oil pressures.

The small quantity of oil in the pad also minimizes the cell's susceptibility to temperature effects.

The pad is very flexible thanks to its peripheral groove. This way, the oil pressure is directly equal to the soil contact pressure on the pad. This undercutting also has the advantage of surrounding the active pad by a rigid annulus that greatly decreases its sensitivity to stresses in directions other than normal to the cell faces.

In the EPC cell, the layer of fluid is much thicker. This makes it less stiff and suitable for installation in less dense soils and mine backfill. The larger volume of fluid also requires that this cell be installed in relatively stable temperature environments with special attention given to the uniformity of the bedding on which the cell is placed.

In use, the cell is embedded and oriented with its plane perpendicular to the anticipated direction of principal stress. A cluster of cells can be installed to permit the measurement of both the magnitude and the direction of the principal stress or to measure stress in different directions. Where the pressure acting on foundation retaining wall, etc. is to be measured, the cell is usually positioned directly between the structure and the fill.

1.2 CONSTRUCTION DETAILS

The TPC pressure cell consist of two steel discs welded around their periphery and then recessed on both sides to provide a central flexible pad. Both sides of the cell are active which gives more reliance on measurements at the inner face. A short length of thick wall steel tubing is welded into the edge of the pressure cell and communicates with a cylindrical housing containing a pressure transducer. During construction, the cell is first put under a vacuum to remove any air, and deaerated oil is injected into the cell under pressure to force the plates apart separating them by a thin fluid film.

The fluid also fills the steel tubing and cavity in the cylindrical housing containing the pressure transducer.

The pressure transducer senses a variation in fluid pressure resulting from changes of load acting on the cell.

The TPC, equipped with fiber optic pressure transducers, are fitted with a watertight cable to allow remote reading of the pressure changes.

The fiber optic transducer pressure cells are monitored manually or automatically using the FTI-10, UMI-4/8 or the DMI-32 data acquisition system.

The EPC hydraulic total pressure cell consists of two thin flexible stainless steel plates with rolled edges that are welded together around their periphery. As with the TPC cell, both sides of the cell are active and the pressure pad communicates with the pressure transducer via a short length of stainless steel tubing. Alternatively, the EPC pressure pad can be connected to a bourdon type pressure gage via a length of flexible plastic or metallic tubing. This version of the EPC is widely used in the mining industry for measuring total pressure in backfill.

All other EPC construction details are the same as for the TPC model.

1.3 SPECIFICATIONS

GENERAL				
Model	**TPC**		**EPC**	
Range with fiber optic transducer (kPa)	200, 350, 500, 750, 1000, 1500, 2000, 3000, 5000, 10000 20000		200, 350, 500, 750, 1000, 1500, 2000	
(psi)	25, 50, 75, 100, 150, 250, 300, 500, 750, 1500, 3000		25, 50, 75, 100, 150, 250, 300	
Construction	Pad with semi-rigid surfaces and peripheral groove		Pad with low rigidity surfaces	
Applications	- Earth and fill embankments - Contact pressure on retaining walls, piers, abutment piles and tunnel linings - Stress in concrete		- Earth and fill embankments	
Overload	2 x FS		2 x FS	
Material	17-4 PH Stainless steel		17-4 PH Stainless steel	
MEASURING SENSOR				
Model	**TPC and EPC**			
Transducer type	**Fiber optic**	**Vibrating wire**	**Pneumatic**	**Electrical**
Accuracy	±0.1% FS (0.05% in option)	±0.5% FS (0.1% in option)	±0.25% FS	±0.5% FS
Resolution	0.01% of full scale	0.01% of full scale	According to pressure gauge	0.01% FS
Pressure range kPa (psi)	0 - 20 000 (0 - 3 000)	0 - 20 000 (0 - 3 000)	0 - 3 500 (0 - 500)	0 - 2 000 (0 - 300)
Electrical surtension protection	-	Included	-	Included
Readout unit	FTI-10, UMI-4/8 DMI-32	Portable MB-6T/6TL PFC-10	Portable PR-20/20D	4-20 mA readout unit
Data acquisition system	All readout unit	Sens-Log	Sens-Log	Sens-Log
DIMENSIONS				
Model	**TPC**		**EPC**	
	Thickness: 0.63 cm		Thickness: 0.99 cm	
Circular cell	Diameter : 23 cm		Diameter: 23 cm	
Rectangular cell	10 x 20 cm		-	
	15 x 25 cm		-	
	20 x 30 cm		-	

