



The World Leader in Vibrating Wire Technology

*48 Spencer Street
Lebanon, NH 03766, USA
Tel: 603•448•1562
Fax: 603•448•3216
E-mail: geokon@geokon.com
<http://www.geokon.com>*

Instruction Manual
Model 1280
(Model A6)
Borehole Extensometer

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1. INTRODUCTION

The Model A6 Multiple Position Borehole Extensometer, (MPBX), is made up of three or four basic components:

- **Borehole anchors**, these may be either groutable or hydraulic types. The groutable type is usually recommended for downward directed boreholes or for holes that must remain sealed. Special equipment will be required for grouting boreholes directed upwards. Hydraulic anchors can be used anywhere and 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 fiberglass encased in ½ inch polyethylene tubing for borehole lengths less than 30 meters, or ½ inch nylon tubing for borehole depths greater than 30 meters. The flexibility of the rods and tubing allows the extensometer to be pre-assembled and coiled at the factory for shipment to the job-site where it can be uncoiled and inserted into the borehole. This greatly speeds up the installation process.
- **Extensometer head assembly**, various styles are available: the head 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 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 A6 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 groutable anchors. Where 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 (Hydraulic Anchors).
13. Portland cement (N0 2) (Groutable Anchors).
14. Quick Setting Cement
15. Grout Tube and fittings (Groutable Anchors).
16. Grout Pump (Groutable Anchors).
17. Grout Plate (Normally Supplied)
18. Water (for flushing and grouting).
19. Sharp Knife
20. Tape (Filament)
21. Tape Masking (Groutable Anchors)
22. Tape (Duct)
23. Spare parts –Swagelok Connectors and spare ferrules, O-rings, setscrews, bolts, screws, etc. (Normally shipped with the extensometer parts).

3. INSTALLATION

3.1 Standard Groutable System with Manual Readout – Downward Directed Boreholes.

A typical system is shown in figure 1

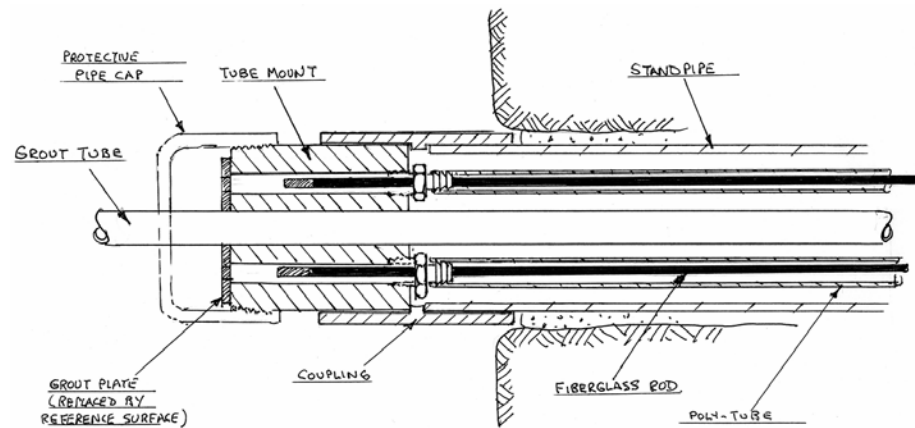


Figure 1

- 3.1.1 Normally, the MPBX is shipped pre-assembled and coiled for shipment. **Care should be taken when removing the tape holding the coils.** Release one coil at a time and keep a tight grip on the rest of the coils so that they cannot suddenly break free and uncoil violently. Do not cut the tapes bundling the rod/tubes together. Lay out the MPBX on a flat dry surface, as close to the borehole as possible.
- 3.1.2 If a **Standpipe** is to be installed it should be assembled now. Glue the **Coupling**, (or **Flange**), to the standpipe using PVC purple primer and cement. 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.
- 3.1.3 If the anchor depths need to be adjusted from those set at the factory see section 4.
- 3.1.4 The MPBX is shipped with the **Grout Tube** coiled separately. It should now be uncoiled and pushed through the hole on the center of the **Grout Plate** and attached lightly to the deepest anchor only, using enough masking tape so that it will not scrape off when the MPBX is pushed into the hole but not so much that it cannot be broken free when grouting commences.
- 3.1.5 Slide the MPBX into the borehole until the **Tube Mount** is about to enter the coupling (or flange), be careful not to bend the MPBX in too tight a radius. Add PVC cement to the outside of the Tube Mount where it seats inside the standpipe coupling. Push the Tube Mount inside the coupling and allow the PVC cement to harden. (If flanges are used instead of couplings, glue the tube mount to the tube mount flange, then bolt this flange to the flange on the standpipe using the bolts supplied).
- 3.1.6 Connect the grout pipe to a grout pump and pump a little water through the grout line to lubricate it. Mix up a batch of cement grout with the consistency of pancake batter. Use Portland No. 2 cement mixed with water in approximately 1:1 mixture. Do not use any sand. 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.
- 3.1.7 After the grout has set up, remove the grout plate and replace it with the **Reference Surface**. Be careful to match the numbers stamped on the Tube Mount with those on the Reference Surface. Take initial readings with the dial indicator and record. Screw on the **Protective Pipe Cap** to protect the Reference Surface.

