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Instruction Manual

Model 1200

(Model A4)

Borehole Extensometer

Revision Initial 2002

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1. INTRODUCTION

The Model A4 Multiple Position Borehole Extensometer, (MPBX), is designed for rapid installation in upwardly directed boreholes, in hard rock, that are smooth and uniform in diameter. It is made up of three or four basic components:

- **Snap-Ring Borehole anchors** are made from Delrin or stainless steel cylindrical blocks on which two retaining rings are held, in their retracted position, by a pull-pin. The anchors are easily installed by pushing them to their correct positions in the borehole and then pulling out the pull-pins allowing the retaining rings to snap out against the borehole wall. Usually the number of anchors lies between one and six.

- **Connecting rods,** the standard rod is made from ¼ inch stainless steel. The sections of stainless steel rod are flush coupled to form a continuous string. Fiberglass rods may also be used, but their higher 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.

- **Extensometer head assembly,** various styles are available: the head is usually designed for recessing into 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 A4 is designed to fit inside boreholes with closely controlled diameters, (+/- 1 to 2mm) This is because the snap-ring anchors have a very limited range of movement. Diamond-drill holes are ideal. Percussively drilled boreholes should be drilled carefully to avoid changes in diameter and excessive rifling. Borehole diameters can be checked using a GO-NO GO-Gage. If the NO/GO gage fits into the borehole, oversize rings or a larger diameter anchor must be used. If the GO gage (snap ring anchor) fits into the borehole, to the predetermined depth, then installation may proceed.

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 installed at least one tunnel diameter, and preferably nearer two tunnel diameters, away from the tunnel wall.

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.

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. Sharp Knife
11. Tape (Filament)
12. Tape Masking
13. Tape (Duct)
14. 2 each Hose Clamps, (sized to match anchor size)
15. Cable for pulling pull-pins
16. Setting Rods, (For anchors larger than 60mm (21/2 inch) dia.
17. Roof Level Instrument Head Positioning tool, (supplied).
18. Extension Rods, (supplied)

3. ASSEMBLY AND INSTALLATION

Note; There are many variations in the design of specific systems manufactured for specific situations. The following instructions are somewhat generic in nature and mainly provide an explanation for why the various procedures are necessary. The reader should be aware that special instructions are included with each system supplied, and these should be the ones used in guiding the installation procedure.

