Spiral Sensor

50900199

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Introduction

Spiral Sensor Applications

The spiral sensor measures the spiral in installed inclinometer casing. Modern self-aligning couplings minimize coupling-induced spiral, but spiral can be inadvertently introduced during installation, when installers attempt to realign misaligned casing or when drillers spin drill casing to break it free for removal.

While the spiral within shorter lengths of casing may be insignificant, in deeper installations, spiralling can accumulate causing some problems with interpretation of readings. In such cases, spiral data can be used to correct readings and ease interpretation.

System Components

Sensor: The sensor is calibrated so that the Digitilt readout (normally used with inclinometer probes) displays the relative axial rotation of its top and bottom wheel housings as a value in arc minutes.

Gauge Blocks: Gauge blocks are used to determine the zero offset of the sensor.

Spirit Level: The spirit level is used check that the gauge blocks are level and in the same plane.

Operation Overview

1. Before the survey, note the zero-offset of the sensor.
2. Perform the spiral survey from the bottom of the casing, in much the same way as an inclinometer survey.
3. Reduce the spiral data to determine the magnitude of spiral.
4. If spiral is significant, compute correction values to be applied to each inclinometer reading.

Measuring Zero-Offset

What is Zero-Offset?

In theory, the spiral sensor outputs "null" when the top and bottom of the probe are in perfect alignment. In practice, many mechanical variables combine to produce a non-zero output, which we call the zero-offset.

The zero-offset is normally quite small, but it is embedded in the spiral readings, and accumulated during data reduction. If not measured and then removed from the readings, the zero-offset makes the spiral survey less accurate.

The zero-offset should be measured before a spiral survey is conducted. The data sheet provides a place for the zero-offset measurements.

Equipment

- Gauge blocks, a spirit level, and a small tool kit. These are supplied with the spiral sensor.
- Digitilt control cable and a Digitilt indicator (both normally used with your inclinometer probe).
- A flat, level surface at least 6 feet or 1.8 meters long. Since a flat, level surface is difficult to find when you are in the field, you may find it useful to carry one with you. You might use your sensor carrying case or a steel beam.

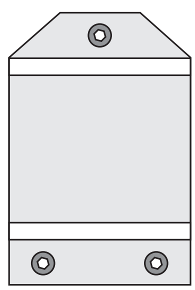
Setting Up

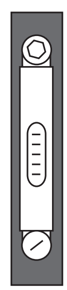
1. Choose a flat, level surface. If you brought a surface with you, make it level.

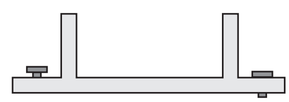
2. Connect control cable to the spiral sensor. A finger-tight connection is sufficient. Connect the other end of the control cable to your indicator. Switch on the indicator and allow the sensor to warm up for 15 minutes. During the warm up time, you can adjust the gauge blocks, as described below.

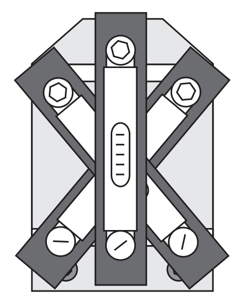
3. Place the gauge blocks on the flat, level surface. They should be about 5 feet (1.5 m) apart to support the wheels of the sensor, as shown in the drawing at the bottom of the page.

4. Adjust levelling screws to make the gauge blocks level. First, back off the levelling screws so that they are flush with the bottom of the block.Then turn the screws to make the blocks level. Try to use the fewest turns possible so that blocks stay in the same plane. Check with the spirit level in three directions, as shown in the drawing.