3.2 Standard Groutable System with Manual Readout – Upward Directed Boreholes

Upward directed boreholes require special grouting techniques.

- 3.2.1 Normally, the MPBX is shipped complete and pre-assembled and coiled for shipment. **Care should be taken when removing the tape holding the coils.** Release one coil at a time and keep a tight grip on the rest of the coils so that they cannot suddenly break free and uncoil violently. Do not cut the tapes bundling the rod/tubes together. Lay out the MPBX on a flat dry surface, as close to the borehole as possible.
- 3.2.2 The standpipe should be assembled first. Glue the coupling, (or flange), to the standpipe using PVC purple primer and cement. Apply quick-setting cement on the outside of the standpipe and insert into the borehole to the desired depth. Use plenty of cement to ensure a grout-tight seal around the standpipe. Hold in place until the cement hardens, using wooden wedges or sackcloth soaked in quick-setting cement, as required.
- 3.2.3 If the anchor depths need to be adjusted from those set at the factory see section 4.
- 3.2.4 Using Figure 2 as a guide, screw the **down-hole grout pipe**, (7), into the back of the Tube Mount, screw the **external grout pipe**, (8), into the front of the Tube Mount, thread the **vent tube**, (6), through these two pipes and tape to the deepest borehole anchor so that it protrudes beyond the anchor by a distance of about 30 centimeters. Now slide the **Valve/Tee assembly**, (1 thru 5), over the vent tube and screw onto the external grout tube. Tighten the Swagelok fitting, (1), onto the vent tube

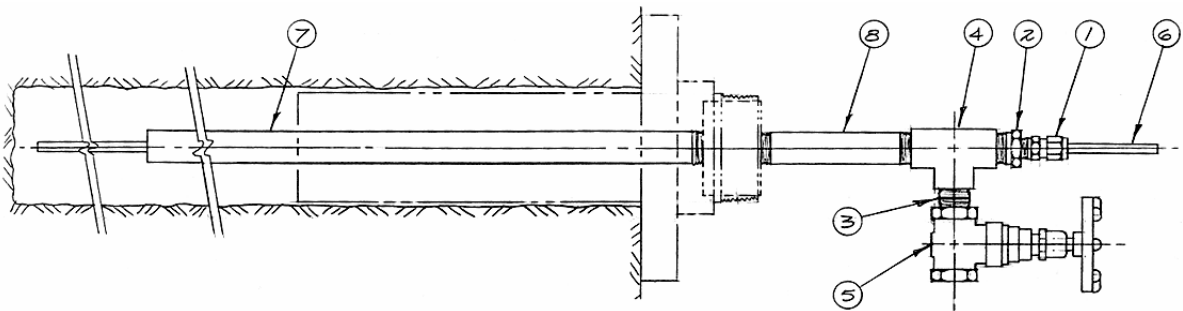


Figure 2

- 3.2.5 Push the entire assembly into the borehole until the head assembly is about to enter the standpipe, be careful not to bend the MPBX in too tight a radius. Add PVC cement to the outside of the head where it seats inside the standpipe coupling. Push the head inside the coupling and allow the PVC cement to harden. (If bolted flanges are used instead of cemented couplings, apply RTV sealant to one of the flange faces then bolt the flange on the head to the flange on the standpipe using the bolts supplied).
- 3.2.6 Because of the high pressures involved the grouting must be done in two stages: The first stage is to grout the first meter and a half, (5ft), of the borehole so as to form a plug, which can seal the borehole and permit the rest of the hole to be grouted. Calculate the amount of grout required to do this. Connect the grout pipe to the gate valve and to a grout pump. Mix up the calculated amount of cement grout with the consistency of pancake batter. (Use Portland No 2 cement and water in about a 1:1 mix). Do not use any sand. With the valve open, pump the measured amount of grout into the borehole. With the valve still open, remove the grout pipe and allow any excess grout, above the level of the end of the down-hole grout pipe inside the borehole, to drain away. Reconnect a water supply to the Valve/Tee assembly and pump a few liters (gallons) of water into the borehole then disconnect the water supply and allow the water to flow back out of the hole and flush the system ready for the second stage of grouting. Allow the grout 24 hours to set up.