2 DATA READING AND ANALYSIS

2.1 PREPARATION FOR INITIAL READING

Gage readings should be taken as soon as the gages are received to ensure they have not been damaged during shipment. All gage transducers are individually calibrated before shipment and a gage factor (7-digit number) and the gage zero obtained at factory, in internal unit of Fabry-Perot cavity length, are supplied with each gage. Before using a transducer with the Universal fiber-optic readout unit from Roctest and Fiso Technologies, its gage factor must first be saved in the readout memory and selected. The calibration factor is already recorded in the transducer's gage factor, which is registered on a label installed on the cable close to the fiber-optic connector and you can also find it on the calibration sheet of the gage. Please review the operating manual of the readout unit before proceeding with readings.

First the gage must be connected in a channel number and the appropriate gage factor must be assigned. **Fiber-optic pressure transducers must be nulled at least once to adjust the zero before taken an initial reading**. For nulling your transducer follow the instructions given in the operating manual of your readout. After nulling your transducer with the appropriate gage factor pre-selected, the reading will indicate 0 or a very small value. Obviously, the transducer should not be submitted to pressure for a true zero reading and should be stabilized in temperature. **The zero adjustment of the transducer is necessary when using for the first time a pressure transducer**. **It is also necessary to take note of the current value at installation of the gage zero (value between 14000 and 24000) when doing a zero adjustment. Knowing it is possible to re-enter the initial gage zero at installation could be useful in the case the readout is reset or its memory content is lost. For more information about zero adjustment and taking note of the gage zero see the operating manual of your readout.**

You can also select the Imperial system of unit (in this case the reading will be displayed in psi) or the Metric system of unit (reading will be displayed in bars). See the operating manual of your readout for more information about the system of units.

Steps before taking a reading

1. Save gage factor into the readout memory
2. Connect each gage to one of the channel input connectors
3. Associate appropriate gage factor to the measuring channel
4. Null gages and ***record the gage zero in internal unit of Fabry-Perot cavity length***
5. Select appropriate system of units
6. Take your initial reading in engineering unit

2.2 PRE-INSTALLATION INITIAL READING

Before installing the sensor, it is necessary to take an initial reading. The procedure for taking an initial reading is the following:

Take a pre-initial reading in air at a stabilized temperature and at a known barometric pressure. Record the reading, the temperature reading and the barometric pressure reading. Do not touch the transducer body with your hand because you will change the temperature of the transducer and you can see a variation of the reading.

2.3 PRESSURE EQUATIONS

The TPC/EPC measure absolute pressure and must be corrected for barometric pressure changes.

The cells are supplied with a temperature correction factor, which is used to correct the pressure reading for significant variations in temperature.

To convert changes in readings to changes in pressure corrected for barometric pressure and temperature changes, use the following equation:

Imperial units (psi)

$$\mathbf{P_{corr} = P_{rec} - CT\,(T_1 - T_0) - 0.491\,(B_1 - B_0)}$$

where:

where:	P_{corr}	=	corrected pressure in psi
	P_{rec}	=	recorded pressure in psi
	CT	=	temperature correction factor in psi/°F
	T_o T_1	=	initial (at installation) and current temperature readings (°F)
	B_o B_1	=	initial (at installation) and current barometric pressure in in. of Hg
	0.491	=	constant for all sensors in psi/in. of Hg.

Example:

P_{rec}	=	22.25 psi
CT	=	0.01879 psi/°F
T_o	=	65°F
T_1	=	80°F
B_o	=	29.8 in. Hg
B_1	=	29.4 in. Hg
P_{corr}	=	22.25 - 0.01879 (80 - 65) - 0.491 (29.4 - 29.8)
P_{corr}	=	22.25 - 0.282 + 0.196 = 22.16 psi

SI units (bar)

$$\mathbf{P_{corr} = P_{rec} - CT\,(T_1 - T_0) - (B_1 - B_0)}$$

where:	P_{corr}	=	corrected pressure in bars
	P_{rec}	=	recorded pressure in bars
	CT	=	temperature correction factor in bar/^oC
	T_o T_1	=	Initial (at installation) and current temperature readings (^oC)
	B_o B_1	=	Initial (at installation) and current barometric pressure in bars.