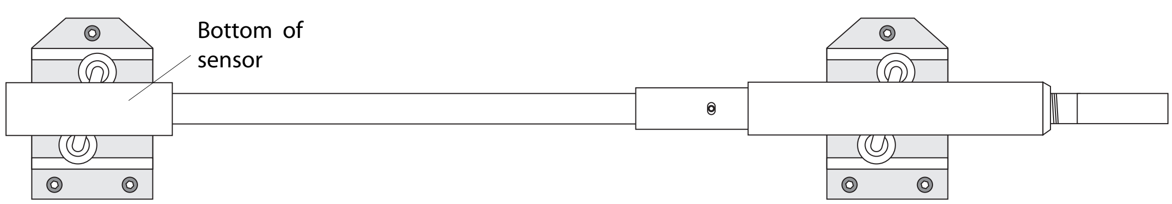

Gauge block from top


Spirit level


Gauge block from side, showing levelling screws

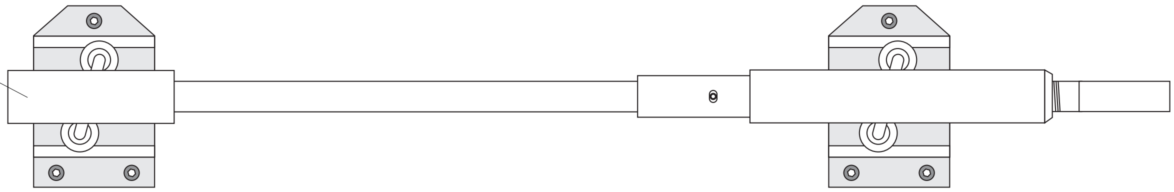

Check levelling in three directions.

5. Finally, place the sensor onto the gauge blocks, as shown in the drawing.

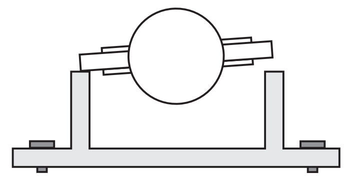


Measuring the Offset

The zero offset is calculated from four separate measurements. For each measurement, you rotate the bottom of the sensor away from the null position, then return it to the null position, and then observe the reading on the indicator.

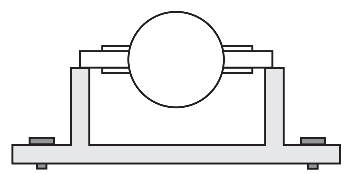


1. Check that the sensor is positioned as shown above. Hold the bottom of the sensor and rotate it away from you, so that the wheel closest to you lifts off the gauge block about 0.25 inch (5 mm). The exact distance of lift off is not important. The other three wheels should stay in their original position on the gauge blocks.



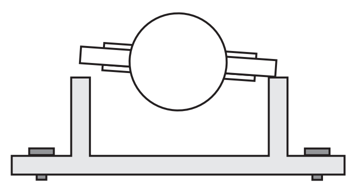
View from bottom end of sensor.

   Now return the sensor to its null position to check the reading on the indicator. Perform these actions several times until you can obtain readings that repeat within 1 or 2 units. This is the first measurement. Write it down.

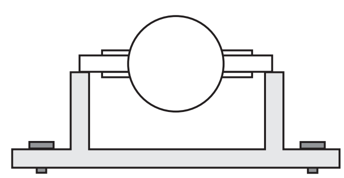


Check reading when sensor is returned to null position

2. For the second measurement, rotate the bottom of the sensor toward you. This lifts the opposite wheel off the gauge block. Check that other wheels have not shifted from their original positions.

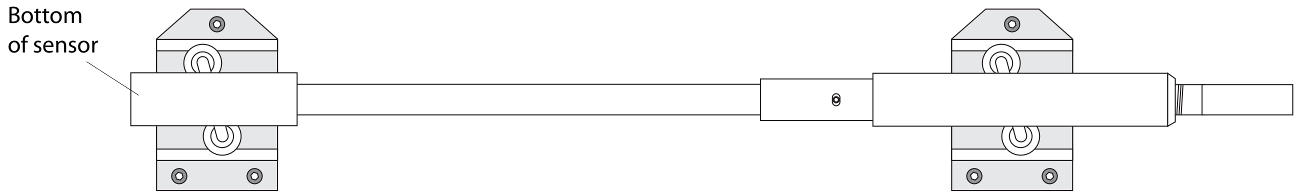


   Now return the sensor to its null position to check the reading on the indicator. Check that you have a repeatable reading. This is the second measurement. Write it down.