- 3.2.7 After the first-stage grout plug has set up, reconnect the grout pump and pump grout until grout is seen exiting the vent tube. (Excessive grout pressures should be avoided since there is a danger of blowing out the plug). When grout is seen issuing from the vent line stop pumping, close the Gate Valve, and disconnect the pump. (In fractured ground there may be some leakage into the fractures causing the top anchor to become un-grouted. To ward against this, the pump can be left connected and grouting can be continued at intervals until, on recommencing the pumping, the grout is seen to flow immediately from the vent tube at which point the grout column is probably complete and covering the top anchor.)
- 3.2.8 After allowing sufficient time for the grout to harden, the grout pipe Valve/Tee assembly should be unscrewed from the MPBX head, or cut off flush with the MPBX head, and discarded. Remove the grout plate and replace it with the Reference Surface. Take initial readings with the dial indicator and record. Screw on the Protective Pipe Cap to protect the Reference Surface.

3.3 Standard Hydraulic System with Manual Readout

Hydraulic anchors may be of the Bladder type or of the Borros type.

- 3.3.1 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.
- 3.3.2 Normally, the MPBX is shipped complete and pre-assembled and coiled for shipment. **Care should be taken when removing the tape holding the coils.** Release one coil at a time and keep a tight grip on the rest of the coils so that they cannot suddenly break free and uncoil violently. Lay out the MPBX on a flat dry surface, as close to the borehole as possible.
- 3.3.3 If the anchor depths need to be adjusted from those set at the factory see section 4.
- 3.3.4 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. **For deep boreholes, requiring a pull-in anchor, see Additional instructions in Appendix 2.**
- 3.3.5 The hydraulic 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.** (It takes about 5 Mpa to begin to inflate the copper bladder on the Bladder type anchor or to drive out the prongs on the Borros type anchor). 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).
- 3.3.6 Repeat this process for the rest of the anchors, in descending numerical order, and for the anchor on the MPBX Head.
- 3.3.7 Take initial readings with the dial indicator and record. Screw on the Protective Pipe Cap to protect the Reference Surface

4. ADJUSTING ANCHOR DEPTHS

Occasionally, unforeseen site conditions may require the anchor depths to be adjusted. This will require the rods and tubes to be either lengthened or shortened.

4.1 Shortening the rods and tubes – groutable and hydraulic anchors

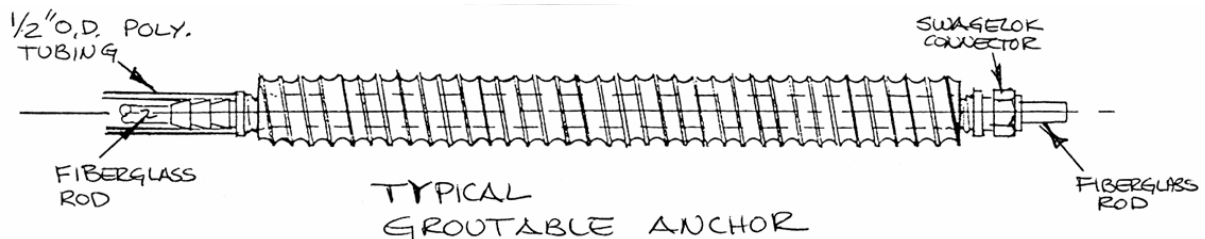


Figure 3

- 4.1.1 With the MPBX uncoiled on a flat surface, measure the amount to be shortened, from the hose barb on the anchor along the **1/2 inch O.D. poly tubing** then mark the tubing. Next, with a sharp knife, cut only the tubing at this mark. Do not cut the fiberglass rod.
- 4.1.2 Loosen the **Swagelok Connector** on the outer end of the anchor and remove the nut and ferrules (olives) from around the **fiberglass rod**.
- 4.1.3 Pull the anchor and the piece of tubing already cut off, from off the fiberglass rod. Remove this piece of tubing from the hose barb and discard.
- 4.1.4 Slide the anchor back over the fiberglass rod and reattach the poly tubing to the hose barb. (If necessary, warm the poly-tube to make this easier). Slide a new set of ferrules and nut over the fiberglass rod and tighten to the Swagelok fitting on the anchor. Make sure that the two parts of the ferrule are correctly oriented and positioned.
- 4.1.5 With a hacksaw saw off the excess fiberglass rod protruding from the anchor.

