Bassett
Convergence System
56806099

This equipment should be installed, maintained, and operated by technically qualified personnel. Any errors or omissions in data, or the interpretation of data, are not the responsibility of Slope Indicator Company. The information herein is subject to change without notification.

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SLOPE INDICATOR

Contents

Introduction

Applications

The Bassett convergence system provides automated surveys of a tunnel section. Typical applications include:

- Recording the behavior of tunnels and other underground openings to verify that actual performance conforms to predictions.
- Monitoring deformation due to nearby construction activity or to slope movements and other natural disturbances.
- Monitoring deformation in tunnels under construction to ensure safety and to control the rate of construction.

Operation

The Bassett system uses tilt sensors to monitor the position of reference pins installed in a tunnel section. The sensors are linked to the pins via a system of low-profile arms. Spatial displacement of any pin changes the tilt of the arms connected to it and results in a changed tilt reading.

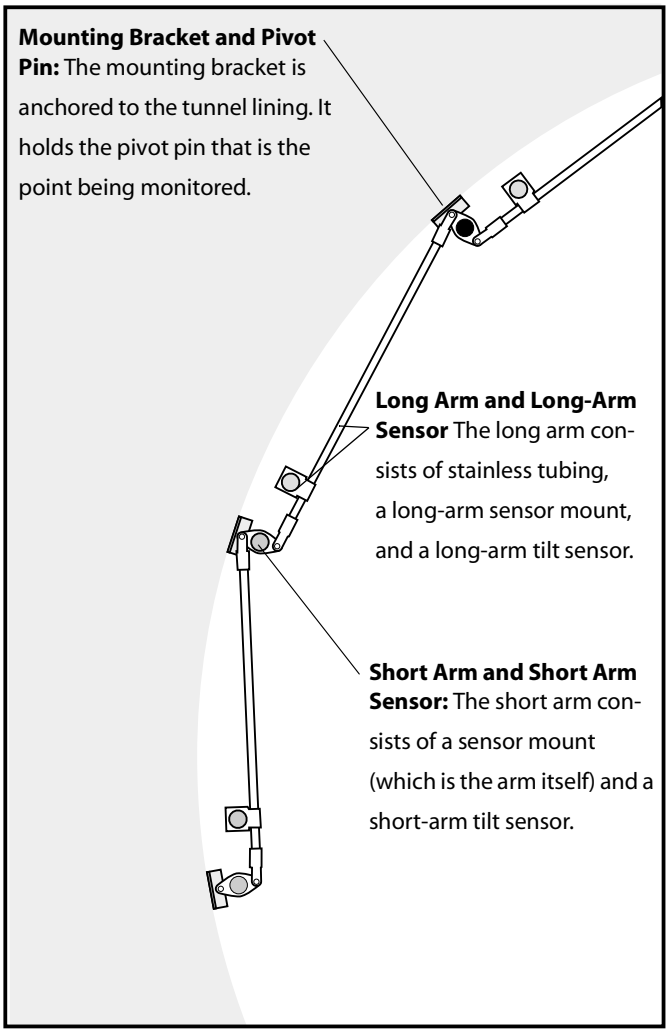
The system can be configured as a closed loop or left open-ended. With closed loops, a Bowditch correction can be applied to minimize the effects of errors. Open-ended systems are referenced to conventional surveys periodically unless one end is known to be stable.

At scheduled intervals, a data logger obtains a survey of the tunnel section by recording a reading from each tilt sensor. This requires five to ten seconds, depending on the number of sensors in the system.

A computer, running customized software retrieves the readings from the data logger, calculates displacement data, and generates a graphic display of the tunnel section.