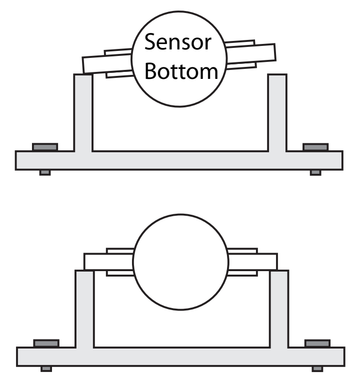


Check reading when sensor is returned to null position

3. Now, rotate the probe axially 180 degrees (turn the entire sensor onto its other side). Check that the sensor is positioned as shown in the drawing. Now you are ready to obtain your third and fourth measurements.

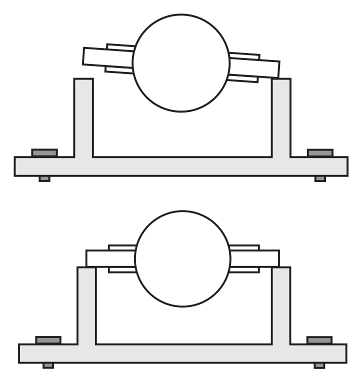


4. For the third measurement, rotate the bottom of the sensor away from you, so that the wheel closest to you lifts off the gauge block. Check that the other three wheels stay on the blocks. Then return the sensor to its null position to check the reading on the indicator. Make sure you can repeat the reading, then write it down.



Check reading when sensor is returned to null position

5. For the fourth measurement, rotate the bottom of the sensor toward you. This makes the opposite wheel lift off the gauge block. Then return the sensor to its null position to check the reading on the indicator. Make sure you can repeat the reading, then write it down.



Check reading when sensor is returned to null position

Calculating the Offset

Your collected measurements should look something like this. Note that the values that you obtain will be different from this example. Also, the values may be negative or positive.

1st Measurement	8
2nd Measurement	5
3rd Measurement	12
4th Measurement	17

1. Find the average offset from each side. Average the first and second measurements. Then average the third and fourth measurements.

<table>
<tr><td>1st Measurement</td><td>8</td><td rowspan="2">6.5</td></tr>
<tr><td>2nd Measurement</td><td>5</td></tr>
<tr><td>3rd Measurement</td><td>12</td><td rowspan="2">14.5</td></tr>
<tr><td>4th Measurement</td><td>17</td></tr>
</table>

2. Now find the average of these two averaged values. This is the zero offset value that you will use later on. In this case, the value is 10.5.

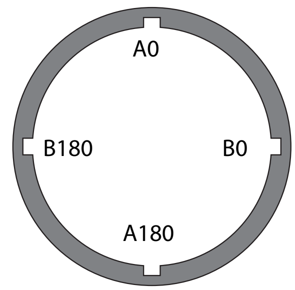
<table>
<tr><td>1st Measurement</td><td>8</td><td rowspan="2">6.5</td><td rowspan="4">10.5</td></tr>
<tr><td>2nd Measurement</td><td>5</td></tr>
<tr><td>3rd Measurement</td><td>12</td><td rowspan="2">14.5</td></tr>
<tr><td>4th Measurement</td><td>17</td></tr>
</table>

Recording a Spiral Survey

Setting Up

A spiral survey consists of readings taken from two passes or four passes through the casing. The table below lists names for these passes. The drawing shows the corresponding grooves in the casing. During the A0 pass, the upper wheel (of both wheel sets) is placed in the A0 groove. In the A180 pass, the upper wheel of both wheel sets is placed in the A180 groove, etc.

Pass	Digitilt DataMate	Manual Data Sheet
1st	A0	0
2nd	A180	180
3rd	B0	90
4th	B180	270



1. Determine the A0 (initial) direction. If the direction is not yet identified, choose the groove closes to the expected direction of movement (for example, the groove pointing down slope). Note the compass heading of the A grooves for later reference.
2. Attach the pulley assembly to the top of the casing. Temporarily remove the pulley wheel.
3. Remove the sensor from the carrying case and apply some oil on each side of wheel bearing. Spin the wheels to distribute the lubricant.
4. Connect the control cable to the sensor and the readout. Tighten the connector to the sensor with your fingers. Tighten it well, but don't use a wrench, which would flatten the O-ring.
5. Switch on the readout. Orient the probe so that the upper wheels of each wheel set will fit into the A0 groove. Then insert the probe and lower it to the bottom of the casing.
6. Replace the pulley wheel and run the cable over the pulley and through the cleats on the pulley assembly. Allow 15 minutes for the probe to adjust to the temperature in the casing.
7. While you are waiting, determine your start depth, and then set up your readout or your data sheet. Instructions for determining your start depth can be found on the next page. A sample data sheet can be found in Appendix A.

