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Instruction Manual

Model 1250

(Model A5)

Borehole Extensometer

(Revision REV A 8/14)

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1. INTRODUCTION

The Model A5 Multiple Position Borehole Extensometer, (MPBX), is made up of three or four basic components:

- **Hydraulic Borehole Anchors**, these are of two types – the Bladder type, designed for all kinds of rock materials and the Borros type, which is used in soft ground only. The Bladder type anchor can be used in all kinds of harder rock material, whereas, the Borros type anchor is for soft ground only. Bladder type hydraulic anchors are particularly suited for use in upward directed boreholes. Usually the number of anchors lies between one and six.

- **Connecting rods and tubing,** the standard rod is made from ¼ inch stainless steel encased in rigid, ¼ inch schedule 40, PVC pipe. The sections of stainless steel rod are flush coupled to form a continuous string. Fiberglass rods may also be used, but their lower modulus may lead to lower precision in applications where high resolution, (< 0.1mm), is required. Graphite rods, which have a very low thermal coefficient, are available for high temperature applications and for applications where thermal effects on the rods must be minimized. Tell-tales, or rods extending below the bottom anchor are sometimes used in tunnel applications. When installed ahead of the tunnel face, the tell-tale is designed to be exposed during the tunneling operation so that the position of the bottom anchor relative to the roof of the tunnel can be accurately determined.

- **Extensometer head assembly,** various styles are available: the head usually has its own hydraulic anchor, which may be designed for recessing into an enlarged section of the borehole or it may have a flange for mounting to a standpipe grouted into the mouth of the borehole. Provision may be made for manual or electronic readout or for both. Manual readout is by a 50mm, or 2 inch, range dial indicator.

- **Electronic displacement transducers, (optional),** the standard transducer is the model 4450 vibrating wire displacement transducer with ranges of 25, 50, or 100 mm. Linear potentiometers are also available.

2. PRELIMINARY REQUIREMENTS

2.1 Borehole Requirements

The Model A5 is designed to fit 75mm (3 inch) or larger diameter boreholes. The mouth of the borehole may be cased with a 2½-inch standpipe or enlarged to take a 3-inch or 3½-inch standpipe or it may be left free. Boreholes should be free of debris and drilled slightly longer, (60cm, (2ft)), than the deepest anchor.

2.2 Anchor Spacing

Anchor spacing is sometimes dictated by geologic features and by the size and geometry of the rock mass being monitored. Drill cores can be inspected to reveal zones and planes of weakness, which would suggest appropriate anchor locations. At least one anchor, usually the deepest anchor, should be located in stable ground so that it can serve as a non-moving point of reference for the rest of the anchors. For extensometers installed in tunnels the deepest anchor should be located at least one tunnel diameter, and preferably nearer two tunnel diameters, away from the tunnel opening.

2.3 Instrument Head Protection

The instrument head should be protected from damage. This may require recessing the instrument head inside the borehole to avoid blasting damage or, in exposed locations, the construction of a protective enclosure to ward against falling objects, moving equipment and vandalism.

MPBX heads installed downwards from street level are best contained within manholes with access covers. The manhole should be large enough to accommodate the instrument head and any datalogger that may be in use. The minimum size of manhole is 300mm (12 Inch). A better size is 550mm (22inch) diameter. Covers may be equipped with a locking device. The manhole should be provided with a drain so that it cannot become filled with rainwater.
Heads may be equipped with a flange to engage the flange on top of any standpipe grouted into the mouth of the borehole. This arrangement works well with Borros type hydraulic anchors. Where Bladder type hydraulic anchors are in use, the instrument head comes equipped with its own hydraulic anchor so standpipes and flanges are not always required.

2.4 List of Installation Tools Required

Note: Installation Tool kits may be purchased as an accessory. They may include the following:

1. Two pair of Vise Grips
2. Adjustable wrenches
3. Screw Drivers
4. Allen Wrenches
5. Hacksaw
6. Files
7. Tape measure
8. Marking Pens
9. Loctite adhesive
10. PVC Cement
11. PVC Primer
12. Hydraulic hand-pump with pressure gage and fittings
13. Sharp Knife
14. Tape (Filament)
15. Tape (Duct)
16. Spare parts –Swagelok Connectors and spare ferrules, O-rings, setscrews, bolts, screws, etc. (Normally shipped with the extensometer parts).