4.2 Lengthening the rods and tubes – groutable and hydraulic anchors

This procedure requires the use of special factory supplied extension kit, which includes fiberglass rod extensions, of the correct length, poly tubing and barbed tube fittings.

- 4.2.1 With the MPBX uncoiled on a flat surface remove the grout plate (or Reference Surface) from the MPBX head, loosen the Swagelok fitting on the outer end of the anchor and remove the nut and ferrules (olives) and then push the fiberglass rod through the anchor until the other end protrudes from the MPBX head.
- 4.2.2 Disconnect the anchor from the poly tube at the barb fitting on the anchor, (cut the tubing if necessary). Connect the correctly measured length of extension poly tube that will position the anchor at its new depth, to the rest of the tubing using a barb/barb fitting, then reconnect this extended tubing to the barb fitting on the anchor. Warming the poly tube so that it softens will facilitate the connection

- 4.2.3 Connect the fiberglass extension rod to the threaded end of the fiberglass rod at the MPBX head end. Use Locktite on the threads. Push the extension rod into the MPBX head until the tip is positioned at the same depth as before. Slide new ferrules and nut onto the fiberglass rod and then tighten the Swagelok fitting on the anchor so that it grips the rod.
- 4.2.4 Usually there is enough extra hydraulic tubing supplied with the hydraulic anchors that the end of the hydraulic tubing will remain accessible. If this is not the case then the hydraulic tubing must be extended using a 1/8 inch Swagelok tube/tube connector.
- 4.2.5 Replace either the Grout Plate or the Reference Surface.

5. 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.

5.1 Electronic Readout Only

A typical MPBX head assembly, designed to accept vibrating wire displacement transducers is shown in figure 4.

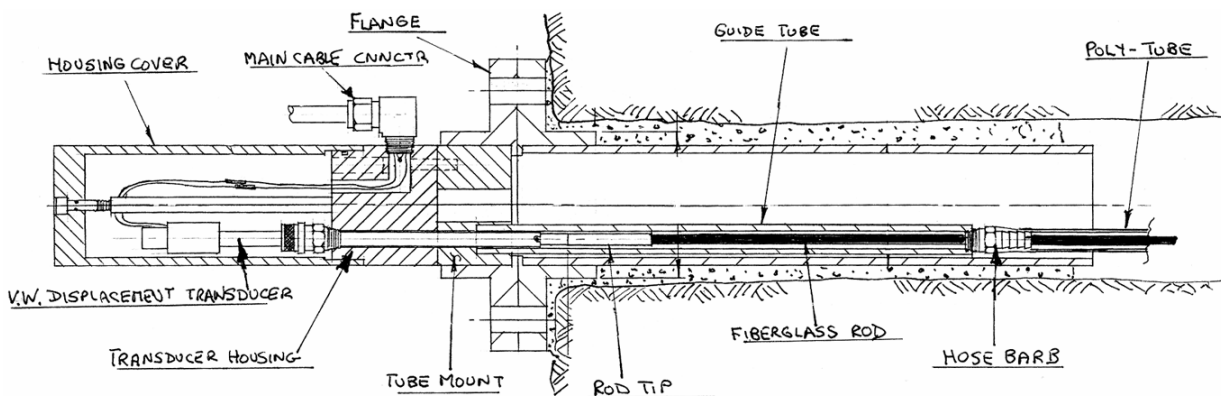


Figure 4

- 5.1.1 The **Guide Tubes** provide a space in which the transducers are located. They may be shipped separately from the coiled fiberglass rods and tubes. If shipped separately then they must be first attached, first to the **Tube Mount** by threading and/or gluing, and then attached to the uncoiled tubing with **Hose Barbs** after a specified amount of the uncoiled tubing has been removed. The amount to be removed is such that when the fiberglass 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.
- 5.1.2 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 to the standpipe. **Extension Rods** are screwed onto the end of the fiberglass rods and are then fastened to the Tube Mount by **Temporary Swagelok**

Connectors. The extension rods are designed to hold the ends of the fiberglass 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 during installation could move the rod tips by an unacceptable amount.