Example:

P_{rec} = 4.500 bars

CT = 0.00143 bar/°C

T_o = 20°C

T_1 = 25°C

B_o = 1.013 bars

B_1 = 1.002 bars

P_{corr} = 4.500 - 0.00143 (25 - 20) – (1.002 – 1.013)

P_{corr} = 4.500 - 0.007 + 0.011 = 4.504 bars

3 INSTALLATION

The TPC/EPC are shipped mounted to a wooden backing board. It is recommended that this wooden backing board be left taped to the cell until the last possible minute. This will prevent undue deformation of both the connecting tube between the pad and the transducer housing and the repressurization tube (optional). During installation, the cells should be read frequently and at the completion of each stage.

3.1 SELECTION OF LOCATIONS

Cells are installed either individually, in pairs or clusters to measure pressures in different directions at the same location. Adjacent cells should be separated by a distance of at least 4 cell diameters in such a way as to prevent the presence of a cell affecting readings on adjacent cells.

The location for the cell or cells is determined according to the specific objectives of the measurements, however each cell should be located in ground that is undisturbed (for example by blasting) and that is typical of the surrounding materials.

The cell must be uniform and in complete contact with the surrounding material. Soil or rock adjacent to the cell should be free from protrusions or unrepresentative material that would result in stress irregularities on the flatjack.

Cells should preferably not be located where they will be exposed to appreciable temperature changes, for example by the action of direct sunlight or cold winds on exposed surfaces. Insulation may be required in such cases.

3.2 INSTALLATION IN SOILS

The most important factors to take into consideration when installing pressure cells in soil or fill are:

a) Ensure intimate contact between the cell and the cell bedding material making sure that the latter is uniformly compacted to the same density as the surrounding fill or soil.

b) Avoid localized or point loading of the cell by large aggregate or pebbles. (It is usually recommended that the largest sized aggregate in contact with the face of an earth pressure cell not be greater than 1/50 the pad diameter.)

c) Avoid disturbing the natural distribution of fill or surrounding soil as much as possible.

To ensure uniform representative loading of the pressure cell pad, **the cell and its transducer are embedded in lenses of stone free excavated material with the same water content and hand compacted to the same density as the surrounding soil.**

The width of each individual lens should be at least 3 times the diameter of the cell pressure pad with no lens being smaller than 10 times the diameter of the largest rock in the embankment material.

The lens should be long enough to encapsulate the pressure transducer and the pressure tube to avoid any differential movements in the area where the cell is embedded.

The total thickness of the embedment lens should be 1/2 to 1/3 the length of the lens depending on the particle size shape and degree of compaction.

To prevent damage to the cells, the lens and cells are installed in an excavation made to accommodate them. The cells are installed in a lens forming a mound on the base of the excavation or within a lens in a pocket excavated in the base of the excavation.

A typical excavation to accommodate a cluster of three cells is shown on Figure 2. In this example, the cells are located in pockets in an excavation. The cell pockets should be excavated with extreme care to avoid disturbance to the soil. The pockets should be located 1 meter away from adjacent pockets or the excavation walls.

The width of the pocket should be equal to a minimum of 3 pad diameters to avoid load bridging. The length of the pocket (axis of the pressure transducer) should be 6 pad diameters to accommodate the length of the pressure cell and to provide 1 pad diameter clearance at either extremity of the pressure cell. (See Figure 2).

The bedding for the cell and the underlying material should be carefully compacted to the same density of the surrounding fill. Any protruding stones should be removed and replaced with compacted stone free excavated backfill. It is important that the cell bedding be of uniformly compacted material.

The cell is then fixed in position taking care that it is fully in contact with the underlying material, and checking to make sure it is functioning correctly.

If required, the position and orientation of the cell can be maintained during installation by means of a plywood template. This template is removed after the material immediately surrounding the cell has been placed and carefully hand-compacted.

Each cell is then backfilled with selected material hand-compacted to a density similar to that of the surrounding soil.

In areas containing appreciable coarse material, the lens should be enclosed in transitional layers of successively coarser material in order to establish a gradation outward to the maximum size material.

Total pressure cell clusters, placed according to the suggested methods outlined above, may be installed whether in trenches, below the temporary embankment grade, or in mounds above the temporary embankment grade. In dams, for example, it is usually convenient to install in trenches in the impervious rolled fill core, and in ramps in the filter zones and compacted rockfill shell zones. In earth embankments, it is convenient to install in trenches. By so doing, adequate degrees of compaction of the backfill can be more easily obtained without damage to the cell clusters or cable arrays.