3. INSTALLATION

3.1 Bladder Type Anchors in Open Boreholes with Manual Readout

A typical system is shown in Figure 1

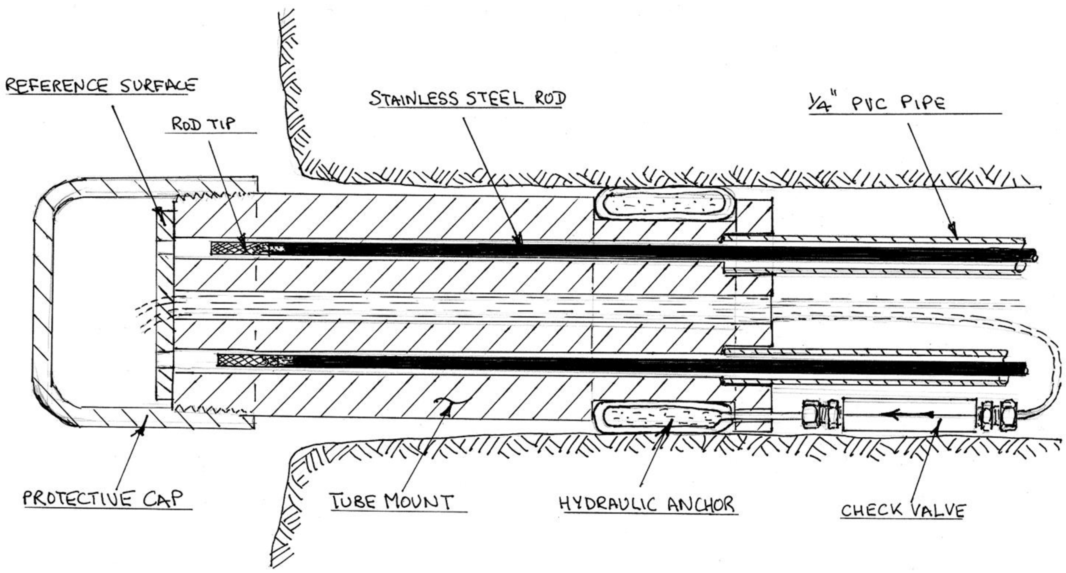

Figure 1

3.1.1 A standpipe, made from steel or PVC pipe, is not usually required except where the mouth of the borehole is fractured, oversize or irregular. If a standpipe is needed to stabilize the borehole collar, then the mouth of the borehole may have to be enlarged so that standpipe used can have at least the same I.D as the rest of the borehole. Apply quick-setting cement on the outside of the standpipe and insert into the borehole to the desired depth. Hold in place until the cement hardens, using wooden wedges or sackcloth soaked in quick-setting cement, as required.

3.1.2 When the various anchor depths have been determined, the assembly of the rod/tube strings is performed on an unobstructed surface. Join together the correct lengths of measurement rod using a pair of vise-grips and Loctite on all the threads. Thread the end with the female connector into the anchor and the rod tip onto the other end.

3.1.3 Slide the ¼-inch PVC pipe over the rods and couple them together using the **PVC Pipe Couplers** provided. When doing this be careful not to put too much PVC cement inside the coupler – the best technique is to put very little glue inside the coupler and plenty on the outside of the pipe. In this way there is no danger of pushing cement into the inside of the pipe where it can set up and grip the rods. Allow sufficient time for the cement to harden. In cold weather it may be advisable to warm the connector with a propane torch.

3.1.4 The final section of PVC is to be cemented in the appropriate hole in the **Tube Moun**t. Note that the Tube Mount is numbered; the shallowest anchor is number 1 and the deepest anchor will be cemented into the hole with the highest number. Before the final section of PVC pipe is connected it must be trimmed to its correct length using a hacksaw. The correct length is that which places the rod tip in the correct position relative to the Reference Surface. For anticipated extensions of the borehole, the rod tip should be positioned 10mm (1/2 inch) below the reference surface. *(Note: If the borehole is in unstable ground, and is cased, then the casing must be pulled while the anchor strings are inside the borehole. If this is the case then the Tube Mount must be installed only after the casing has been pulled*

3.1.5 When all the rod/pipe assemblies have been glued to the Tube Mount, (and the Tube Mount Flange, if used, has been cemented to the Tube Mount), use nylon filament tape to bundle the various rod/pipe assemblies together. Start at the head and tape every 2 meters. Tape near but not directly on top of the anchors.

3.1.6 Push the MPBX into the borehole until the hydraulic anchor on the head assembly is well inside the borehole, (or inside the standpipe if one is used), be careful not to bend the MPBX in too tight a radius. (Not less than 2 meters).

3.1.7 The hydraulic bladder anchors are expanded beginning with the deepest anchor. (Anchors are numbered so that the shallowest anchor is number one. Thus the deepest anchor will have the highest number). If the end of the hydraulic tubing is plugged by a nail, cut off about 20mm of the tubing and attach one of the 1/8 inch Swagelok tube fittings. When tightening Swagelok fittings use a wrench to tighten the nut 1¼ turns beyond finger tight; tighter than this can pinch the tube shut. If the end of the tube is already sealed by a Swagelok tube fitting, remove the cap. Connect the hydraulic line to the hand-pump filled with hydraulic oil and inflate the cells. **Watch the pressure gage while pumping and be sure never to exceed a pressure of 10 MPa (1400 psi). More pressure than this can burst the tubing.** Continue pumping until the anchor pressure holds steady at about 9 MPa (1300psi). Disconnect the hydraulic pump – the check valve at the anchor will maintain the anchor pressure. (Note: tests have shown that the anchor will continue to hold even if the anchor pressure drops to zero).

3.1.8 Repeat this process for the rest of the anchors, in descending numerical order, and for the anchor on the MPBX Head.

3.1.9 Take initial readings with the dial indicator and record. Screw on the Protective Pipe Cap to protect the Reference Surface.

3.2 Bladder Type Anchors in Grouted Boreholes – Manual Readout

Occasionally it may be necessary to seal the borehole with a Bentonite grout. These instructions cover this eventuality.

3.2.1 A standpipe, made from steel or PVC pipe, is not usually required except where the mouth of the borehole is fractured, oversize or irregular. If a standpipe is needed to stabilize the borehole collar, then the mouth of the borehole may have to be enlarged so that standpipe used can have at least the same I.D as the rest of the borehole. Apply quick-setting cement on the outside of the standpipe and insert into the borehole to the desired depth. Hold in place until the cement hardens, using wooden wedges or sackcloth soaked in quick-setting cement, as required.

3.2.2 When the various anchor depths have been determined, the assembly of the rod/tube strings is performed on an unobstructed surface. Join together the correct lengths of measurement rod using a pair of vise-grips and Loctite on all the threads. Thread the end with the female connector into the anchor and the rod tip onto the other end.