Installation

Components



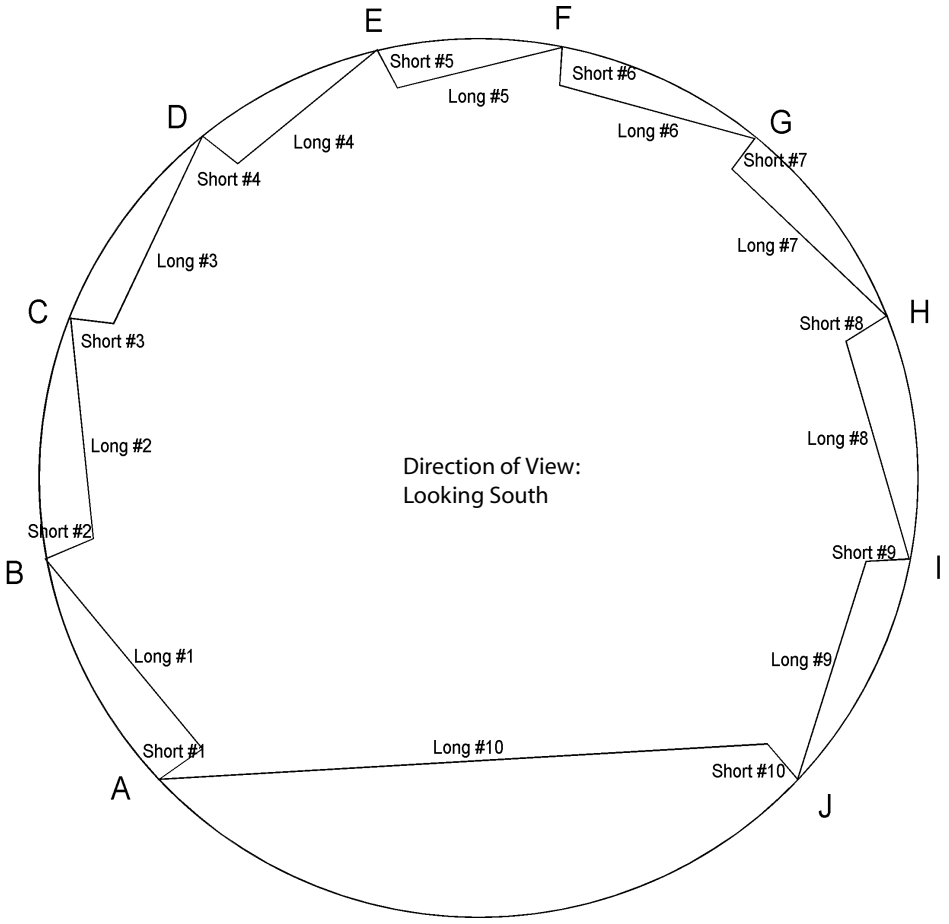
Installation Tasks

1. Establish a direction of view for the computer display.
2. Install mounting brackets in tunnel lining.
3. Install and align pivot pins in mounting brackets.
4. Install short arms.
5. Install long arms.
6. Install sensors.
7. Install data logging system.
8. Test, zero, and document sensors.
9. Install and test software.

Direction of View

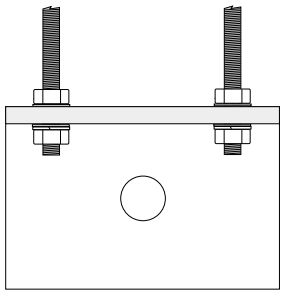
In the tunnel, you can view the Bassett System from either side, but on the computer screen, you can view the system from just one side. Therefore, it is necessary to establish a convention to relate the computer display to the real-world.

1. The computer screen will look similar to the drawing below. As you look through the Basset section, what is the direction of your view? Specify a compass direction, such as "Looking North," "Looking East," etc.
2. "As-Installed" documentation must use the same direction of view. Starting from the lower left side, label the monitored points as A, B, C, D, etc, as shown below.
3. Two sensors will be installed for each monitored point, a short-arm sensor and a long-arm sensor. Starting from the lower left, label the sensors short #1 & long #1, short #2 & long #2, etc, as shown below.



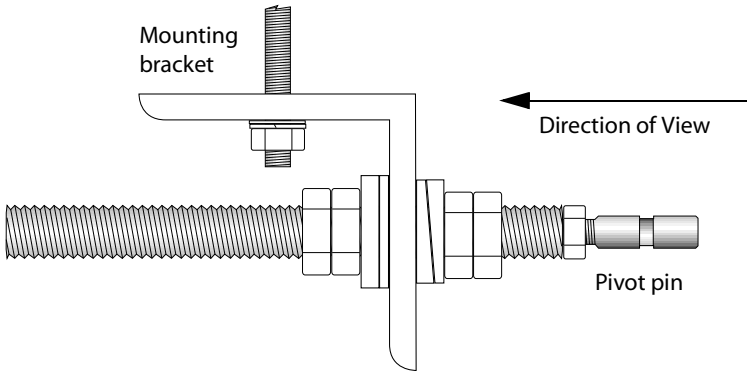
Install Mounting Brackets

1. Mark locations for mounting brackets so that the plane of the Bassett section will be perpendicular to the tunnel lining.
2. Orient brackets so that anchor holes are on the side away from the viewer (see drawing below).
3. Install mounting brackets. Grouted-in anchors are better than expanding anchors.