Determining Depths for the Survey

1. Pull up on the control cable to align the first available cable mark with your reference. Check the depth of the cable mark. This will be the start depth for each pass of your spiral survey.

2. Next, assign depths for all subsequent readings. The next depth should be divisible by 1.5 meters (metric systems) or 5 feet (English systems). The top depth would be 1.5 meters for metric systems and 5 feet for English systems.

Example of Metric Depths

You lowered the sensor to the bottom of the casing. The exact cable depth was 54.7 meters. The cable cannot be aligned at 54.7 meters, so you pull the cable up to 54.5 meters. You'll take your first reading at 54.5, and subsequent readings at 54 m (divisible by 1.5), 52.5 m, 51 m, ... to the top depth of 1.5 m.

Example of English Depths

You lowered the sensor to the bottom of the casing. The exact cable depth was about 183.2 feet. The cable mark cannot be aligned at 183.2 feet, so you pull the cable up to 182 feet. You'll take your first reading at 182', and subsequent readings at 180 (divisible by 5), 175', 170', ... to the top depth of 5 feet.

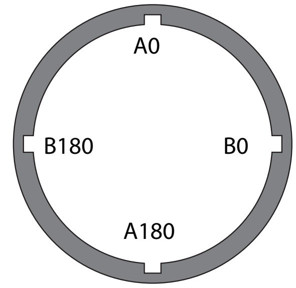
Specifying a Start Depth for the Digitilt DataMate

When you take a spiral survey with the Digitilt DataMate, you must specify a start depth, an interval, and an end depth. The DataMate calculates its depth prompts using the start depth and the interval. Since we want our depths to be multiples of 1.5 m or 5 feet, we must specify a start depth that is also a multiple of 1.5m or 5 feet.

In the metric example above, we will record the first reading at an actual cable depth of 54.5 meters, but we must specify a start depth of 55.5 meters for the DataMate so that it will provide subsequent depths that are multiples of 1.5 m (52.5 m, 51 m...).

In the English example above, we will record the first reading at and actual cable depth of 182 feet, but we must specify a start depth of 185 feet for the DataMate so that it will provide subsequent depths that are multiples of 5 feet (180', 175', ...).

Recording Readings



1. Start the survey at the bottom of the casing (at the start depth determined previously) with the probe oriented to the A0 groove. Record the reading at the start depth. Raise the probe to the next depth and record the second reading. Continue raising the probe and recording readings until you have recorded a reading for the top depth.

2. Pull the probe out of the casing. Rotate the probe so that the upper wheels can be inserted in the A180 groove. Lower the probe to the bottom of the casing, then raise it to the start depth. Record readings for each depth, just as in the A0 pass. When you have recorded a reading for the top depth, remove the probe. This completes the 2-pass survey.

3. For greater accuracy, you should continue with the third and fourth pass through the casing. In the third pass, the upper wheels of the sensor or placed in the B0 groove, and in the fourth pass, the upper wheels are placed in the B180 grooves.

Data Reduction

Introduction

Spiral data is normally processed by software, such as DMM for Windows. This software reduces the spiral data and plots the spiral in the casing. It can also generate spiral corrections for use with inclinometer plots. Refer to the software manual for more details.

This chapter explains how to reduce spiral data manually. The information can also be used to set up a spreadsheet.

Completing the Spiral Data Sheet

If you wrote down spiral reading on a data sheet, you have a column of depths and two or four columns of spiral data. A sample data sheet is supplied in Appendix A.

1. Average the readings for each depth. Record the results in the proper depth slots in the AVG column of the data sheet.
2. Subtract the sensor zero offset from each averaged reading and write the result in the Corrected Data column.
3. Sum the corrected data from the shallowest depth to the deepest depth (top to bottom). Record the running total in the $\sum$ Spiral column.

The sample data sheet in Appendix A shows casing that is slightly spiralled. The total spiral is +203 arc minutes or 3.4 degrees. This indicates that at the deepest depth recorded, the casing is rotated 203 arc minutes clockwise relative to the top of the casing (the position of the upper wheels at the shallowest reading depth).