3.1 <u>Standard System with Manual Readout</u>

A typical system is shown in figure 1

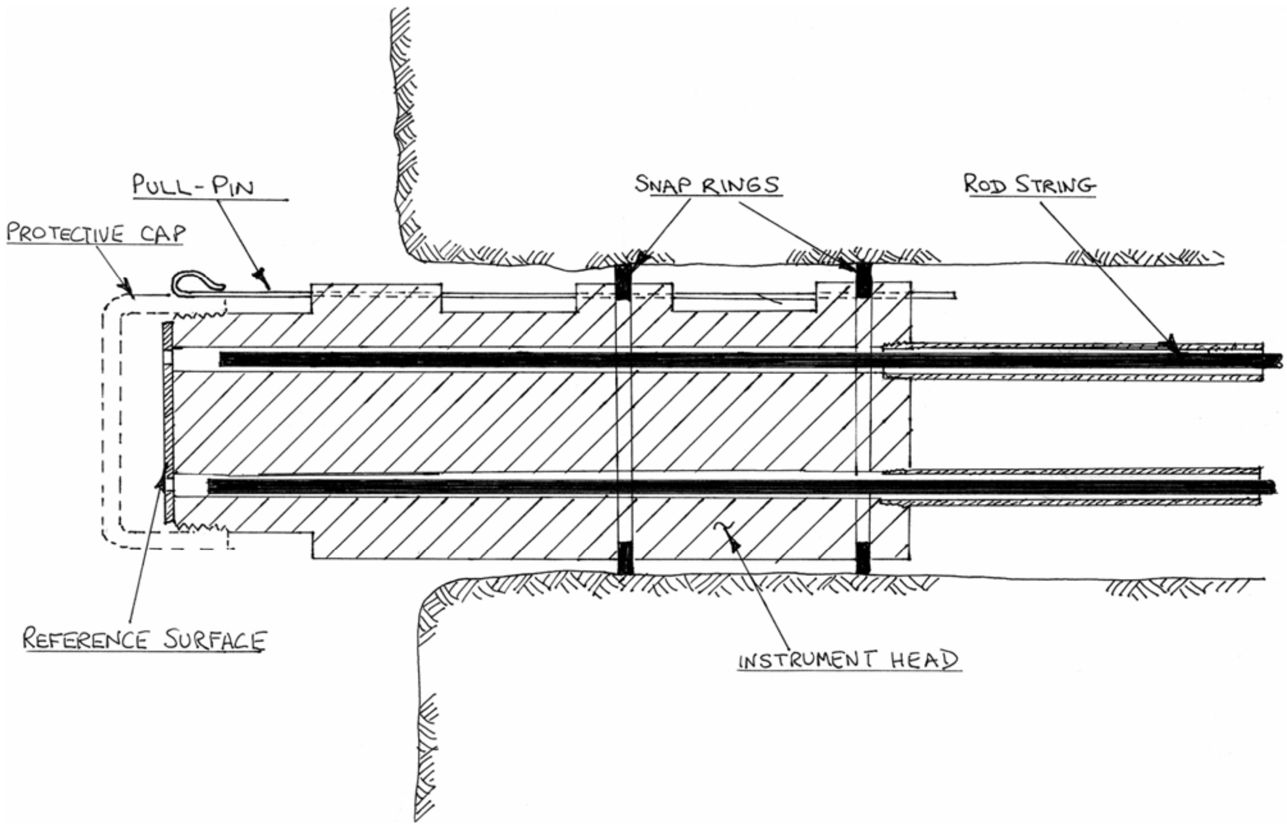


Figure 1

3.1.1 Once the anchor depths have been determined the correct lengths of ¼ inch rods can be selected and screwed together using a pair of Vise-Grips and Loctite or similar adhesive on the threads. Rods are supplied, bundled according to the anchor depths specified, or, bundled in different lengths to be used with a rod table, which specifies how many of each length should be used to make up each rod string. The readout end of the rod string uses a stainless steel rod tip that is marked in red. This special rod tip has a setscrew that has been machined flat.

3.1.2 Select the correct anchor to be attached to the rod string. Anchors are numbered: number one anchor is usually the shallowest anchor and the largest number is on the deepest anchor. The anchor end of the rod string is pushed, first through the anchor, and then out through the Swagelok fitting on the far side of the anchor. The Swagelok connector is now tightened onto the rod string at a point that gives the correct anchor depth. Excess rod length can be removed by using a Hacksaw on the rod protruding beyond the anchor.

3.1.3 It is important that the readout ends of all the rod strings terminate at the same correct depth inside the mouth of the borehole. (The correct depth is that which will place the ends of the rods at the desired distance away from the Reference Surface inside the instrument Head. This distance will depend on the magnitude and direction of the movement anticipated. Normally, where anticipated movements are extensions, the distance is around 10mm). The position of the reference surface must also be decided upon, i.e. whether it is to be recessed inside the borehole, flush with the mouth of the borehole or protruding to some degree). This is accomplished by screwing extension rods onto the ends of rod strings. The threads are not tightened and no Loctite is used. Each extension rod is marked with a Magic Marker at a point that will be opposite the roof level when the rod string is inserted to the proper depth. Also each extension rod should be marked with the anchor number.

3.1.4 Mark the mouth of the borehole with an orientation indicator. This mark will be the orientation point for all anchors and coincides with the orientation of the deepest rod string marked on each of the anchors and in the head assembly. The purpose of this is to prevent the rod strings from becoming tangled inside the borehole.