3.2.3 Slide the ¼-inch PVC pipe over the rods and couple them together using the **PVC Pipe Couplers** provided. When doing this be careful not to put too much PVC cement inside the coupler – the best technique is to put very little glue inside the coupler and plenty on the outside of the pipe. In this way there is no danger of pushing cement into the inside of the pipe where it can set up and grip the rods. Allow sufficient time for the cement to harden. In cold weather it may be advisable to warm the connector with a propane torch.

3.2.4 The final section of PVC is to be cemented in the appropriate hole in the **Tube Moun**t. Note that the Tube Mount is numbered; the shallowest anchor is number 1 and the deepest anchor will be cemented into the hole with the highest number. Before the final section of PVC pipe is connected it must be trimmed to its correct length using a hacksaw. The correct length is that which places the rod tip in the correct position relative to the Reference Surface. For anticipated extensions of the borehole, the rod tip should be positioned 10mm (1/2 inch) below the reference surface. *(Note: If the borehole is in unstable ground, and is cased, then the casing must be pulled while the anchor strings are inside the borehole. If this is the case then the Tube Mount must be installed only after the casing has been pulled.*

3.2.5 When all the rod/pipe assemblies have been glued to the Tube Mount, (and the Tube Mount Flange, if used, has been cemented to the Tube Mount), use nylon filament tape to bundle the various rod/pipe assemblies together. Start at the head and tape every 2 meters. Tape near but not directly on top of the anchors.

3.2.6 Thread the grout tube through the hole in the Tube Mount and through the hole in each of the bladder anchors. Cut two or three notches in the side of the grout tube near its bottom end then attach the end of the grout tube to the deepest anchor only, using masking tape, so that the end of the grout tube protrudes a short distance (about 30 cm) beyond the anchor. Do **not** tape the grout tube to the rest of the bundle.

3.2.7 Push the MPBX into the borehole until the hydraulic anchor on the head assembly is well inside the borehole, (or inside the standpipe if one is used), be careful not to bend the MPBX in too tight a radius. (Not less than 2 meters).

3.2.8 The hydraulic bladder anchors are expanded beginning with the deepest anchor. (Anchors are numbered so that the shallowest anchor is number one. Thus the deepest anchor will have the highest number). If the end of the hydraulic tubing is plugged by a nail, cut off about 20mm of the tubing and attach one of the 1/8 inch Swagelok tube fittings. When tightening Swagelok fittings use a wrench to tighten the nut 1¼ turns beyond finger tight; tighter than this can pinch the tube shut. If the end of the tube is already sealed by a Swagelok tube-fitting, remove the cap. Connect the hydraulic line to the hand-pump filled with hydraulic oil and inflate the cells. **Watch the pressure gage while pumping and be sure never to exceed a pressure of 10 MPa (1400 psi). More pressure than this can burst the tubing.** Continue pumping until the anchor pressure holds steady at about 9 MPa (1300psi). Disconnect the hydraulic pump – the check valve at the anchor will maintain the anchor pressure. (Note: tests have shown that the anchor will continue to hold even if the anchor pressure drops to zero).

3.2.9 Repeat this process for the rest of the anchors, in descending numerical order, and for the anchor on the MPBX Head.

3.2.10 When all the hydraulic anchors have been set, and with the Grout Plate in place on the Tube Mount, connect the ½ -inch polyethylene grout pipe to a grout pump and pump a little water through the grout line to lubricate it. Mix up a batch of neat cement grout with the consistency of pancake batter. Use Portland No. 2 cement, with 5 to 10% of Bentonite powder added, mixed with water in approximately 1:1 mixture. Pump the grout into the borehole while slowly pulling the grout tube from the borehole. If the grout tube is to be used again flush it now with water.

3.2.11 Take initial readings with the dial indicator and record. Screw on the Protective Pipe Cap to protect the Reference Surface.

3.3 Borros Type Anchors – Manual Readout

Borros Anchors are reserved for applications in soft ground. Where large compressions or tensions are anticipated it will be necessary to introduce telescoping joints into the PVC Pipe string. (*Alternatively, more compressible nylon tubing may be used, in conjunction with fiberglass rods. For installations of this type consult the Installation Manual for the Model 1280 (A6) MPBX*). Often the ground is too weak for a borehole to remain open without being cased. Where the hole will stay open the installation can proceed as described in section 3.
The following procedure is for cased boreholes. Here it is necessary to install the rod/tube/anchor assemblies before pulling the casing. They can then be attached to the Tube Mount after the casing has been pulled.

3.3.1 When the various anchor depths have been determined, the assembly of the rod/tube strings is performed on an unobstructed surface. Join together the correct lengths of measurement rod using a pair of vise-grips and Loctite on all the threads. Thread the end with the female connector into the anchor.

3.3.2 Slide the ¼-inch PVC pipe and telescoping sections over the rods and couple them together using the **PVC Pipe Couplers** provided. When doing this be careful not to put too much PVC cement inside the coupler – the best technique is to put very little glue inside the coupler and plenty on the outside of the pipe. In this way there is no danger of pushing cement into the inside of the pipe where it can set up and grip the rods. Allow sufficient time for the cement to harden. In cold weather it may be advisable to warm the connector with a propane torch. Use masking tape to tape the telescoping sections in their correct positions – closed for anticipated extensions or open for anticipated compressions.

3.3.3 Before the final section of PVC pipe is connected it must be trimmed to its correct length using a hacksaw. The correct length is that which places the rod tip in the correct position relative to the Reference Surface. For anticipated extensions, the rod tip should be positioned 10mm (1/2 inch) below the reference surface.