Working with the Spiral Calculation Sheet

For most applications, it is sufficient to merely measure the spiral in the inclinometer casing and determine the quality of the installation. If there is more than 10 or 15 degrees of spiral, it may be useful to use the spiral data to correct the inclinometer data.

To perform spiral correction of inclinometer data, the spiral data set must be first expanded into depths and spiral values that correspond with the inclinometer depths. Again, this processing is normally done with software such as DMM for Windows.

1. Adjust the ∑ SPIRAL data for the offset in the control cable depth marking. When used with an inclinometer, the marks on the Digitilt control cable originate at the midpoint of the inclinometer's gauge length (wheelbase).

   When used with the spiral sensor, the cable marks originate from a point approximately 1 foot or 0.25m below the upper wheels. Since the ∑ SPIRAL indicates accumulated spiral to the location of the spiral sensor's lower wheels, the spiral must be adjusted to make the spiral readings coincide with the center of the inclinometer's wheelbase.

   Add 4 feet for the English or 1.25 m for the metric to the spiral depths and record them in the ADJ DEPTH column of the Spiral Calculation Sheet.

2. Copy the ∑ SPIRAL figures for the cable mark depths on the Spiral Data Sheet to the related, adjusted depths on the Spiral Calculation Sheet.

3. Record the inclinometer depths for the casing from the shallowest to the deepest in the DEPTH column on the Spiral Calculation Sheet.

4. Copy the figures in the ∑ SPIRAL column to the SCA' column, for those inclinometer depths that duplicate adjusted spiral depths.

5. Compute the spiral correction angles in arc minutes for intermediate inclinometer depths by interpolation averaging and record in the SCA' column.

$$SCA'_{ID} = [\ (SI - (ID - NSSD)) \times (\sum SPIRAL_{NSSD}) + (SI - (NDSD - ID)) \times (\sum SPIRAL_{NDSD})\ ] \div SI$$

$$\text{for } SASD - SI \leq ID \leq DASD$$

Where:

SCA'_{ID} = spiral correction angle in arc minutes calculated for the intermediate inclinometer depth.

SI = the spiral survey depth interval.

ID = the current inclinometer depth.

NSSD = the next shallowest adjusted spiral depth.

NDSD = the next deepest adjusted spiral depth.

ΣSPIRAL = the summed spiral for the given adjusted spiral depth.

SASD = the shallowest adjusted spiral depth.

DASD = the deepest adjusted spiral depth.

For example, referring to the sample Spiral Calculation Sheet at the 29 foot inclinometer depth:

$SCA' = [(5 - (29 - 27)) \times (104.75) + (5 - (32 - 29)) \times (116.75)] \div 5$

SCA' = 109.6 arc minutes

6. Convert the spiral correction angles in arc minutes to angles in degrees by dividing them by 60. Record them in the SCA° column.

7. Add any azimuth correction to the SCA° figures and record in the SCA° + AZIMUTH column. Here azimuth is defined as the clockwise angle in degrees that the A0 (reference) groove is rotated from the planned orientation. The planned orientation may be a compass heading, the direction of anticipated movement, downhill, or some other direction as determined by the application.

Correcting Inclinometer Data with Spiral Data

This process is normally done by software such as DigiPro for Windows.

1. Copy the algebraic differences or changes in differences for the inclinometer depths from your inclinometer data sheet (not shown), to the Inclinometer Spiral Correction sheet. Whether you choose differences or changes will depend on your objectives. Use differences if you are correcting an initial data set and computing corrected deviations. Use changes if you are correcting a subsequent data set and computing corrected displacements.

2. Convert the rectangular coordinates, represented by A-axis and B-axis algebraic differences or changes, into polar coordinates. At each inclinometer depth, the magnitude and angle are calculated by:

   $MAG = SQR (A^2+B^2)$

   $ANGLE = ARCTAN (B/A)$

The angle is the clockwise rotation from the A0 groove, computed in degrees, with a range of 0 to 360. Expressing angles from 180 to 360 degrees as negative angles may result in fewer digits to record.

