



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 1150

(Model A3)

Borehole Extensometer

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Revision A

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1. INTRODUCTION

Borehole extensometers, as the name implies, are used primarily for measuring **extensions** associated with rock failures brought about by strata separations, joint openings, shearing and cracking. A series of borehole anchors, (maximum number 8), installed at different depths, each with a measurement rod attached leading to the surface enable the amount of movement in each inter-anchor zone to be measured. The Model A3 extensometer is one of the easier types to install since the measurement rods and groutable anchors can be assembled on the ground surface along with a grout tremie pipe: the whole assembly can then be pushed or lowered into a borehole, which is then filled with a cement grout. The measurement rods are protected from the grout by PVC pipes. These pipes are weak enough that they will stretch and snap under tension so that the anchors will always follow the movement of the adjacent rock. The PVC pipes are highly compressible compared to the surrounding rock so that they can accommodate a limited compressive movements also. However, **the Model A3 extensometer is not suitable for soft soils** and for these applications the Model A5 or Model A6 extensometer using hydraulic borehole anchors or Boros anchors are recommended.

The Model A3 Multiple Position Borehole Extensometer, (MPBX), is made up of three or four basic components:

- **Borehole anchors**,. The groutable type anchor is usually recommended for downward directed boreholes or for holes that must remain sealed. Special equipment will be required for grouting boreholes directed upwards. An optional accessory, (Model No.1150-13), is a bayonet connector on the anchor so that the connecting rods can be detached from one slot in the anchor and then re-attached at another slot a known distance away. This procedure gives a method by which the free movement of the connecting rods, inside the protective tubing, can be checked. 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 tubing. 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. Tell-tales, or rods extending below the bottom anchor are sometimes used in tunnel applications. 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 may be designed for recessing into an enlarged section of the borehole. Or, more usually, it will have a flange or coupling 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.

Plus a **Grout Pipe**, made from ¾ inch polyethylene pipe. Used in conjunction with a grout pump.

2. PRELIMINARY REQUIREMENTS

2.1 Borehole Requirements

The Model A3 is designed to fit 75mm (3 inch) or larger diameter boreholes. The mouth of the borehole is usually enlarged and cased with a 2½-inch or 3-inch galvanized steel or PVC 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 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.

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) diameter. A more convenient size would be a medium duty iron casting 560 mm (22 inch) 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 are equipped with a flange or coupling to engage the flange or coupling on top of any standpipe grouted into the mouth of the borehole.

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. Portland cement (N0 2)
13. Quick Setting Cement
14. Grout Tube and fittings
15. Grout Pump
16. Grout Plate (Normally Supplied)
17. Water (for flushing and grouting).
18. Sharp Knife
19. Tape (Filament)
20. Tape Masking
21. Tape (Duct)
22. 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