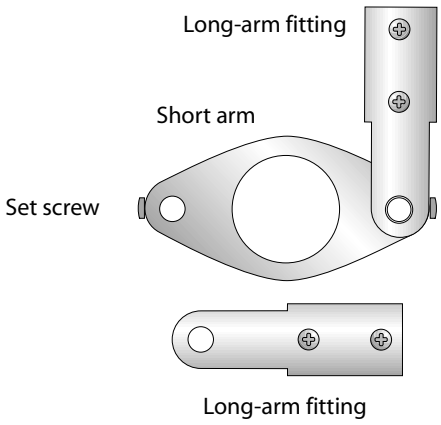
Install Pivot Pins

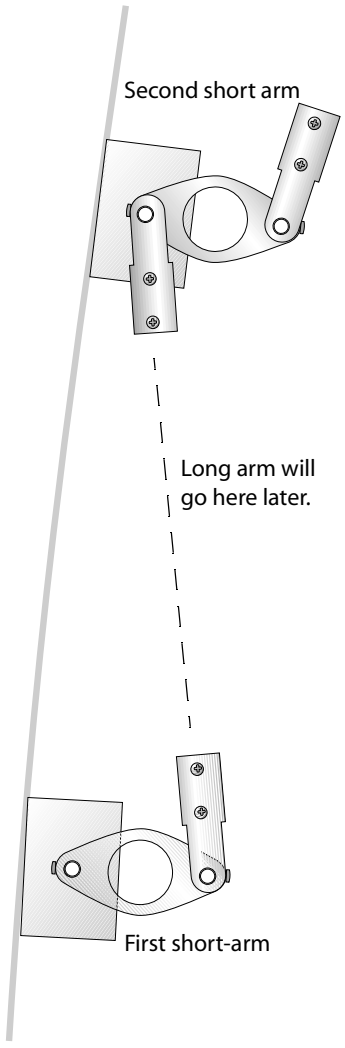
1. Fit a pivot pin to each mounting bracket. Pivot pins should point towards the viewer (away from the viewing direction).
2. Adjust nuts so that the tip of each pin is in the same plane as the others. Then tighten nuts to keep pins in place.



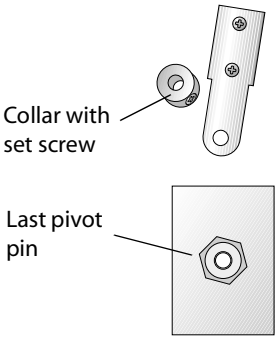
Install Short Arms

Short arms are packaged in plastic bags. Each bag contains a short-arm and two long-arm fittings. One fitting is attached to the short arm. One fitting is loose.