Note: Electronic calculators may not be sensitive to which quadrant the computed angle is in. For example, the ARCTAN function may return an angle of -15 degrees, when actual angle of the polar conversion should be +165 degrees (180 - 15). The quadrant must be determined by noting the algebraic signs of the A and B inclinometer data (rectangular coordinates) just as when using trigonometric tables.

For example, at the 3 foot depth on the sample Inclinometer Spiral Correction sheet, you can find the algebraic difference readings for A and B axes, 3030 and -226 respectively. Converted into polar coordinates, the magnitude is 3038 and the angle is -4.27 degrees.

3. Copy the SCA + AZIMUTH figures for the inclinometer depths from the Spiral Calculation sheet. Add these angles (algebraically) to the polar coordinate angles derived from the inclinometer data. The results are the corrected angles. Record these in the Corrected Angle column.

4. Convert the polar coordinates, using the Corrected Angles, back into rectangular coordinated to derive the corrected A and B axis readings. Record these in the appropriate columns on the Inclinometer Spiral Correction sheet.

   CORR A = MAG X COS(CORR ANGLE)

   CORR B = MAG X SIN(CORR ANGLE)

   The 3 foot depth shows corrected A and B differences of 3038 and 30 digits. In this example, these corrected readings give the magnitudes for both axes in terms of the direction of interest. They have been corrected for casing spiral and the azimuth error between A0 casing groove and the planned orientation of the casing (as shown in the figure at the top of the Spiral Calculation Sheet).

5. The corrected A and B differences or changes can be converted to corrected deviations or displacements using the appropriate instrument constant and depth interval.

Inspection and Maintenance

Wheel Bearing Check

Check the wheel bearings for wear by gently wiggling with your fingers and feeling for both axial and radial play. Play in the wheel bearings should not be detectable.

Zero Calibration Check

See the chapter on measuring zero offset. The difference between the 1st and 2nd measurements or the 3rd and 4th measurements should be less than 15 units.

Sensor Span Check

This is a function check to test for a fault in the spiral sensor transducer or calibration amplifier circuit.

Remove the protective caps from the sensor and cable connectors. Connect the chrome connector on your control cable to your indicator and the larger stainless steel connector to the spiral sensor. Grasp the upper wheel housing while tightening or loosening the connector on the sensor. Snug the connector nut with the wrench supplied. Turn on the indicator and allow the sensor to warm up (15 minutes). Set the indicator to read A-axis.

Lay the spiral sensor down where it can remain totally undisturbed. Watch the indicator readings carefully for about 5 minutes. The displayed reading should be stable, not varying more than 1 digit.

Check the sensor for the proper operation by holding the upper wheel housing and slowly rotating the lower wheel housing clockwise (as viewed from the top) to the mechanical stop. Do not use force against the stop. The indicator should become increasingly positive and peak at about +275 to +325 arc minutes. Rotate the lower wheel housing counter-clockwise and the readings should peak at about -275 to -325 arc minutes.

Optional: Record the readings obtained in the previous step to be used for subsequent comparison. Subsequent tests should indicate fair repeatability of the readings. If the transducer and amplifier would appear satisfactory.

General Maintenance

Wheels: Lubricate the sensor wheels often to prevent premature wear of the wheel bearings. The sensor's performance is extremely dependent upon good coupling between the casing grooves and the sensor via the wheel assemblies. Use a lubricant that is designed to drive moisture from the surface. Displacement of water from the bearings is important for the lubricant to do its job.

Keep the surfaces of the wheels that contact the casing clean, free of buildup. Any tar-like substance may be cleaned with a cloth moistened with solvent, but do not allow the solvent to wash lubricant from the bearings.

Electrical Connector: The electrical connector may be occasionally cleaned with a cotton swab moistened with denatured alcohol. Do not flood the connector with alcohol and be gentle to avoid bending and possibly breaking the contact pins. Never use aerosol lubricant on the electrical connector. Use of petroleum products or chlorinated solvents on electrical connector can swell the insulator and prevent the mating connector from fully seating. Such a condition defeats the O-ring seal, allows water to enter the sensor, and causes sensor failure.

Occasionally lubricate the O-ring at the electrical connector lightly with a vegetable grease, silicone based grease, or lubricant manufactured for O-rings. Use the protective cap to keep the O-ring and electrical contacts clean.