3.3.4 Use nylon filament tape to bundle the various rod/pipe assemblies together. Start at the head end and tape every 2 meters. Tape the rod/tubes to the Borros anchors in such a way that they do not lie directly over the ports from which the prongs will emerge. If the hole is to be grouted using a Bentonite grout, then the grout tube should be taped to the bottom anchor using masking tape so that it can be broken free at the commencement of grouting.

3.3.5 Tie a nylon cord to the rod/tube bundle and use it lower the bundled rod/tubes into the cased borehole . If stainless steel rods are in use be careful not to bend the MPBX in too tight a radius (>2 meters) or the stainless steel rods could be permanently bent. Use as many people as required to support the rod/pipe string along its length. Suspend the bundle rod/tubes in their final position by tying the nylon cord to the top of the drill tower.

3.3.6 As the first section of casing is pulled it is recommended that the deep anchor be actuated: this is done by connecting the hydraulic line to the hydraulic pump and at first SLOWLY applying a pressure of no greater than 17 Mpa (2500 psi) to the Borros anchor. **Pressures greater than 17 Mpa, (2500psi), can burst the hydraulic tubing.** The prongs on the Borros anchor will begin to expand at a pressure of around 5 Mpa (700psi) and will continue to arc out into the soft ground as the pressure is increased. For maximum anchor engagement the pumping pressure can now be increased until the tubing bursts.

3.3.7 As each section of casing is pulled the nylon cord is untied from the drill mast and the casing section is then threaded over it. The nylon cord is re-tied back to the mast and casing is pulled until the next anchor position is cleared. This anchor is actuated and then the procedure is repeated for all the other anchors.

3.3.8 When the casing has been completely removed from the borehole then the Standpipe, with its flange or coupling attached to the top, can be lowered into the top of the borehole and temporarily wedged in place at a position lower than its final position. The borehole can now be grouted if necessary.

3.3.9 Screw the rod tips onto the ends of the measurement rods, if they are not already in place.

3.3.10 The ends of the PVC tubes can now be cemented in the appropriate hole in the **Tube Moun**t. Note that the Tube Mount is numbered; the shallowest anchor is number 1 and the deepest anchor will be cemented into the hole with the highest number. (If a flange is being used, then it is important to place it over the rod/tube bundle before the PVC tubes are cemented to the Tube Mount. When all the PVC tubes have been cemented this flange can then be attached to the Tube Mount).

3.3.11 When the PVC cement has hardened, the Standpipe is loosened and raised until either the two flanges can be bolted together, or, the Tube Mount can be cemented inside the coupling. The standpipe is now wedged in its final position and quick-setting cement used to cement it into the borehole.

3.3.12 Initial readings can now be taken and the Protective Cap threaded onto the Tube Mount.

4. ELECTRONIC READOUT - VIBRATING WIRE DISPLACEMENT TRANSDUCERS

Electronic readout is usually accomplished by means of transducers and a transducer housing that are assembled and bolted to the MPBX head after the initial installation of the anchors and head has been performed. There are many variations and **specific and detailed instructions are supplied with each extensometer**. The following instructions apply, in a general way only, to the two main standard designs: one that permits electronic readout only and one that permits both electronic and manual readout. These general instructions will serve as an explanation for the more detailed instruction and why they are necessary.

4.1 Electronic Readout Only

A typical MPBX head assembly, designed to accept vibrating wire displacement transducers is shown in figure 2. This particular design uses a flanged Standpipe to grip the MPBX Head rather than a hydraulic anchor.

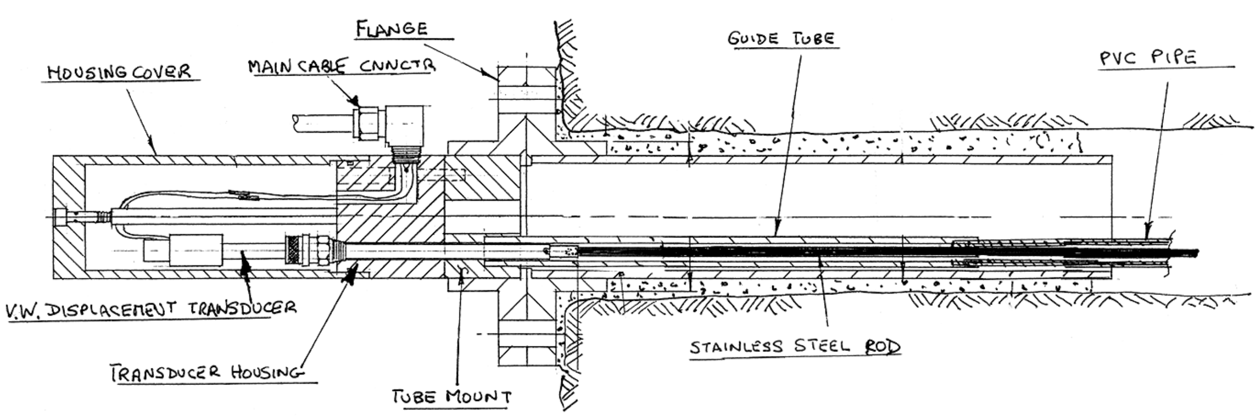

Figure 2

4.1.1 The **Guide Tubes** provide a space in which the transducers are located. They may be shipped separately. If shipped separately then they must be attached, to the **Tube Mount** by threading and/or gluing, and then, by gluing, to the **PVC pipe,** after a specified amount of the PVC pipe has been removed. The amount to be removed is such that when the stainless steel rod is connected to the transducer the transducer will be correctly positioned within the Guide Tube. Numbers stamped on the Tube Mount ensure that the correct anchor is connected to the corresponding Guide Tube and transducer.