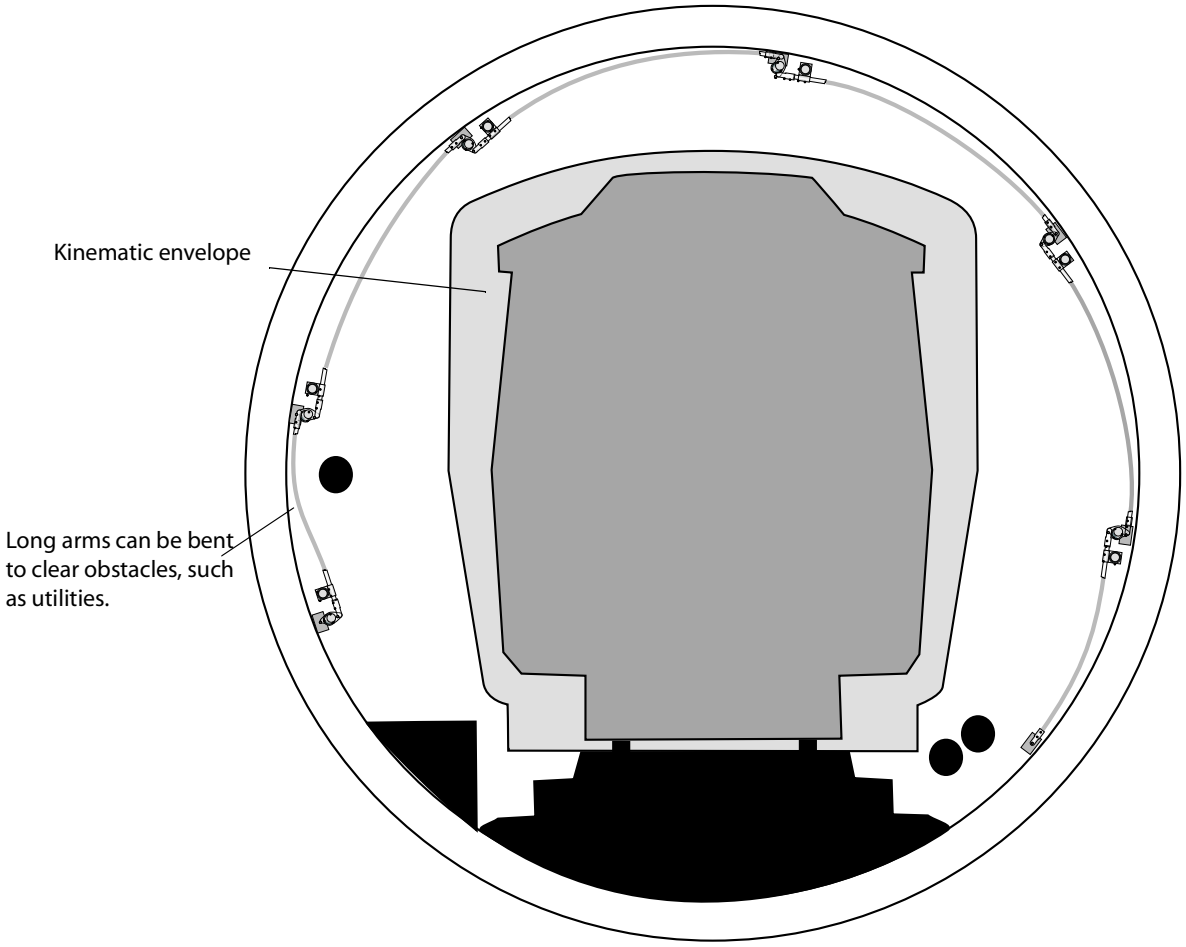


1. Start at the bottom pivot pin on the left side. Avoid working from both sides at once.
2. Fit the first short arm onto pivot pin. Tighten set screw. Save loose long-arm fitting for use on the last pivot pin.
3. Move to next pivot pin. Fit long-arm fitting onto short arm, then push both onto pivot pin. .
4. Continue mounting short arms until you reach the last pivot pin. It may be necessary to temporarily secure the long-arm fittings so that they will not hang into the kinematic envelope where they may be struck by vehicles.
5. At the last pivot pin, use only a long-arm fitting. Slide the collar into the fitting and push both onto the pivot pin. Then tighten the set screw.



Install Long Arms

Long arms are made from stainless tubing, which you must measure, shape to fit, and cut. Start at the bottom left and work your way around to the last pivot pin on the right.



View Towards North

Measure tubing

1. Hold the first short arm perpendicular to the tunnel. Point its long-arm fitting at the next pivot pin.
2. At the same time, hold the next long arm fitting (the one mounted on the next pivot pin) and point it back at the first pivot pin.
3. Measure the distance between the two long-arm fittings. The tubing should fit all the way into the fittings. Allow extra length for the tubing if it is necessary to bend the tubing for clearance or to go around obstacles.

Bend tubing

Bend tubing as required.

1. Check that obstacles are cleared by at least 20 mm.
2. Be sure to keep 250 mm of straight tubing at either end.

Check length and cut tubing

1. Hold tubing next to the long-arm fittings to check the fit.
2. Also, check that the long-arm fitting is not locked against the short arm.
3. Cut the tubing. This is now a long arm.

Install sensor mount

Slide the long-arm sensor mount onto the long arm. (The end that will be nearest the first short arm).

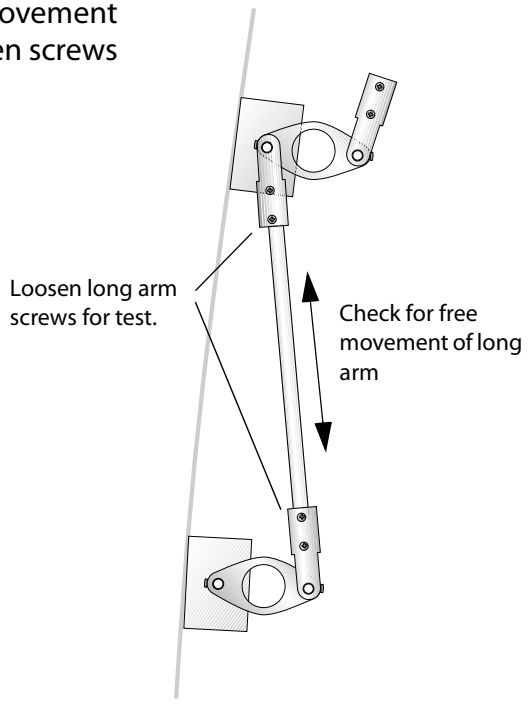
Install long arm

1. Fit the long arm into both long arm fittings.

- It may be necessary to loosen screws in the long arm fittings.
- It may be necessary to disconnect the long arm fitting from the short arm, slide it onto the long arm, and then reconnect the fitting to the short arm.