Rotation Stops: On either side of the lower portion of the upper wheel housing there is a slot in which there is a hex head capscrew. These slots and screws act as rotation stops and guide the sensor and reduce performance. Keep the slots and hex capscrews free of dirt and grit by keeping them wrapped with a layer or two of tape. Do not remove these screws, since calibration of the sensor could be affected

Specifications

Materials: Stainless steel and aluminum
Weight: 8 pounds (3.6 kg).
Length overall: 5.6 ft (1.7 m).
Gauge length: 5 ft or 1.5 m.
Accuracy: ±10 arc minutes per gauge length.
Maximum rotation: ± 4 degrees per length.
Calibrated rotation: ±3 degrees from sensor zero reference.

Appendix A

Note This appendix contains sample worksheets from 1985. The convention of recording spiral data at multiples of 5 feet or 1.5 meters, was not in place at that time.

Contents

Spiral Data Sheet

Sheet 1 of 1

Site SINCO Seattle

Installation No. I-3

Description Demonstration and testing borehole.

Date 18 NOV. 1985 Sensor S/N 1432

Indicator 50300900 S/N 1327

Read R.H. Calc J.S. Checked T.B.

Zero Measurements		Averaged	Zero Offset
1st	8	6.5	10.5
2nd	5		
3rd	12	14.5	
4th	17		

Depth	0°	180°	0°/90°	180°/270°	AVG	Corrected Data	Σ Spiral
3	45	47	49	50	47.75	37.25	37.25
8	6	10	10	11	9.25	-1.25	36.0
13	13	18	20	21	18.0	7.5	43.5
18	32	39	37	37	36.25	25.75	69.25
23	43	47	47	47	46.0	35.5	104.75
28	18	25	22	25	22.5	12.0	116.75
33	15	22	21	23	20.25	9.75	126.5
38	10	14	10	11	11.25	0.75	127.25
43	22	30	28	30	27.5	17.0	144.25
48	18	22	22	22	21.0	10.5	154.75
53	34	40	35	40	37.25	26.75	181.5
58	32	32	32	32	32.0	21.5	203.0

Slope Indicator Co., Seattle WA USA

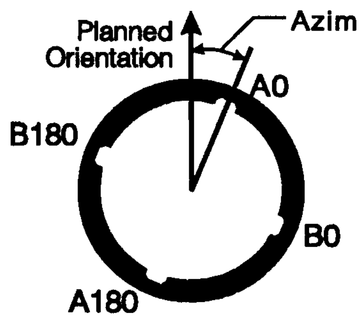
SINCO 70001479 11-91

FIGURE 4

Spiral Calculation Sheet

Sheet 1 of 2

Site SINCO Seattle
Installation No. I-3
Description Demonstration and testing borehole.
Date 18 NOV. 1985 Sensor S/N 1432
Indicator 50300900 S/N 1327
Read R.H. Calc J.S. Chkd T.B.



Spiral Survey		Inclinometer Depths			
Adj. Depth	Σ Spiral	Depth	SCA′ (minutes)	SCA° (degrees)	SCA° + Azimuth
7	37.25	3	7.5	0.13	4.84
12	36.0	5	22.4	0.37	5.08
17	43.5	7	37.3	0.62	5.33
22	69.25	9	36.8	0.61	5.32
27	104.75	11	36.3	0.61	5.32
32	116.75	13	37.5	0.63	5.34
37	126.5	15	40.5	0.68	5.39
42	127.5	17	43.5	0.73	5.44
47	144.25	19	53.8	0.90	5.61
52	154.75	21	64.1	1.07	5.78
57	181.5	23	76.4	1.27	5.98
62	203.0	25	90.6	1.51	6.22
		27	104.8	1.75	6.46
		29	109.6	1.83	6.54
		31	114.4	1.91	6.62
		33	118.7	1.98	6.69
		35	122.6	2.04	6.75
		37	126.5	2.11	6.82
		39	126.8	2.11	6.82
		41	127.1	2.12	6.83
		43	130.7	2.18	6.89
		45	137.5	2.29	7.00
		47	144.3	2.41	7.12
		49	148.5	2.48	7.19
		51	152.7	2.55	7.26