4.1.2 If a **Standpipe** is in use, the rods and anchors are pushed into the borehole and the **Tube Mount,** with its Guide Tubes, is now glued, or bolted, to the standpipe. **Extension Rods** are screwed onto the end of the stainless steel rods and are then clamped to the Tube Mount by **Temporary Swagelok Connectors**. The extension rods are designed to hold the ends of the stainless steel rods in their correct positions relative to the head of the MPBX while the anchors and rods are being installed inside the borehole. Without them the friction and pull of the anchors, and changes of temperature, during installation could move the rod tips by an unacceptable amount.

4.1.3 After the installations have been made, as per the instructions of Section 3, the extension rods and Temporary Swagelok Connectors are removed.

4.1.4 The **Transducer Housing** can now be bolted to the Tube Mount using the numbers stamped on the tube mount to ensure correct orientation.

4.1.5 **Vibrating Wire Displacement Transducers** are now threaded onto the end of the stainless steel rod tips. **Be sure the pin in the Transducer shaft is in the notch on the transducer when the Transducer is screwed onto the rod tip. If the pin is not in the notch when the Transducer is twisted then serious damage can result.** Once connected, they can then be extended to the correct part of their range before being gripped by the Swagelok fittings in the Transducer Housing. **Note: if difficulty is experienced connecting the transducer t the rod tips, completely remove the Swagelok fitting from the head, this will permit the connection to be made.**

4.1.6 The installation is completed, by connecting the individual transducer leads to the main cable connector inside the MPBX Head and bolting the **Housing Cover** to the Transducer Housing using the long Standoff Bolts provided. Wiring Charts are given in Appendix 1.

4.1.7 Initial Readings can now be taken.

4.2 Electronic Readout with Manual Readout Capability

4.2.1 A typical MPBX head assembly, designed to accept vibrating wire displacement transducers and also permit manual readout is shown in figure 3. In this arrangement the transducers are not directly in line with the stainless rods but, instead, are recessed in guide tubes alongside the rods, leaving the tip of the rods free to be sensed by a dial indicator.

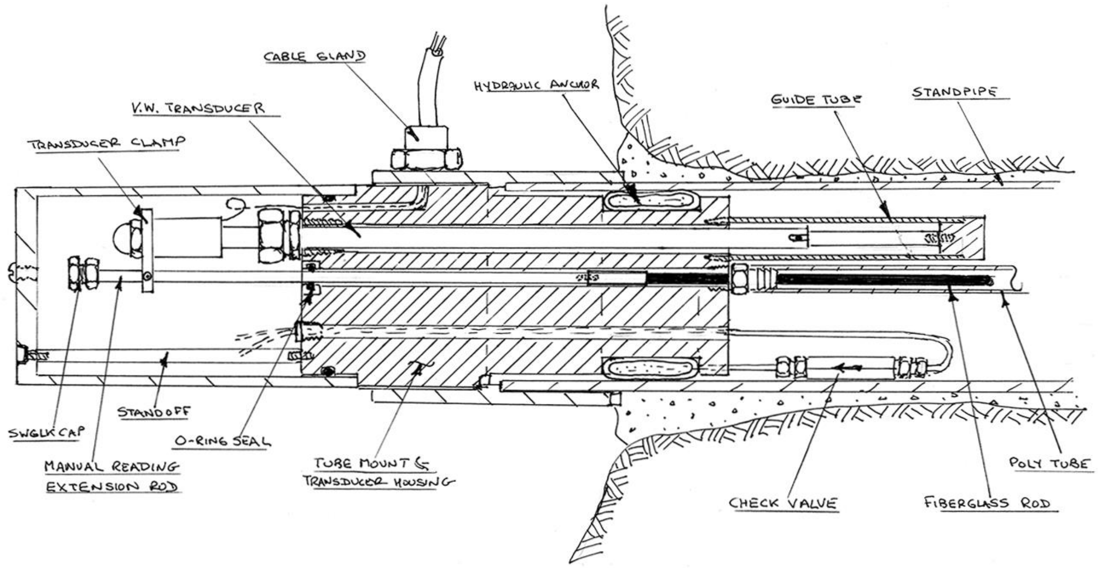

Figure 3

4.2.2 The **Tube Mount** must first be separated from the MPBX Head Assembly by removing the cap and unbolting the Tube Mount from the **Transducer Housing**. The **Guide Tubes** provide a space in which the transducers are to be located; they are shipped already attached to the **Tube Mount.** These Guide Tubes need to be kept clean during any grouting operation. (They can be plugged with the **O-ring plugs** provided).

4.2.3 After the anchors and rod/pipe strings have been assembled they must now be cemented to the Tube Mount, but before this is done the last PVC pipe section must be trimmed to the correct length. The amount to be removed is such that when the installation is completed the tip of the stainless steel rod will be in the correct position relative to the Reference Surface. Numbers stamped on the Tube Mount ensure that the anchors are connected in the proper sequence.

4.2.4 If a **Standpipe** is in use it should be installed now, after which the installation may proceed in accordance with the instructions of Section 3.

4.2.5 After the installation of the rods, pipes and anchors is completed, tapered Bullets are screwed onto the outer ends of the stainless steel rods so that the Transducer Housing can now be slid over these rods, without damaging the **O-ring Seals** in the Transducer Housing. The Transducer Housing can now be bolted to the Tube Mount.