3.1.5 Mount the deepest anchor onto the setting rod and connect the pulling cable to the pull-pin. Now push the assembly into the borehole, adding additional setting rods as required (and maintaining orientation) until the mark on the extension rod coincides with the plane of the rock face.

3.1.6 When the anchor is at the correct depth, (i.e. the mark on the extension rod is opposite the roof level), hold the position of the setting rods and pull the pulling cable to release the pull out pin and set the anchor. Remove the setting rods and pull pin cord for use on the next anchor.

3.1.7 Repeat steps 3.1.1 through 3.1.6 for successive anchors, feeding subsequent connecting rods through the appropriately numbered holes in the anchors while maintaining orientation. When all the anchors are set, the quantity of extension rods sticking out of the hole will equal the amount of the position anchors installed. Be sure that all the marks on the extension rods end up at the same position, relative to the mouth of the borehole rock face and that the numbers on the extension rods are in their proper sequence corresponding with the sequence of numbers marked on the instrument head.

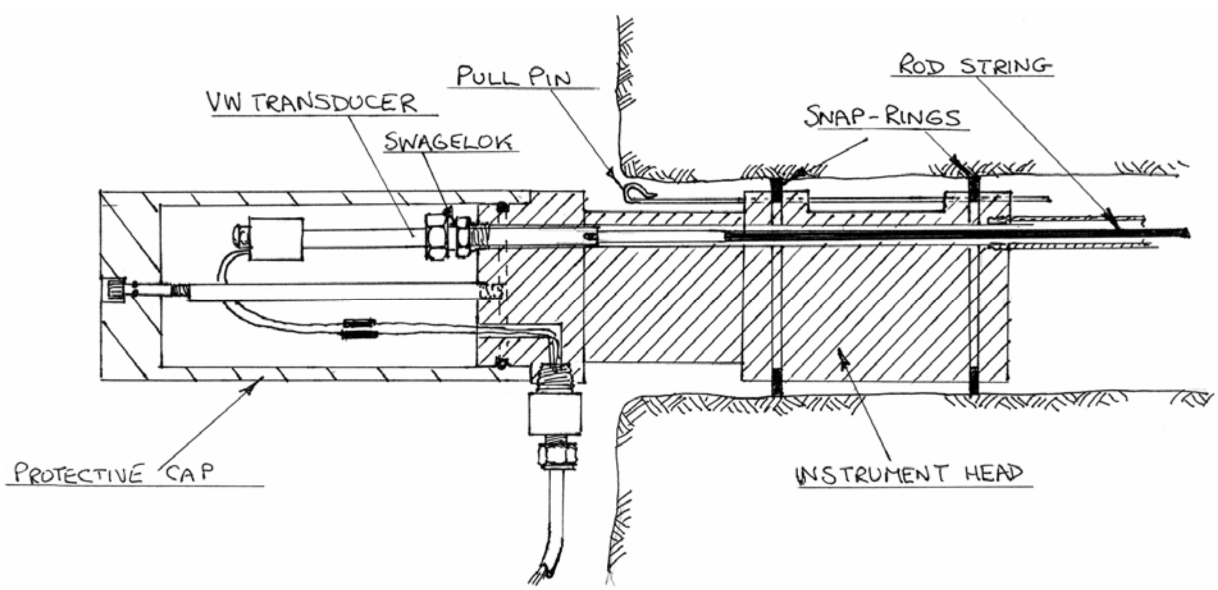
3.1.8 Connect the roof-level positioning tool to the threaded hole in the center of the stainless steel Reference Surface. Connect the pulling cable to the Head Anchor pull-pin. Slide the matching numbered extension rods into the same numbered holes in the roof level anchor. Push the instrument head into the borehole and stop at the predetermined elevation. Hold the position of the roof level positioning tool and pull the pulling cable to release the pull out pin and set the anchor