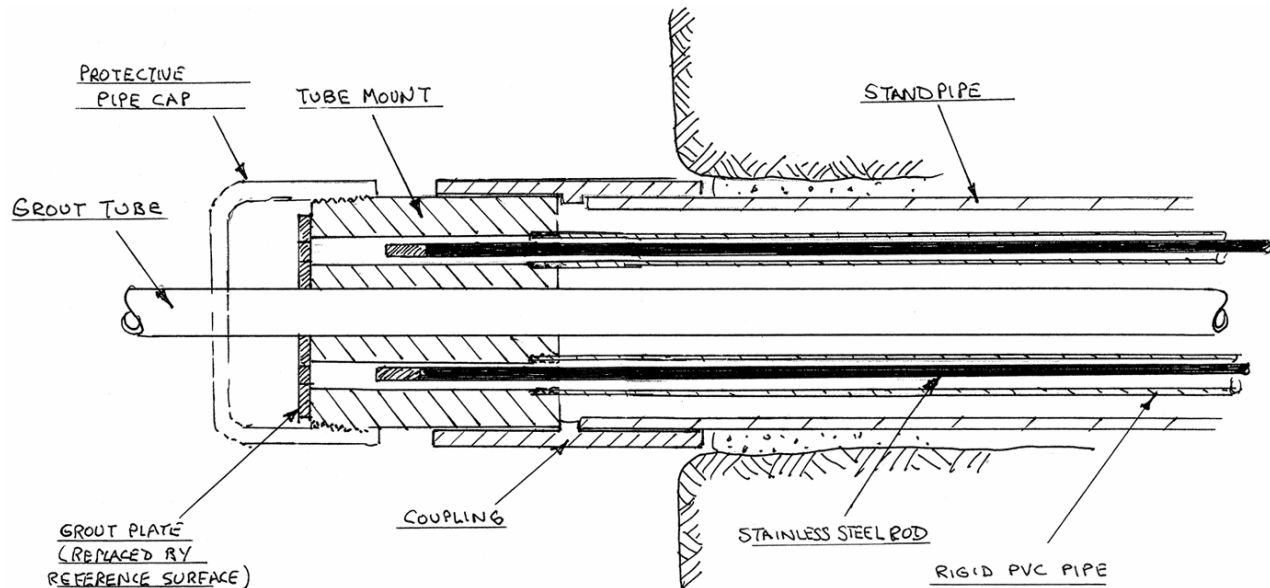


Figure 1 – Typical A3 Extensometer

3.1.1 If a **Standpipe** is to be installed it should be assembled now. For galvanized steel standpipes, screw on the **Flange**, for PVC Standpipes, glue the **Coupling**, (or **Flange**), to the standpipe using PVC purple primer and cement. Apply quick-setting cement to 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 female connector into the anchor, (or into the bayonet fitting on 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 **Tubemount**. Note that the Tubemount 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, 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 If a flange is used on the standpipe then the mating Tube Mount Flange should be placed over the rod/pipe bundle now. When all the rod/pipe assemblies have been glued to the tube mount, (and the Tube Mount Flange, if used, 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. Do not tape directly on top of the anchors. Do not tape the grout tube to the rest of the bundle.

3.1.6 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.

3.1.7 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 (>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. Add PVC cement to the outside of the Tube Mount where it seats inside the standpipe coupling, (or flange), Push the Tube Mount inside the coupling and allow the PVC cement to harden. (If a flange is used instead of a coupling, glue the Tube Mount to the Tube Mount Flange then bolt this flange to the flange on the standpipe using the bolts supplied).

3.1.8 Cut two or three notches in the side of the grout tube close to its lower end. (This is so that the end of the grout tube cannot become blocked as it is pushed into the borehole). 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 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.

3.1.9 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 The standpipe should be assembled now. For galvanized steel standpipes, screw on the **Flange**, for PVC Standpipes, glue the **Coupling**, (or **Flange**), to the standpipe using PVC purple primer and cement. Apply plenty of quick-setting cement to the outside of the standpipe and insert into the borehole to the desired depth. Make sure that there is enough cement to seal the hole completely. Hold in place until the cement hardens, using wooden wedges or sackcloth soaked in quick-setting cement.

3.2.2 Assemble the anchors and rod/pipe strings and attach the Tube Mount as described in section 3.1.

3.2.3 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

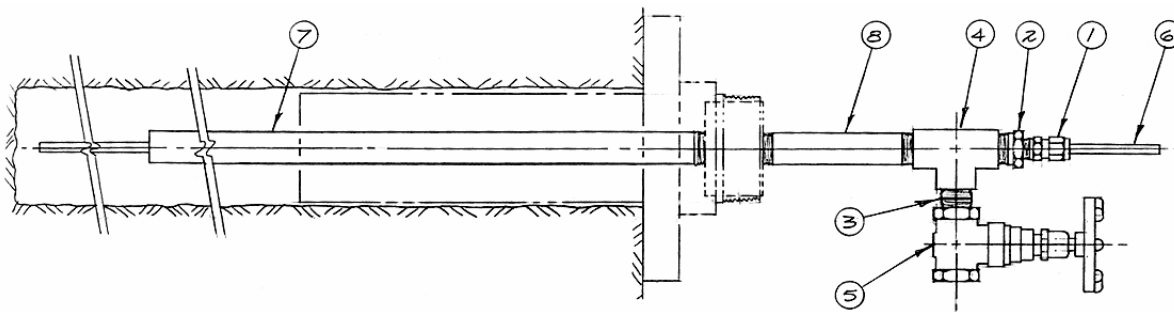


Figure 2 – Upwards Installation Assembly

3.2.4 Push the entire MPBX 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 flanges are used instead of couplings, bolt the flange on the head to the flange on the standpipe using the bolts supplied).

3.2.5 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, (4ft), 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 neat cement grout with the consistency of pancake batter. 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.

3.2.6 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.)

3.2.7 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.

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 3.