Cable details are outlined below. The precautions to be observed in protecting the cable from damage by heavy vibratory compaction equipment should also be observed in connection with the cell clusters. In general, all material in the instrument lenses should be placed by hand and compacted with pneumatic or gasoline backfill tampers. The first layers of transitional material over the lenses should be placed in 10 cm lifts and similarly compacted until at least 46 cm of material has been so placed. At that time rubber-tired equipment can cross the lens location, but no heavy vibratory rollers should be permitted across the lens until it is protected by a compacted thickness of at least 3 m of fill.

As the cells are being covered and compacted, repeated readings should be taken to ensure that the cells are continuing to function properly.

3.3 INSTALLATION FOR MEASUREMENTS ON STRUCTURES

In backfill for piers, piles, retaining walls, culverts and other structures where load measurements are desired, the cells are either attached to the forms and placed in the structure before concreting, fastened to the structure after concreting prior to backfilling or embedded in the backfill a short distance away from the structure. For the three methods, the contact between the cell and the backfill should be effected by means of a lens of stone free selected material, preferably the same as the surrounding fill material as previously described.

In the first method, where the cell is installed in the form work before concreting, it is necessary to ensure that the cell is securely held in place against the formwork during the concreting operation. The cable should be secured to the formwork or reinforcing steel at intervals not exceeding 0.5 meter. Concrete vibrators should not be allowed to come in contact with the cell or lead cables.

Attaching the cell to an existing structure prior to backfilling can be accomplished using cement mortar.

A pad of cement mortar (for example 1:2 cement:sand, 4 second flow cone reading) is trowelled onto the structure’s surface and the cell is placed against the pad squeezing out mortar until a layer no more than 5-10 mm thick remains beneath the flatjack. Entrapment of air bubbles must be avoided. The cell is secured in position such that the cell remains in place during the backfilling operation.

The cable is led along the wall of the structure or excavation to the terminal unit, is labeled and fixed securely.

In certain applications, because of individual structural configurations, it may be desirable not to place the cell directly in contact with the structure’s surface. The cell is bedded in a lens of stone free fill material with dimensions, density and water content as described for cells embedded in soils. In such instances, a minimum of 5 cm of fine selected material may be placed between the cell and the structure’s surface. If the cell is to be oriented other than parallel to the surface, the minimum spacing between the cell and the structure should also be at least 5 cm.

3.4 INSTALLATION AT THE INTERFACE BETWEEN CONCRETE AND ROCK

The area of rock or concrete over which the cell is to be placed should be prepared flat ±10 mm. Loose material should be removed. The area should be pre-coated with a 15 mm thick layer of cement mortar. The cell should be cleaned of grease and any aluminum paint and dipped in cement mortar.

A pad of cement mortar (for example 1:2 cement: sand, 4 second flow cone reading) is trowelled onto the rock or concrete surface and the cell is placed against the pad squeezing out mortar until a layer no more than 5-10 mm thick remains beneath the flat jack. Entrapment of air bubbles must be avoided. The cell is secured in position either by tying to pins in the rock or concrete, or by securing it to nearby reinforcement.

The cell is then coated with a 10-25 mm layer of the cement mortar which is allowed to set completely before the shotcreting operations begin. To avoid bridging between the cell and the concrete due to the differential expansion of the concrete and the cell, it is necessary to keep the temperature of the mortar as low as possible during the cure. This can be achieved by keeping the mortar covered with a wet burlap during the initial cure.

The cable is led along the wall of the structure or excavation to the terminal unit, is labeled, and is fixed securely to the reinforcement or to pins in the rock or concrete. If the cable is to be embedded in concrete or shotcrete, it must be secured at intervals not exceeding 3 m along its length. Kinks and constrictions in the cable must be avoided. A cable that is not to be protected by embedment in concrete must be protected by other means, for example by metal conduit.

The correct functioning of each cell is to be checked and any leaks repaired before concrete or shotcrete is placed.

3.5 INSTALLATION IN MASS CONCRETE

The cell is fixed to the reinforcement or the structure. Its positioning should be such as to ensure an all round cover of concrete. Entrapment of air must be avoided. Cell alignment should be within ±10° of that specified. Cells must be fixed securely to ensure that alignment is maintained during pouring of concrete.