3.1.9 Remove the extension rods and take initial readings with a Dial Indicator.

3.1.10 Thread the protective cap onto the Instrument Head.

3.2 Standard System with Vibrating Wire Readout

A typical system is shown in figure 2



3.2.1 Once the anchor depths have been determined the correct lengths of ¼ inch rods can be selected and screwed together using a pair of Vise-Grips and Loctite or similar adhesive on the threads. (Allowance must be made for the length of the transducers in use and their position inside the mouth of the borehole). Rods are supplied, bundled according to the anchor depths specified, or, bundled in different lengths to be used with a rod table, which specifies how many of each length should be used to make up each rod string. The readout end of the rod string uses a stainless steel rod tip that is marked in red. This special rod tip has a setscrew that has been machined flat.

3.2.2 Select the correct anchor to be attached to the rod string. Anchors are numbered: number one anchor is usually the shallowest anchor and the largest number is on the deepest anchor. The anchor end of the rod string is pushed, first through the anchor, and then out through the Swagelok fitting on the far side of the anchor. The Swagelok connector is now tightened onto the rod string at a point that gives the correct anchor depth. Excess rod length can be removed by using a Hacksaw on the rod protruding beyond the anchor.

3.2.3 It is important that the readout ends of all the rod strings terminate at the same correct depth inside the mouth of the borehole. (The correct depth is that which will place the ends of the rods at the desired depth inside the instrument Head. This distance will depend on the length of the VW Transducers and the depth to which they are to be recessed inside the borehole. This distance must be determined in advance of installation). This is accomplished by screwing extension rods onto the ends of rod strings. The threads are not tightened and no Loctite is used. Each extension rod has ataper on its outward end and is marked with a Magic Marker at a point that will be opposite the roof level when the rod string is inserted to the proper depth. Also each extension rod should be marked with the anchor number.

3.2.4 Mark the mouth of the borehole with an orientation indicator. This mark will be the orientation point for all anchors and coincides with the orientation of the deepest rod string marked on each of the anchors and in the head assembly. The purpose of this is to prevent the rod strings from becoming tangled inside the borehole.

3.2.5 Mount the deepest anchor onto the setting rod and connect the pulling cable to the pull-pin. Now push the assembly into the borehole, adding additional setting rods as required (and maintaining orientation) until the mark on the extension rod coincides with the plane of the rock face.

3.2.6 When the anchor is at the correct depth, (i.e. the mark on the extension rod is opposite the roof level), hold the position of the setting rods and pull the pulling cable to release the pull out pin and set the anchor. Remove the setting rods and pull pin cord for use on the next anchor.

3.2.7 Repeat steps 3.1.1 through 3.1.6 for successive anchors, feeding subsequent connecting rods through the appropriately numbered holes in the anchors while maintaining orientation. When all the anchors are set, the quantity of extension rods sticking out of the hole will equal the amount of the position anchors installed. Be sure that all the marks on the extension rods end up at the same position, relative to the mouth of the borehole rock face and that the numbers on the extension rods are in their proper sequence corresponding with the sequence of numbers marked on the instrument head.

3.2.8 Remove the Housing Cap from the Transducer Housing by loosening the cap screw holding the Cap to the Center Post. The Cap screw has an O-ring on it.

3.2.9 Attach the pulling cable to the pull-pin on the transducer housing. Connect the roof-level positioning tool to the Center Post.