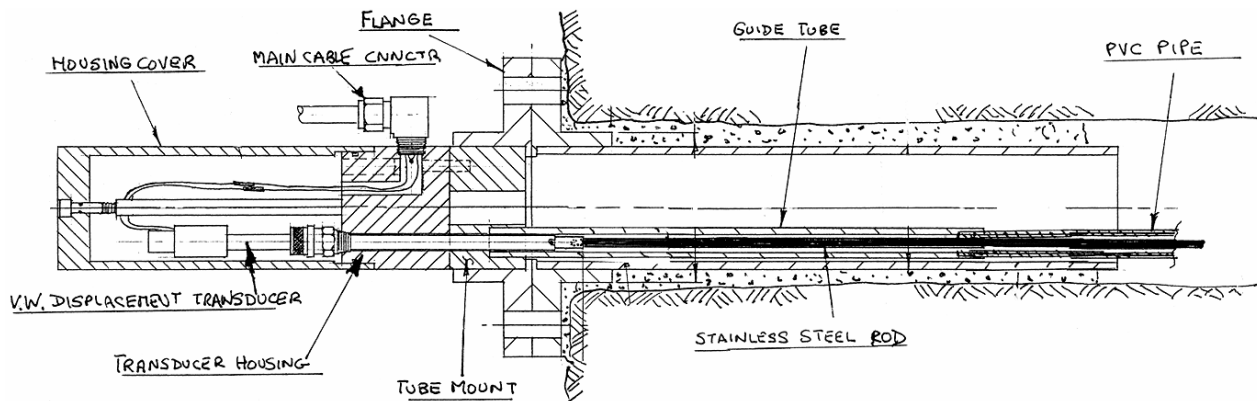


Figure 3 – Electronic Readout Set-up

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 first attached, first to the **Tube Mount** by threading and/or gluing, and then cemented 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 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.

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.

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 4. 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.

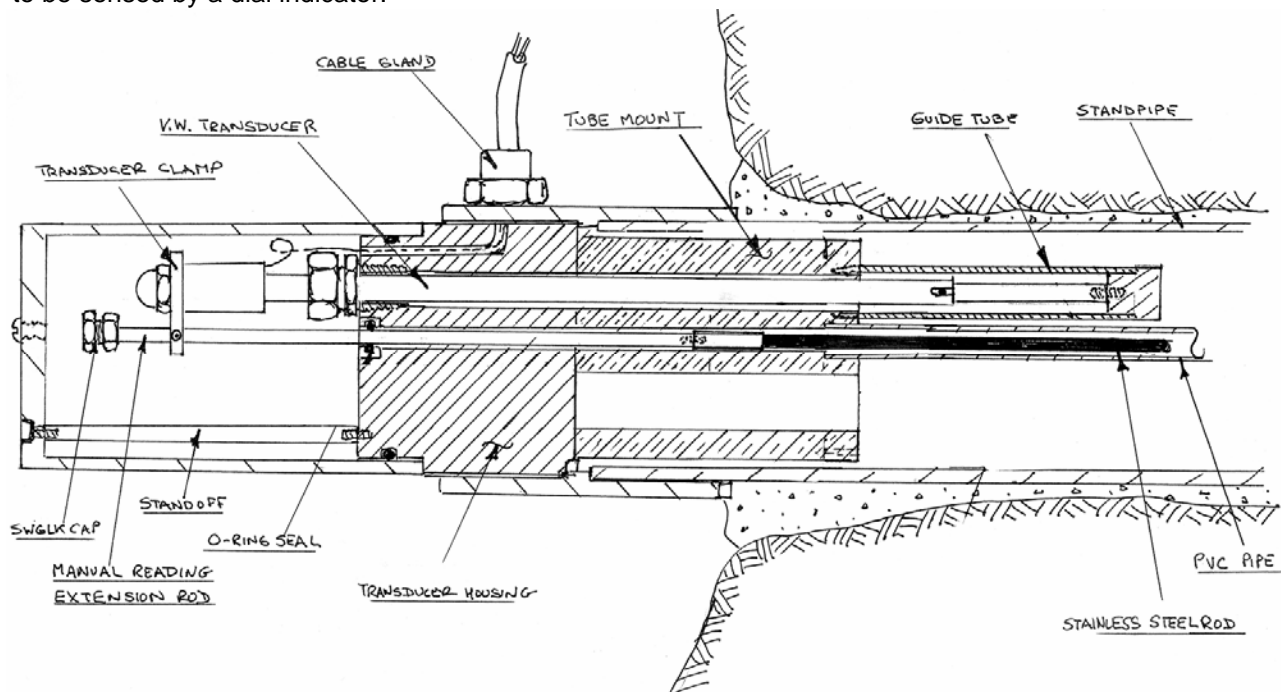


Figure 4 – Manual Readout Set-up

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 the grouting operation and should now 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 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 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 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

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 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

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 5.