- 5.1.3 After the installations have been made as per the instructions of Section 3, the extension rods and Temporary Swagelok Connectors are removed. For hydraulic anchors it may be necessary to cut off the ends of the hydraulic lines and cap the hole on the Tube Mount with a pipe plug.
- 5.1.4 The **Transducer Housing** can now be bolted to the Tube Mount using the numbers stamped on the tube mount to ensure correct orientation.
- 5.1.5 **Vibrating Wire Displacement Transducers** are now threaded onto the end of the fiberglass 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.
- 5.1.6 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.
- 5.1.7 Initial Readings can now be taken.

5.2 Electronic Readout with Manual Readout Capability

- 5.2.1 A typical MPBX head assembly, designed to accept vibrating wire displacement transducers and also permit manual readout is shown in figure 5. In this arrangement the transducers are not directly in line with the fiberglass 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.

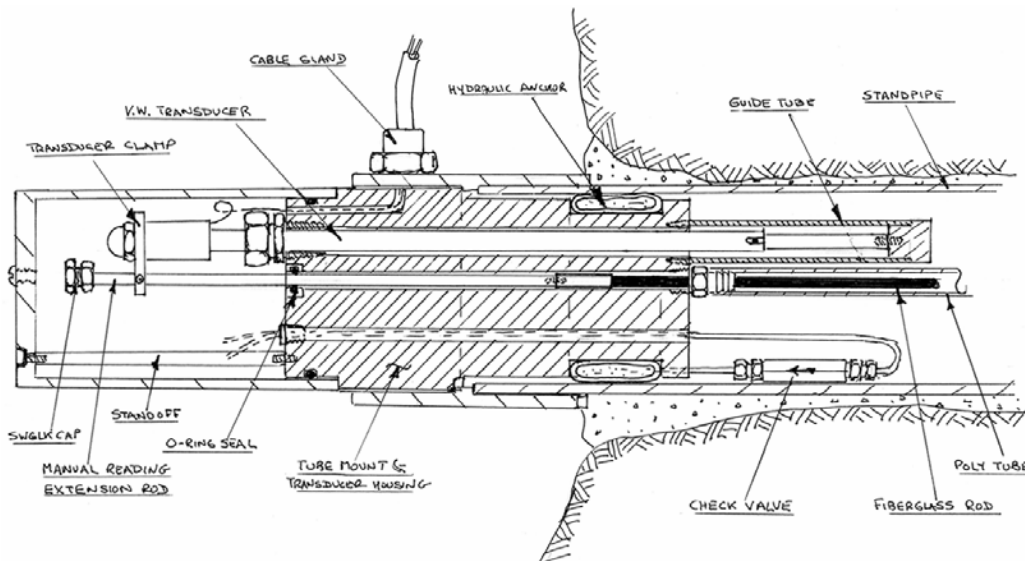


Figure 5

- 5.2.2 The **Tube Mount**, if not shipped already connected to the fiberglass rods and tubes, 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 located; they are shipped already attached to the **Tube Mount**. Where groutable anchors are to be installed, these Guide Tubes need to be kept clean and should now be plugged with the **O-ring plugs** provided.

- 5.2.3 After uncoiling the **fiberglass rods** and **poly tubing**, the poly tubing, (if not already connected), is connected to the Tube Mount with **Hose Barbs** after a specified amount of the uncoiled tubing has been removed. The amount to be removed is such that when the installation is completed the tip of the fiberglass 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.
- 5.2.4 Stainless steel **Extension Rods** are screwed, finger tight onto the end of the fiberglass rods and are then held to the Tube Mount by Temporary Swagelok fittings tightened onto the extension rods. The extension rods are designed to hold the ends of the fiberglass 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 during installation could move the rod tips by an unacceptable amount.
- 5.2.5 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.
- 5.2.6 After the installation of the fiberglass rods, poly tubes and anchors is completed, then the Temporary Swagelok fittings and extension rods can be removed. The stainless steel **Manual Readout Rods** are connected to the end of the fiberglass rods. Tapered Bullets are threaded onto the outer ends of the Manual Readout 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.
- 5.2.7 The **Vibrating Wire Transducers** can now be installed inside the Guide Tubes by removing the O-ring Plugs and then 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 Manual Readout 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.
- 5.2.8 The bullets are removed from the end of the Manual Readout Rods and replaced by **Swagelok Caps**, which will provide a large flat surface for the dial indicator tip to find.
- 5.2.9 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.
- 5.2.10 Initial readings can now be taken – both manual and electronic.