3.2.10 Slide each of the numbered extension rods into the matching numbered Guide Tube on the base of the Transducer Housing. . Push the instrument head into the borehole and stop at the predetermined depth. Hold the position of the roof-level positioning tool and pull the pulling cable to release the pull out pin and set the anchor

3.2.11 Remove all of the extension rods and the roof-level positioning tool.

3.2.12 Select a transducer and record a) the serial number b) the extensometer that it is being used in and c) the specific anchor position. Remove the ty-rap around the transducer shaft. (This ty-rap prevents damage to the transducer during shipment.)
NOTE: **DO NOT EXTEND THE TRANSDUCER BY PULLING ON THE SHAFT BEYOND ITS RANGE. DO NOT TWIST THE SHAFT INSIDE THE REST OF THE BODY BEYOND ONE HALF TURN**

3.2.13 Loosen, but do not remove, the Swagelok nut in the #1 position.

3.2.14 Push the transducer through the fitting until it engages the end of the connecting rod. Rotate the sensor clockwise until it is tight on the connecting rod (about 16 turns) **BE SURE THE PIN IN THE TRANSDUCER SHAFT IS IN THE NOTCH ON THE TRANSDUCER TUBE BEFORE TIGHTENING,** otherwise the wire will break.

3.2.15 Now, connect the GK-401 or GK-403 Readout Box to the #1gage leads and turn on the box (Position B). Note: the range of the sensor is approximately 5,000 digits, starting at 2,000 and ending at 7,000 (plus some over-range capability.) To set the sensor at mid-range, the reading should be about 4,500. For 1/3 compression, 2/3 extension, set at approximately 3,600. For 1/3 extension and 2/3 compression, set at approx. 5,300. Repeat for all the gages.
Note: The reading may be unsteady with the shaft pin inside the tube notch and the transducer fully closed.

3.2.16 While observing the readout box display, gently pull on the sensor until the desired reading is obtained. Then, with the Tube wrench supplied, tighten the Swagelok nut one full turn beyond finger tight.

3.2.17 Repeat steps 3.2.12 to 3.2.16 for the remaining transducers.

3.2.18 The next step is to attach the lead wires from the transducers to the cable wires in the cap using a crimping tool. Cut the sensor wires to an acceptable length and then strip back the insulation approximately 3/8” (8mm). Push the stripped wire into the crimp and actuate the crimper. Test each lead after crimping by pulling on it. If any are loose, cut off the crimp and remake the splice.

3.2.19 Now, check the gages with the VW readout box by connecting the 10 pin connector on the cable from the head assembly.

3.2.20 Slide the Housing Cap over the O-ring seal on the Transducer Housing and secure in place to the Center Post using the ¼-20 cap-screw with the O-ring seal. Tighten the cable gland nut to secure the cable in the cap.

4. 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.

5. 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.

5.1 **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	38.91	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

5.1.1 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	0.81	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