4.2.6 The **Vibrating Wire Transducers** can now be installed inside the Guide Tubes after removing the O-ring Plugs by threading the Transducers onto the setscrew in the bottom of the Guide Tube. **Be sure the pin in the Transducer shaft is in the notch on the transducer when the Transducer is screwed onto the rod tip. If the pin is not in the notch when the Transducer is twisted then serious damage can result.** The **Transducer Clamps** are slid over the stainless steel rods and secured to the backs of their corresponding Transducers. Each Transducer is connected in turn to a Readout Box and the Transducer is set in the desired part of its range. In most instances, where the movements being monitored are extensions, this will mean that the Vibrating Wire Transducer will be almost fully extended. When the correct position is selected then the setscrew in the Transducer Clamp is tightened onto the Manual Readout Rod.

4.2.7 The bullets are removed from the end of the stainless steel rods and replaced by **Swagelok Caps,** which will provide a large flat surface for the dial indicator tip to find. (The rods may be trimmed to their correct length, if necessary, by means of a hacksaw).

4.2.8 The individual transducer leads are connected to the main cable connector and the **Standoffs** and Cap are replaced. Wiring Charts are given in Appendix 1.

4.2.9 Initial readings can now be taken – both manual and electronic.

5. TAKING READINGS

The most important reading is the first reading: it is the base reading to which all subsequent readings will be compared. Verify that the readings are correct. If possible install the MPBX well ahead of the time that movements are expected so that the MPBX has time to stabilize. (Most installations are subject to a "bedding in" process during which slight movements can occur. These movements generally cease after two or three days). Often the best results can be obtained by using as the base line readings the readings taken on the third day. This, of course may not be possible if the ground is already moving.

Manual readings are best taken using a dial indicator, although, depth micrometers have also been used. To take manual readings simply poke the stem of the indicator through the holes in the Cap on the MPBX Head assembly until the tip bears against the underlying Swagelok Cap. With the collar of the dial indicator held flush against the MPBX Cap or the Reference Surface take a reading on the indicator.

Electronic readout can be made using the Micro 10 Datalogger or the GK401 or GK402 Readout Boxes set to Channel B. For further details consult the relevant manuals.

Readout frequency should be suitable to the purpose for which the readings are being made. All readings should be compared with previous readings as soon as they are taken. In this way, sudden changes of readings can be instantly checked to see if they are real or perhaps a reading error. If real then the observer is alerted to the possibility of serious ground movements or to possible instrument damage and can look for further evidence of either.

6. DATA ANALYSIS

Raw data can be treated in a number of ways to reveal zones or planes of weakness in which movement is occurring. All raw data must be converted into time plots without delay. Failure to plot the data in a timely manner can negate the purposes of the monitoring program. Inspection of the plots will show whether movements are steady or are accelerating or have stopped. They may suggest the need for remedial measures and will be useful in monitoring their efficacy.

6.1 <u>An Example of MPBX Data Reduction for a Situation where the Deep Anchor is in Stable Ground</u>

Table 1 shows a series of entries into a field book. In this example Anchor 3 is located in stable ground.

Date	Anchor 3 (Depth 20 mtrs) millimeters	Anchor 2 (Depth 10 mtrs) millimeters	Anchor 1 (Depth 3 mtrs) millimeters	Remarks
12/01/00	38.10	25.19	34.75	Initial Reading (R_0)
12/02/00	38.91	26.01	35.51	
12/03/00	39.01	26.11	35.61	
12/05/00	39.12	26.16	35.61	
12/06/00	39.14	26.16	35.61	
12/08/00	40.18	27.13	36.58	Blasting in the Area
12/09/00	40.13	27.18	36.63	
12/10/00	40.26	27.31	36.65	
12/11/00	40.64	27.61	36.65	
12/15/00	43.82	28.58	36.83	Heavy Rain
12/16/00	43.87	28.58	36.83	
12/18/00	43.94	28.63	36.88	
12/20/00	43.99	28.65	36.88	

Table 1 Raw Data

6.1.1 The first task is to calculate the measured displacements between the head and each anchor. This can easily be done for each anchor, by subtracting the initial reading, R_0 from each of the subsequent readings. When this is done we have a table of figures as shown in Table 2.

Date	Anchor 3 (Depth 20 mtrs) millimeters	Anchor 2 (Depth 10 mtrs) millimeters	Anchor 1 (Depth 3 mtrs) millimeters	Remarks
12/01/00	0.00	0.00	0.00	Installed
12/02/00	0.81	0.82	0.76	
12/03/00	0.91	0.92	0.86	
12/05/00	1.02	0.97	0.86	
12/06/00	1.04	0.97	0.86	
12/08/00	2.08	1.94	1.83	Blasting in the Area
12/09/00	2.03	1.99	1.88	
12/10/00	2.16	2.12	1.90	
12/11/00	2.54	2.42	1.90	
12/15/00	5.72	3.39	2.08	Heavy Rain
12/16/00	5.75	3.39	2.08	
12/18/00	5.84	3.44	2.13	
12/20/00	5.89	3.46	2.13	

Table 2. Relative Movement between the Instrument Head and Each Anchor

6.1.2 However, in the example chosen, it is the deepest anchor that is stable, not the Instrument Head, so that the movement of each of the anchors should be calculated relative to Anchor 3 and not to the head of the MPBX. Immediately it will be realized that the apparent movement of anchor 3 is actually the absolute movement of the instrument head relative to stable ground.