2. Check the long arm one more time and then partially tighten the screws in the long-arm fittings.
3. Repeat for remaining arms.

Test for free movement then tighten screws



Follow the procedure below to check movement of each arm. Work from left to right.

1.Start at the first long arm on the left side. Loosen long-arm screws at both ends.

2.Check that long arm can freely slide in and out of long-arm fittings. If arm is binding, adjust position of pivot pin. (The tips of pivot pins must be in same plane. Also, the axis of the pivot pin must be parallel with other pivot pins.

3.Tighten long arm screws. If you use a thread locking compound, be careful not to spill it on pivot points.

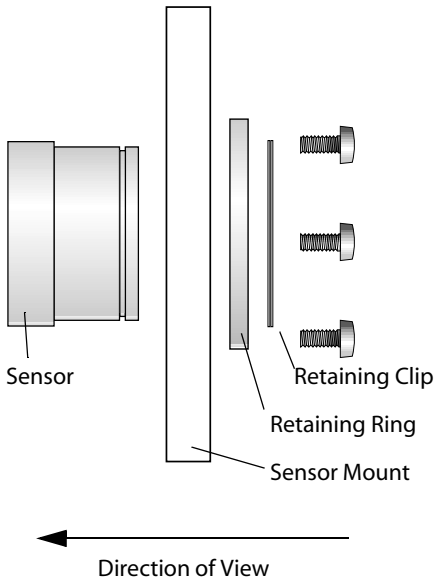
Install Sensors

The short-arm sensors look exactly like the long-arm sensors, so you must distinguish them by labels and serial numbers. Short arm sensors are mounted in the short arm. Long arm sensors are mounted on the long arm. The mounting procedure is the same for both.

1. Decide where your data logger will be placed.
2. Start installing sensors at the farthest point from the data logger and worked towards the data logger, dressing signal cables as you go.

Installation procedure

1. Insert sensor into sensor-mount as shown in drawing. If sensor is inserted from opposite side, make a note for the programmer.
2. Place retaining ring over end of sensor.
3. Slide retaining clip into groove in sensor body.
4. Insert screws but do not tighten until sensor is zeroed.