6. 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 GK403 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, in a timely manner, to the possibility of serious ground movements or to possible instrument damage and can look for further evidence of either.

7. 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.

7.1 An Example of MPBX Data Reduction for a Situation where the Deep Anchor is in Stable Ground

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	38.92	26.00	35.51	
12/03/00	39.02	26.10	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 (Taken by a Depth Micrometer)*

***Note that readings taken with a dial indicator will get smaller as the anchors diverge**

- 7.1.1 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 Table2.

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	0.82	0.81	0.76	
12/03/00	0.92	0.91	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	

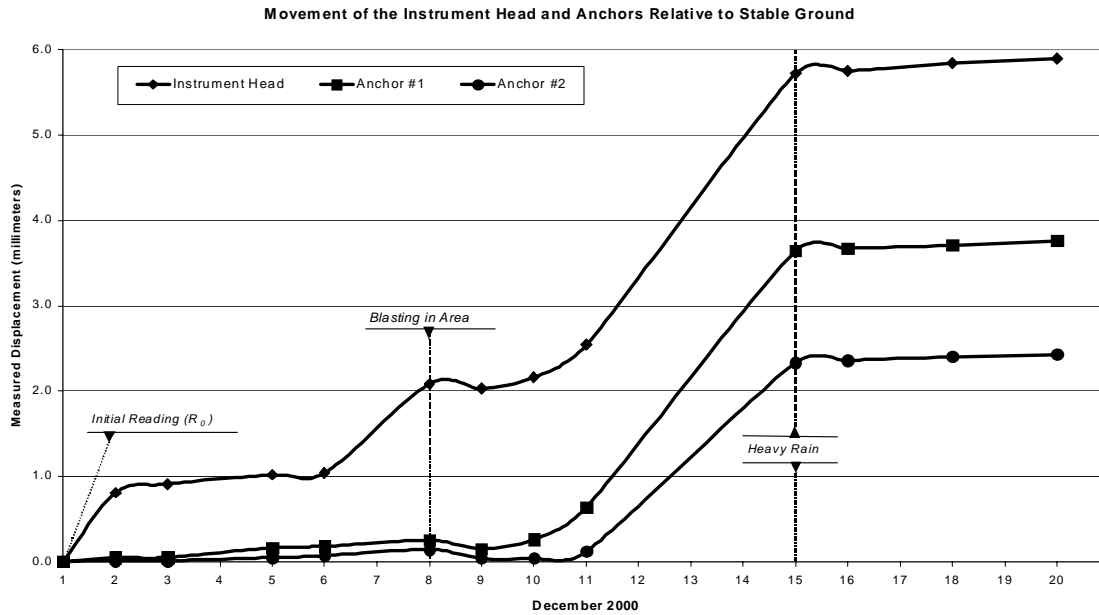
Table 2. Relative Movement between the Instrument Head and Each Anchor

- 7.1.2 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	0.06	0.82	
12/03/00	0.01	0.06	0.92	
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

7.1.3 The data shown in Table 3 could be plotted and shown in a graph similar to the one shown in Figure 6.

**Figure 6. Movement of the Instrument 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 6, or they can be plotted separately as shown in figure 7.