Date	Anchor 2 (Depth 10 mtrs) millimeters	Anchor 1 (Depth 3 mtrs) millimeters	Instrument Head millimeters	Remarks
12/01/00	0.00	0.00	0.00	Installed
12/02/00	0.01	0.05	0.81	
12/03/00	0.01	0.05	0.91	
12/05/00	0.05	0.16	1.02	
12/06/00	0.07	0.18	1.04	
12/08/00	0.14	0.25	2.08	Blasting in the Area
12/09/00	0.04	0.15	2.03	
12/10/00	0.04	0.26	2.16	
12/11/00	0.12	0.64	2.54	
12/15/00	2.33	3.64	5.72	Heavy Rain
12/16/00	2.36	3.67	5.75	
12/18/00	2.40	3.71	5.84	
12/20/00	2.43	3.76	5.89	

Table 3. Movement of the Instrument Head and Anchors Relative to Anchor 3 in Stable Ground

6.1.3 The data shown in Table 3 could be plotted and shown in a graph like the one shown in Figure 4.

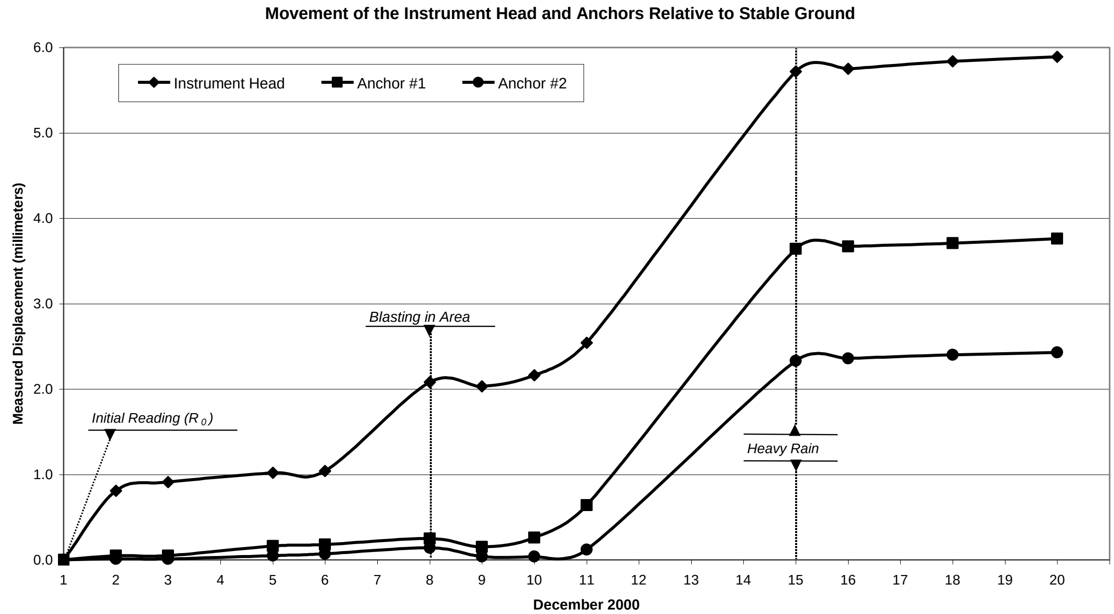

Figure 4. Movement of the Head and Anchors Relative to Anchor 3 in Stable Ground

Inspection of the plot shows that initial movement occurred in the zone closest to the surface during the first 3 days and again on day 8 following blasting in the area. On day 15, following a heavy rainfall, deep-seated movements occurred in the zone between anchors 2 and 3 and also in the shallower zones. Movements occurring in any inter-anchor zone can be inferred from the spacing between the individual plots of Figure 4, or they can be plotted separately as shown in figure 5

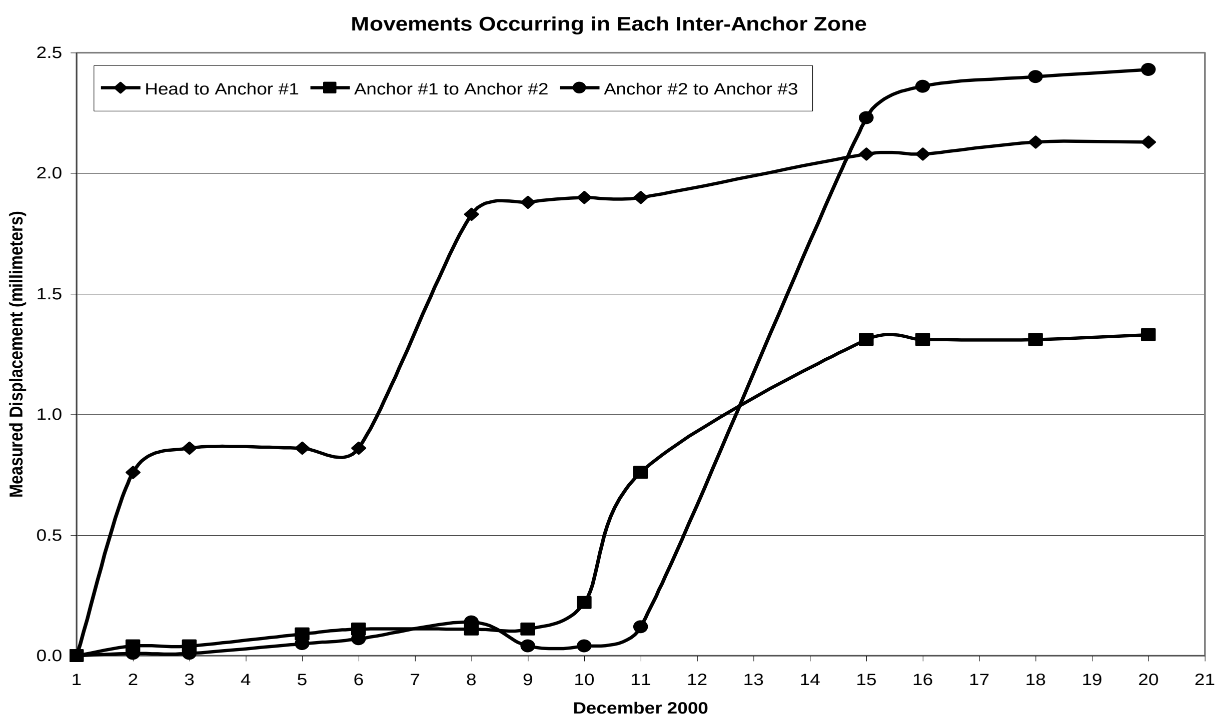

Figure 5 Movements Occurring in Each Inter-Anchor Zone

6.2 <u>Instrument Head located in stable ground</u>

When the Instrument head is located in stable ground, such as would be the case for a MPBX head located at street level in a borehole drilled downwards to terminate slightly above a tunnel being excavated below, then the measured movements on each anchor are taken directly from the readings on each anchor. The analysis of the data would then proceed as before without the need for the step described in section 6.1.2