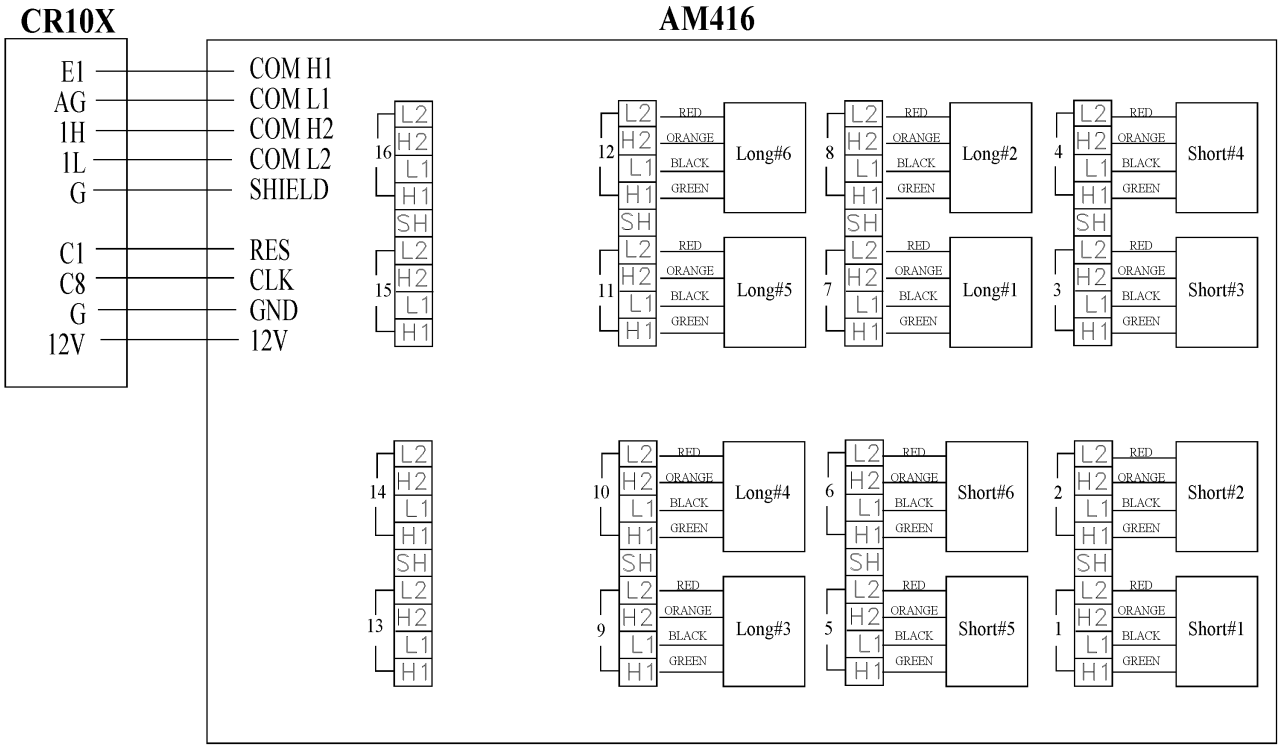


Dressing the cable

- Direct cable towards the data logger.
- Allow slack in the cable for strain relief. This will be needed when the arms move.
- If possible, fix cable to tunnel lining rather than to the arms.
- Avoid crossing pivot points. Make a loop in the cable to avoid moving parts.

Install Data Logger

- Install data logger as close as possible to the BSC system to avoid long runs of signal cable.
- Cut off excess signal cable. Do not loop excess signal cable under the logger. This can cause interference from adjacent high-voltage cables.
- Before connecting signal cable to the logger, cut off dirty ends and strip insulation back to expose clean conductors.
- Wire the data logger as directed by the wiring diagram supplied with the logger. A typical wiring diagram is shown below.



Note: For each sensor, drain wire for screen or shield should be connected to L1 terminal on AM416.

Test, Zero, and Document the Sensors

Use the installation record on the next page to document the sensors. Items to document are:

1. Direction of view
2. Sensor position
3. Sensor serial number
4. Sensor orientation (use raw readings)
5. Zero reading
6. Length of long arms

Testing sensors

1. Using PC208W, monitor the sensor input locations.
2. Note direction of view on installation record.
3. Note sensor position and its serial number on the installation record.
4. Check operation of sensor by rotating sensor and observing raw readings. Short arm sensor should have a range from 2 to 8 and read 5 at true horizontal. Long arm sensor should have range from 3.5 to 6.5 and read 5 at true horizontal.
5. Rotate sensor clockwise. Does reading increase or decrease? Note reading on installation record. This establishes the orientation of the sensor.

Zero sensors

1. Move the sensor until the output shows a null reading, which in raw units is a value of 5.0 ±0.1 for both the long-arm and short-arm sensors.
2. Tighten the three screws to lock the sensor in position. Check that the null reading has not changed significantly.

Documentation

1. Record the straight line distance between the two ends of the long arms to the nearest mm. Use the installation record on the next page. All short arms are 100 mm long.
2. The Northing, Easting and elevation of points A, B, C, D, etc. should be established by optical survey. If it is not possible to survey in all of the points, calculate the coordinates using triangulation methods or measure the distances between pivot points. See Pin Coordinates form on page 12.

BCS INSTALLATION RECORD

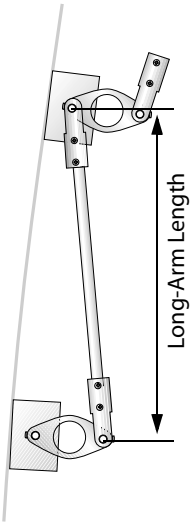
Project Title:

Date of Installation:

Direction of View:

Project Engineer:

Sensor	Serial Number	Rotate sensor clockwise. Does reading increase (+) or decrease (-)? Mark the appropriate column.		Zero reading	Arm length: the straight line distance from pin to pin
		+	–		mm
Short arm #1					100
Short arm #2					100
Short arm #3					100
Short arm #4					100
Short arm #5					100
Short arm #6					100
Short arm #7					100
Short arm #8					100
Short arm #9					100
Short arm#10					100
Long arm #1					
Long arm #2					
Long arm #3					
Long arm #4					
Long arm #5					
Long arm #6					
Long arm #7					
Long arm #8					
Long arm #9					
Long arm #10					