5.1.2 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

5.1.3 The data shown in Table 3 could be plotted and shown in a graph like the one shown in Figure 5.

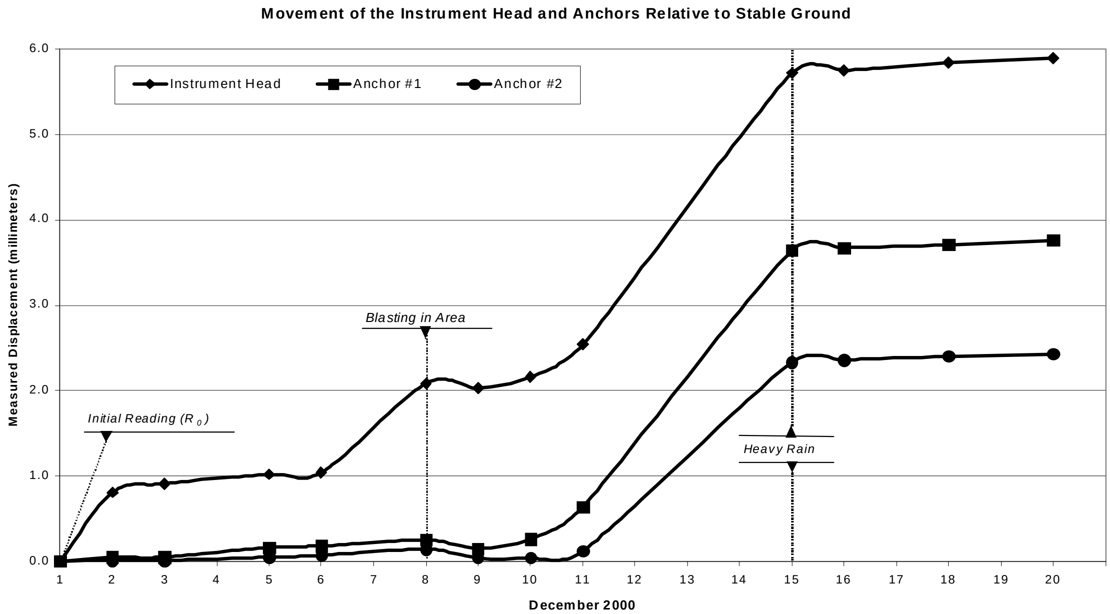


Figure 5. Movement of the Head and Anchors Relative to Anchor 3 in Stable Ground

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 5, or they can be plotted separately as shown in figure 6

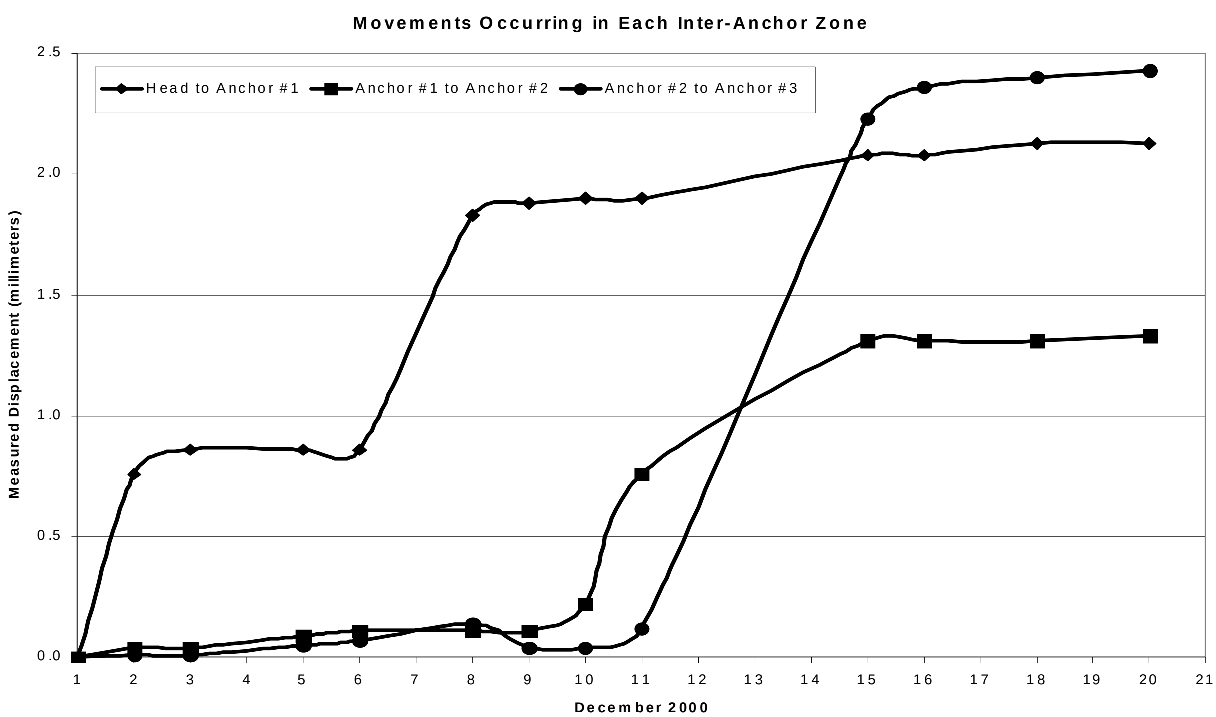


Figure 6 Movements Occurring in Each Inter-Anchor Zone

5.2 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 5.1.2

6 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 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 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.

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