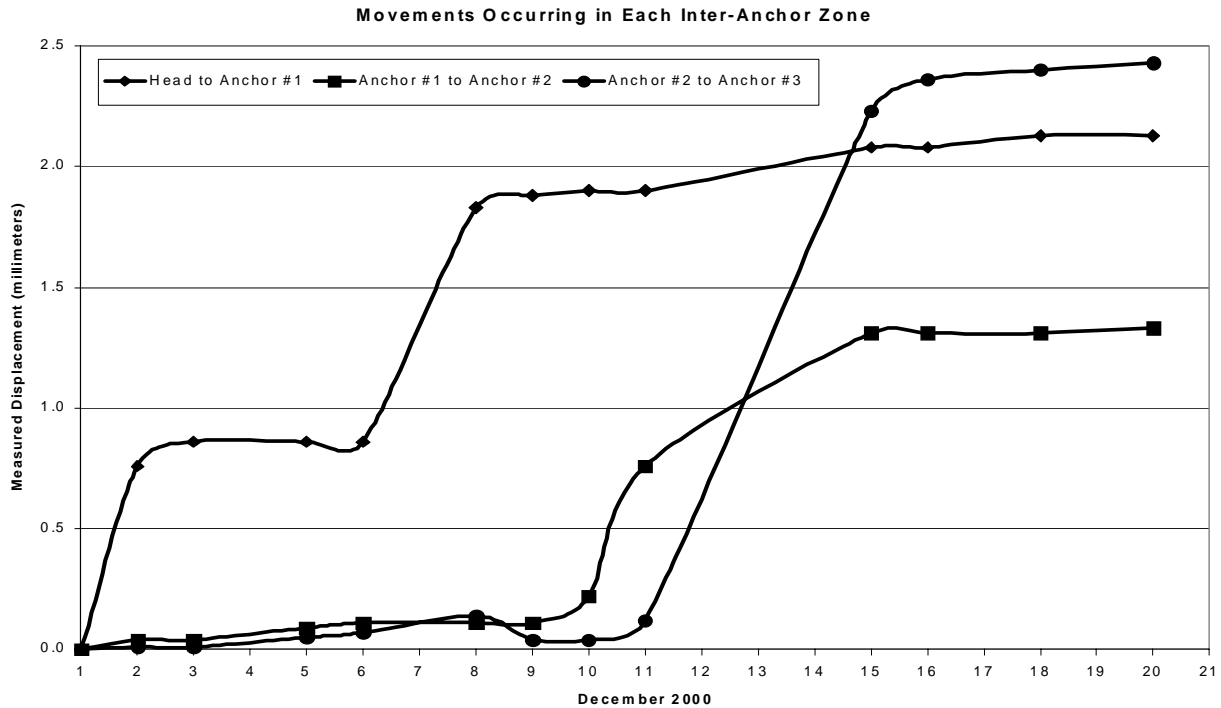


Figure 7 Movements Occurring in Each Inter-Anchor Zone

7.2 Instrument Head located in stable ground

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 7.1.2

8. 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.

- ✓ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, transformers, arc welders and radio transmission towers. 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 5.

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 $180\Omega, \pm 10\Omega$. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately $14.7\Omega/1000'$ or $48.5\Omega/km$, 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 ($<100\Omega$) 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.

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-
N/C	Blue	Thermistor
N/C	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-
N/C	Yellow	Thermistor
N/C	Black of Yellow	Thermistor
N/C	Shields (7)	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	Blue	Thermistor
Black	Black of Blue	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-
N/C	White	Thermistor
N/C	Red of White	Thermistor
N/C	Shields (13)	Ground

Appendix 2. Using a Pull-in Anchor in Deep Boreholes

For deep boreholes oriented horizontally, upwards, or inclined downwards at a large angle to the vertical it may not be possible, due to the flexibility of the extensometer assembly, and friction against the walls of the borehole, to push the assembly all the way into the borehole. To overcome this problem a pull-in anchor should be used.

This pull-in anchor comprises a Bladder type Hydraulic Anchor of the same type as the other anchors. This pull-in anchor carries a pulley wheel so that a plastic-coated stainless-steel aircraft cable can be threaded around the pulley and be used to pull the extensometer anchor string into place.

The pull-in anchor has a left-handed pipe thread adapter to enable the attachment of ¼ inch pipe sections, (available in 22ft sections), that can then be coupled together and used to push the pull-in anchor, with the aircraft cable looped around the pulley, to the back of the borehole. To disengage the rods from the deep anchor they can be turned clockwise.

Once in place the hydraulic bladder anchor is inflated. One end of the aircraft cable is now attached to the eyebolt on the underside of the bottom anchor of the extensometer string. Before pulling the extensometer into place, **it is very important to trap the other intermediate depth hydraulic anchors onto the extensometer string** so that as the string is pulled into the borehole the friction against the borehole walls does not cause the intermediate anchors to slide down the rod/tubing assemblies. To trap the anchors it is recommended to use electrical tape to create a lump around the tubing immediately above each one of the intermediate depth anchors. The lumps should be big enough to prevent them from sliding through the holes in the hydraulic anchor.

The pull-in anchor also has the advantage of ensuring that the rod/tubing assemblies are pulled into a straight line configuration, removing most of the friction that would occur between the rod and the tubes if they were snaked inside the borehole.