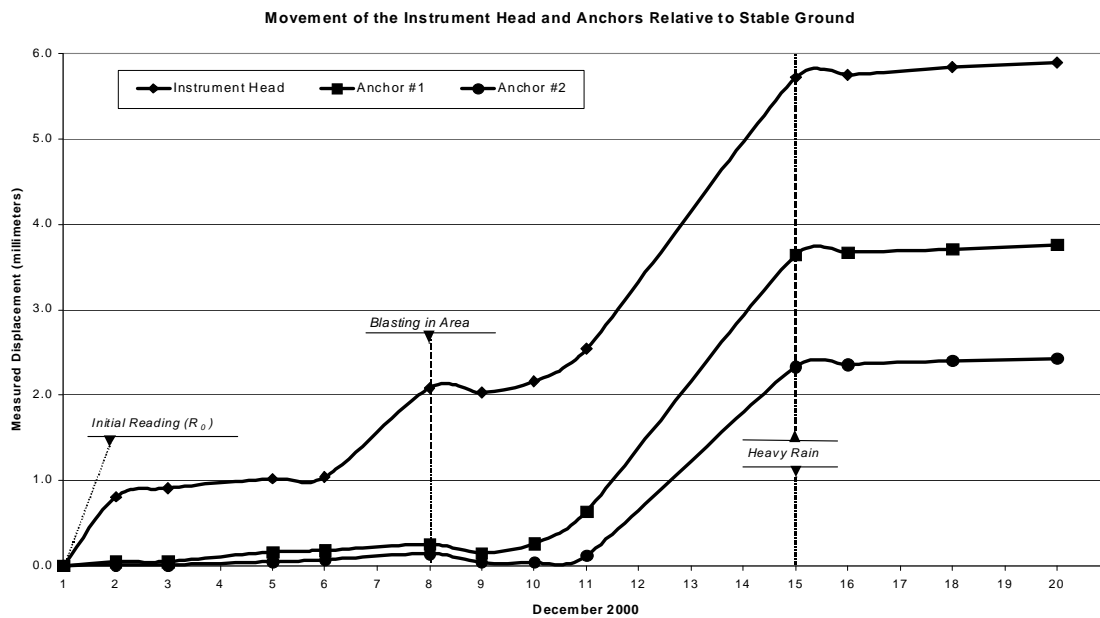


Figure 5. Movement of the Head and Anchors Relative to Anchor 3 in Stable Ground

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

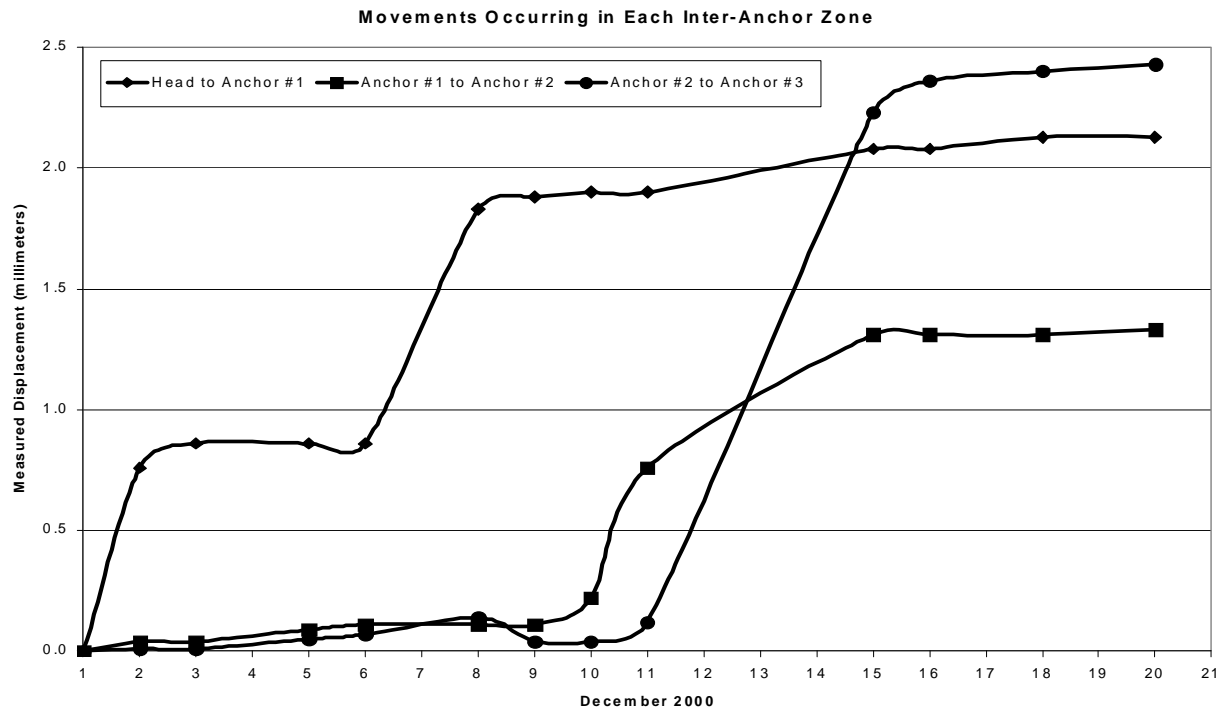


Figure 6 Movements Occurring in Each Inter-Anchor Zone

6.2 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 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 $180\Omega, \pm 10\Omega$. 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.

Wiring Chart 1 - 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

Wiring Chart 2 - 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

Wiring Chart 3 - 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

Wiring Chart 4 - 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	Black of Brown	Thermistor
N/C	Shields (7)	Ground

Wiring Chart 5 - 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