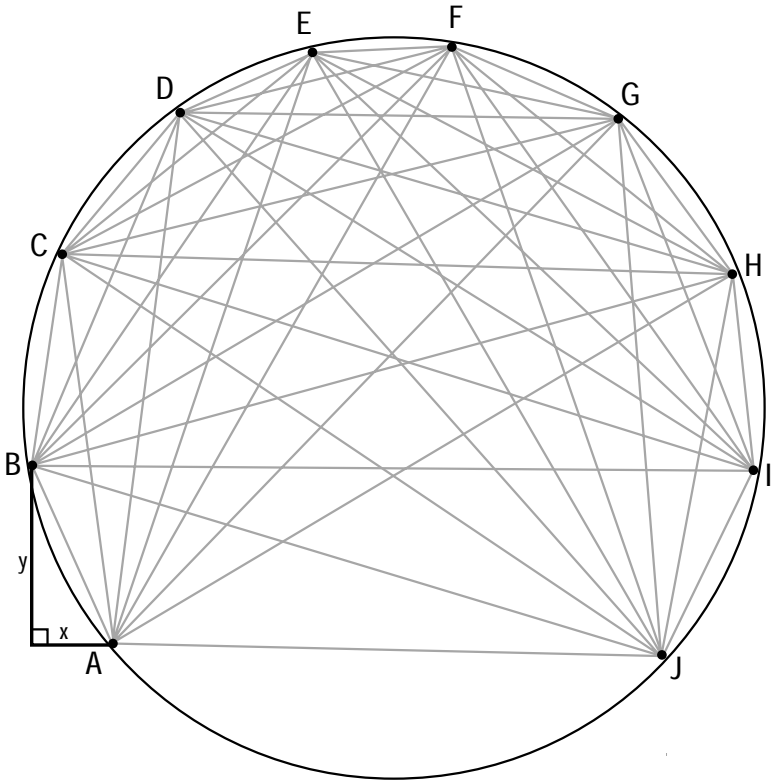


Pin Coordinates

Measurements

Obtain the coordinates of all fixed pivot pins using an optical survey. In the example below, you would provide coordinates for pivot pins A through J.

Alternatively, you can measure distances from pin to pin, as shown in the drawing below. Measurements must be to the nearest mm. You must also provide the x and y distances between pins A and B, as shown in the drawing.



X								
Y								
AB								
AC	BC							
AD	BD	CD						
AE	BE	CE	DE					
AF	BF	CF	DF	EF				
AG	BG	CG	DG	EG	FG			
AH	BH	CH	DH	EH	FH	GH		
AI	BI	CI	DI	EI	FI	GI	HI	
AJ	BJ	CJ	DJ	EJ	FJ	GJ	HJ	IJ

Software

Overview

Software for the Bassett Convergence System is customized for each application. Information required for customization includes:

- Direction of View
- Sensor ID scheme (see direction of view)
- BCS Installation Record
- Pin coordinates or pin to pin measurements.

Platforms

The software was originally developed for DOS, which used a DOS graphics display library. More recent versions are displayed by a customized version of MultiMon, which has been developed for Windows.

Instructions are customized for each Bassett system. The example notes below are for the DOS version of the software.

180 MONTIGUE STREET BCS
Notes On Software Installation And Operations

1. The software for this project is supplied on the disk attached.
2. Create one working directory as follows.
3. MD \MONTIGUE
4. Copy all files on the disk for up-line into directory \MONTIGUE.
5. Enter **MENU** at DOS prompt in one of the working directories - The screen will display the main menu.

   A Tunnel Profile Plot
   B Time Graphs

6. Before proceeding any further, it is necessary to obtain some data from the loggers. Use PC208W to down load data from Storage area 1 and stored in \MONTIGUE" as BASSETT.DAT.
7. Option A in the menu for BCS can now be run to process the off-loaded data. The instructions are given on the following pages.
8. The executable files in this system are DOS programs and have been compiled for use on a 386 PC or above. It requires expanded memory (EMS) to run, otherwise the "Out of mem-

ory" error would occur. Expanded memory can be set up by including the line below in CONFIG.SYS:

```
DEVICE = C:\WINDOWS\HIMEM.SYS
DEVICE = C:\WINDOWS\EMM386.EXE RAM
```

9. The programs also require a color VGA display to show graphic. Hard copy of any graphical display can be obtained by screen dump to a graphic printer connected to LPT1. It is necessary to load the memory resident GRAPHICS prior to running the system. The command is "GRAPHICS GRAPHICS" for a dot matrix graphic printer, or "GRAPHICS DESKJET" for a HP Deskjet or Laserjet printer. Please check with DOS manual for a detailed description of the GRAPHICS command.