7. TROUBLESHOOTING

The multiple anchor design tends to show confirming changes of readings on several rods from movements that affect more than one anchor. Bad readings on any intermediate anchor will tend to stand out as incompatible with the movements of the surrounding anchors. Nevertheless it *is* possible that cracks in one zone might open while those in an adjacent zone might close.

Dial Indicators

Dial Indicators are delicate instruments and should be kept clean and dry at all times. It is advisable to have a Standard, which can be used to check that the dial gage gives the same reading at all times when checked against this Standard. The Standard might be a block of steel in which a hole has been bored.

Vibrating Wire Transducers

Symptom: Displacement Transducer Readings are Unstable

✓ Is the readout box position set correctly? If using a datalogger to record readings automatically are the swept frequency excitation settings correct? Try reading the displacement transducer on a different readout position. For instance, channel A of the GK-401 and GK-403 might be able to read the transducer. 1.

✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, transformers, arc welders and antennas. Make sure the shield drain wire is connected to ground whether using a portable readout or datalogger. If using the GK-401 Readout connect the clip with the green boot to the bare shield drain wire of the pressure cell cable. If using the GK-403 connect the clip with the blue boot to the shield drain wire.

✓ Does the readout work with another displacement transducer? If not, the readout may have a low battery or be malfunctioning. Consult the appropriate readout manual for charging or troubleshooting directions.

✓ Has the transducer gone outside its range? If so, the transducer can be reset using the installation instructions in section 4.

Symptom: Displacement Transducer Fails to Read

✓ Is the cable cut or crushed? This can be checked with an ohmmeter. Nominal resistance between the two gage leads (usually red and black leads) is 180Ω, ±10Ω. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 14.7Ω/1000' or 48.5Ω/km, multiply by 2 for both directions). If the resistance reads infinite, or very high (megohms), a cut wire must be suspected. If the resistance reads very low (<100Ω) a short in the cable is likely.

✓ Does the readout or datalogger work with another transducer? If not, the readout or datalogger may be malfunctioning. Consult the readout or datalogger manual for further direction.

Symptom: Displacement Transducer is hard to connect to the rod tip.

✓ Completely remove the Swagelok fitting from the housing so that there is more freedom to make the connection.

Appendix 1 Wiring Charts for Vibrating Wire Transducers.

Single Transducer

Internal Wiring	Geokon Cable #02-205V6 (Blue)	Function / Description
Red	Red	Gage 1+
Black	Black	Gage 1-
Red	White	Thermistor
Black	Green	Thermistor
N/C	Shield (1)	N/A

Three Transducers

Internal Wiring	Geokon Cable #04-375V9 (Violet)	Function / Description
Red	Red	Gage 1+
Black	Black of Red	Gage 1-
Red	White	Gage 2+
Black	Black of White	Gage 2-
Red	Green	Gage 3+
Black	Black of Green	Gage 3-
Blue	Blue	Thermistor
Black of Blue	Black of Blue	Thermistor
N/C	Shields (5)	Ground

Four Transducers

Internal Wiring	Geokon Cable #05-375V12 (Tan)	Function / Description
Red	Red	Gage 1+
Black	Black of Red	Gage 1-
Red	White	Gage 2+
Black	Black of White	Gage 2-
Red	Green	Gage 3+
Black	Black of Green	Gage 3-
Red	Blue	Gage 4+
Black	Black of Blue	Gage 4-
Yellow	Yellow	Thermistor
Black of Yellow	Black of Yellow	Thermistor
N/C	Shields (6)	Ground

Five Transducers

Internal Wiring	Geokon Cable #06-500V7 (Orange)	Function / Description
Red	Red	Gage 1+
Black	Black of Red	Gage 1-
Red	White	Gage 2+
Black	Black of White	Gage 2-
Red	Green	Gage 3+
Black	Black of Green	Gage 3-
Red	Blue	Gage 4+
Black	Black of Blue	Gage 4-
Red	Yellow	Gage 5+
Black	Black of Yellow	Gage 5-
Red	Brown	Thermistor
Black of Brown	Black of Brown	Thermistor
N/C	Shields (7)	Ground

Seven Transducers

Internal Wiring	Geokon Cable #012-625V5 (Brown)	Function / Description
Red	Red	Gage 1+
Black	Black of Red	Gage 1-
Red	White	Gage 2+
Black	Black of White	Gage 2-
Red	Green	Gage 3+
Black	Black of Green	Gage 3-
Red	Blue	Gage 4+
Black	Black of Blue	Gage 4-
Red	Yellow	Gage 5+
Black	Black of Yellow	Gage 5-
Red	Brown	Gage 6+
Black	Black of Brown	Gage 6-
Red	Orange	Gage 7+
Black	Black of Orange	Gage 7-
White	White	Thermistor
Red of White	Red of White	Thermistor
N/C	Shields (13)	Ground