Because the cell has a higher temperature coefficient that concrete, it will expand during the curing of the concrete and as the concrete cools the cell contracts and breaks contact with the concrete.

To overcome this problem, it is necessary to use one or a combination of the following methods:

1. Cast the cell in a concrete briquette using the same as the mass concrete after having removed any aggregate larger than 30 mm. The briquette should **not** be cast sooner than 48 hours prior to the mass concrete pour.

   The briquette should be at least 2 cell diameters wide by 1/2 of a diameter thick and long enough to encapsulate the pressure transducer.

2. Encapsulate the cell in situ following the method described in section 3.4.

3. Use the optional model total pressure cell especially designed for the measurement of stress changes in concrete. A post-stressing tube is included with the cell, allowing for repressurization of the cell. Fluid is forced back into the cell by crimping the repressurization tube and noting the change in pressure versus the length of tubing crimped. Before complete contact between the concrete and the pressure cell is achieved, the pressure increase in the cell should be small per centimeter of crimping. Once complete contact is achieved, the pressure will rise quickly. The initial internal pressure of the cell is approximately 69 - 97 kPa. Normally, a 21 - 69 kPa increase above the initial internal pressure would be required to attain a complete contact. See Figure 3 for a typical plot of centimeters crimped versus internal pad pressure.

When crimping the repressurization tube, do not crimp within about 7 ½cm of the fitting on the end to ensure that the internal ferrules do not become warped. A pair of heavy duty vise grips with smooth jaws makes a good crimping device, and care should be taken to avoid curing the tube during crimping. Monitor the pressure increase continually and avoid overpressurization.

The repressurization tube may be bent in order to route the tube through rebar, etc. out to an accessible area. However, the exposed tubing will need to be protected from equipment and personnel traffics because it is always an integral part of the sensing system. Care must be taken when bending the tube so that the inside diameter does not close.

All other aspects of the installation in mass concrete should follow the specifications in section 3.4.

3.6 PLACEMENT OF CABLE

Cable placement procedures vary with individual installations. In general, however, all installations have in common the requirements that: 1) the cable must be protected from damage by angular particles of the material in which the cable is embedded; 2) the cable must be protected from damage by compaction equipment; 3) in earth and rock embankments and backfills, the cable must be protected from stretching as a result of differential compaction of the embankment and 4) in concrete structures, the cable must be protected from damage during placement and vibration of concrete.

The cable should be permanently marked with the instrument serial number using metal tags at regular intervals along its entire length.

3.6.1 CABLE EMBEDMENT

In embankments, cables may be embedded in a protective covering of sand or selected fine embankment materials. A typical installation comprises the positioning of a series of cables on a prepared layer consisting of not less than 20 cm of compacted selected fine material. The prepared layer may be located either in a trench or on an exposed ramp.

In rockfill dams with earthfill cores, it is frequently convenient to install cable in trenches in the core and fine filter zones, and in ramps in the coarse filter and compacted rock fill shell zones. Individual cables should be spaced not less than 2 cm apart, and no cable should be closer than 15 cm to the edge of the prepared layer. In instances in which cables must be placed in a given array, the cables should be separated from each other by a vertical interval of not less than 15 cm of selected fine embankment material. Place the cable with "S" shaped meanders, to enhance the elongation capability of the electrical cable. At transition zones, the "S" shaped meanders can be set in vertical zones of hand compacted fine grain materials.

During the backfill of trenches in earth dams, a plug, approximately 61 cm in width, made of a mixture of 5% bentonite (by volume) from an approved source and exhibiting a free swell factor of approximately 60%, and 95% embankment material, can be placed in the trenches at intervals of not greater than 7½ m. The bentonitic plugs reduce the possibility of water seepage through the embankment core along the back filled trenches.

Cable placement from cells installed on or adjacent to structures involves similar considerations. Two advantages of this type of installation should be noted. First, the cables may be partially or completely embedded in the structure, thereby assuring maximum protection. Second, the cables may be installed in protective conduit attached to the surface of the structure or embedded in the structure.

Placement of cables to be embedded in concrete involves positioning and immobilizing the cables in such a way that damage during concrete placement and vibration is minimized.

Whenever possible, cables should be placed in the plane of reinforcing mats, and secured firmly to the mats with tie wire.

3.7 CABLE IDENTIFICATION

The cables are identified with the gage factor that is labeled on the piezometer housing. The gage factor is stamped on a tag that is fastened to the readout end of the cable. Should the cable be cut, we recommend the use of our cable splice kits.