10. For PC with Windows 95, the program should be run under MSDOS prompt or in MSDOS window. Hard copy of graphical display can be obtained by first pressing the PrtSc key to capture the screen into clipboard, and then paste into a bitmap editor such as Microsoft Paint for printing out.

Option A Tunnel Profile Plot

When evoked, the program will display Slope's logo for 5 seconds. If the data file BASSETT.DAT exist in the directory, the program will process the newly acquired data first before displaying the following menu:

```
1. Set Period of plots
2. Section plots
3. Movement plots of points
```

Select **option 1** to set the beginning and end date/time of section plots and points plots. Use cursor up, cursor down, Page up, page down, Home and End keys to move to another date/time. Press ENTER to confirm selection. This will set the datum date/time and store they in DATENULL in each working directory.

Select **option 2** to view the section plots. Before the plots are displayed, use the horizontal scroll bars to set the magnification factor and the delay between plots. An animation of how the section deforms will then start. The plots can be single stepped by pressing the space bar repeatedly, terminated by pressing Esc, or dumped to a printer by pressing F8. For each time step, the original, the previous and the current profiles are displayed. To the left of the plots, the deflections in the horizontal (x) and vertical (y) directions together with the resultant deflections are displayed in numeral.

Select **option 3** to view the movement of any pair of points.

Before the plots are displayed, the user can change plotting ranges and use the horizontal scroll bar to set the delay between plots. The pair of points are selected by press a pair of letters, and an animation of how the pair of point move will follow.

Option B - Time Graphs

After evoking option F, the program will display the following MENU:

1. Set period of trend plots
2. Trend plots of movement

Set period of plots Select this option to set the date/time 'FROM' and 'TO' which the trend plots, the profile plots and the movement table will be generated. When prompt for 'FROM', a default starting date/time (e.g. 22-May-1996 03:00:00) stored in file DATENULL will be displayed. Use the cursor up, cursor down, PgUp, PgDn, Home, and End keys to move through the data/time available in the BASSETT.MDB data base until the <RETURN> is pressed to make the selection. The same procedure also applies when the program prompts for 'TO' date/time, where the default date/time will be those of the latest reading. The final step of the option requires the user to determine whether to use the 'FROM' date/time as datum. Use cursor left and cursor right keys to move between 'Yes' and 'No' then <RETURN> to confirm and return to the main menu. If a new "FROM" date has been specified, the default stored in DATENULL will be updated at this point.

Use this option only if the user requires 'FROM' and 'TO' date/times other than the default date/time in the BASSETT.MDB data base.

Trend plots of movement Select this option to display deflect vs. time graphs for each of the points, raw reading vs. time, and temperature vs. time graphs for each of the EL sensors. On selection, the graph No. and associated sensor No. will be displayed. Use the cursor up, cursor down, PgUp, PgDn, Home, and End keys to move through the sensors available in the BASSETT.MDB data base until the <RETURN> is pressed to make the selection.

Once selected, the movement vs. time graph for the sensor will be displayed for all date/times between the selected 'FROM' and 'TO' date/times in the data base. By default, the relative movement with reference to the datum values for electrolevels and absolute values for the temperature sensors will be plotted unless the user specifies otherwise in option 1 above. The graphs can be enlarged, zoomed in, zoomed out and windowed. A hard copy of

the plot can be obtained by screen dump.

1. Press 'M' to enlarge the graph with y-axis between the minimum and the maximum values.
2. Press 'O' to return the plotting scale to between default plotting range.
3. To define a window for zooming-in, follow the procedures below:

- Press 'T' to enter the setting mode for top-left corner, use cursor left, cursor right, Cursor up, and cursor down for fine cursor movement, Control + cursor left, Control + cursor right, Control + cursor up, and Control + cursor down for coarse movement to define top-left extend of the window, and press <RETURN> to confirm the setting.
- Press 'B' to enter the setting mode for top-left corner, use cursor left, cursor right, Cursor up, and cursor down for fine cursor movement, Control + cursor left, Control + cursor right, Control + cursor up, and Control + cursor down for coarse movement to define bottom-left extend of the window, and press <RETURN> to confirm the setting.
- Press <SPACE> to redraw graph within the window in full screen.