4 MISCELLANEOUS

4.1 CONVERSION FACTORS

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

* at 4 °C

E6TabConv-990505

Table 1: Conversion Factors

4.2 SCHEMATIC DIAGRAM OF MODELS EPC AND TPC

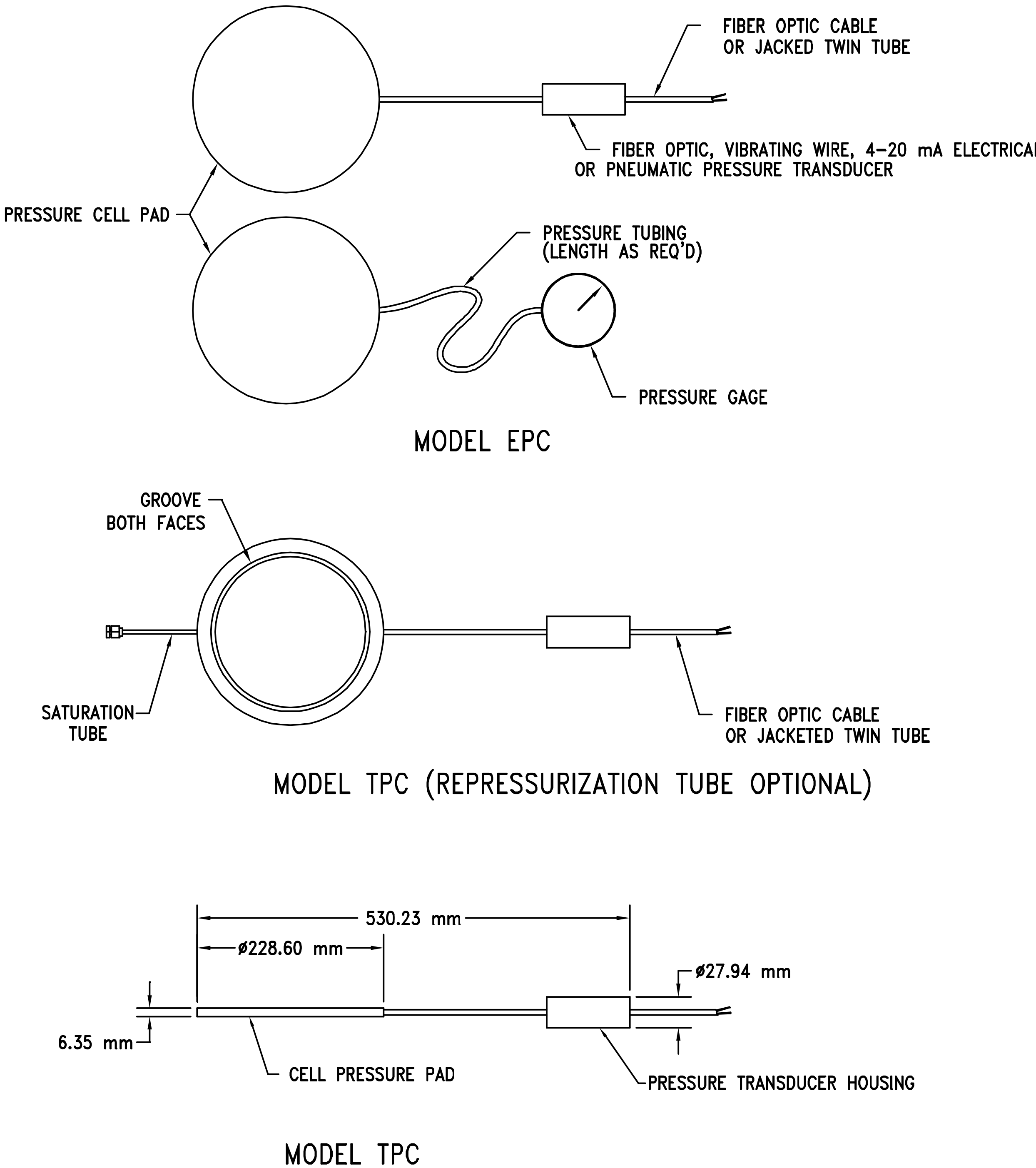


FIGURE 1 SCHEMATIC OF TPC/EPC

E20078–03

4.3 TYPICAL LAYOUT OF EMBEDMENT EARTH PRESSURE CELLS

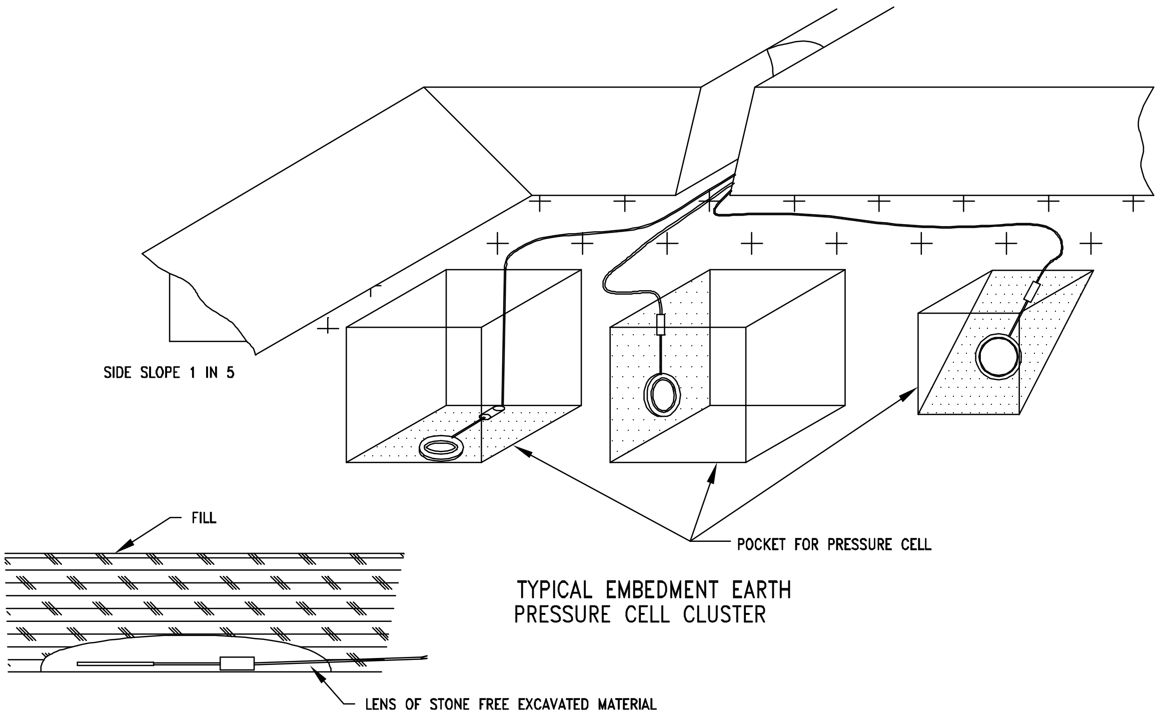
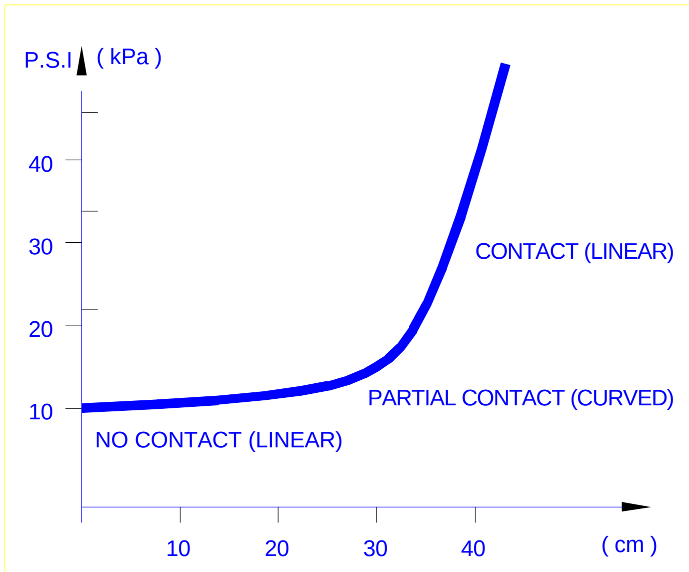


FIGURE 2 TYPICAL LAYOUT OF EMBEDMENT EPC/TPC

E20078-02

4.4 TPC REPRESSURIZING CURVE



FOTPC TYPICAL REPRESSURIZING CURVE

FIGURE 3