Slope Indicator Co., Seattle WA USA

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FIGURE 5 (1 of 2)

Spiral Calculation Sheet

Sheet 2 of 2

Site SINCO Seattle

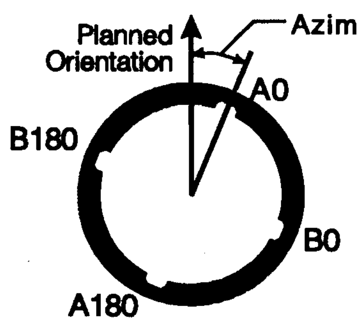
Installation No. I-3

Description Demonstration and testing borehole.

Date 18 NOV. 1985 Sensor S/N 1432

Indicator 50300900 S/N 1327

Read R. H. Calc J. S. Chkd T. B.



Spiral Survey		Inclinometer Depths			
Adj. Depth	Σ Spiral	Depth	SCA′ (minutes)	SCA° (degrees)	SCA° + Azimuth
		53	160.1	2.67	7.38
		55	170.8	2.85	7.56
		57	181.5	3.03	7.74
		59	190.1	3.17	7.88
		61	198.7	3.31	8.02

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FIGURE 5 (2 of 2)

Inclinometer Spiral Correction

Sheet 1 of 2

Site: SINCO Seattle

Installation No.: I-3

Description: Demonstration and testing borehole.

Date: 18 NOV. 1985 Sensor S/N: 1432

Indicator: 50300900 S/N: 1327

Read: R.H. Calc: J.S. Checked: T.B.

Mag = $\sqrt{A^2 + B^2}$

Angle = ARC TAN (B/A)

Corrected Angle = Angle + SCA + Azimuth

Corrected A = MAG x COS (Corrected Angle)

Corrected B = MAG x SIN (Corrected Angle)

Depth	A	B	MAG	Angle	SCA + Azimuth	Corrected Angle	Corrected A	Corrected B
3	3030	-226	3038	-4.27	4.84	0.57	3038	30
5	3057	-174	3062	-3.26	5.08	1.82	3060	97
7	3036	-277	3049	-5.21	5.33	0.12	3049	6
9	2986	-289	3000	-5.53	5.32	-0.21	3000	-11
11	2997	-277	3010	-5.28	5.32	0.04	3010	2
13	2987	-275	3000	-5.26	5.34	0.08	3000	4
15	2979	-289	2993	-5.54	5.39	-0.15	2993	-8
17	2972	-312	2988	-5.99	5.44	-0.55	2988	-29
19	2938	-297	2953	-5.77	5.61	-0.16	2953	-8
21	2927	-294	2942	-5.74	5.78	0.04	2942	2
23	3045	-316	3061	-5.92	5.98	0.06	3061	3
25	3008	-307	3024	-5.83	6.22	0.39	3024	21
27	3035	-350	3055	-6.58	6.46	-.12	3055	-6
29	2979	-323	2996	-6.19	6.54	0.35	2996	18
31	2986	-312	3002	-5.97	6.62	0.65	3002	34
33	2956	-335	2975	-6.47	6.69	0.22	2975	11
35	2963	-348	2983	-6.70	6.75	0.05	2983	3
37	2981	-376	3005	-7.19	6.82	-0.37	3005	-19
39	3048	-261	3059	-4.89	6.82	1.93	3057	103
41	2972	-345	2992	-6.62	6.83	0.21	2992	11
43	2940	-327	2958	-6.35	6.89	0.54	2958	28
45	2976	-341	2995	-6.54	7.00	0.46	2995	24
47	3035	-373	3058	-7.01	7.12	0.11	3058	6
49	3058	-394	3083	-7.34	7.19	-0.15	3083	-8
51	2982	-361	3004	-6.90	7.26	0.36	3004	19

FIGURE 6 (1 of 2)

Inclinometer Spiral Correction

Sheet 2 of 2

Site SINCO Seattle

Installation No. I-3

Description Demonstration and testing borehole.

Date 18 NOV. 1985 Sensor S/N 1432

Indicator 50300900 S/N 1327

Read R.H. Calc J.S. Checked T.B.

$$Mag = \sqrt{A^2 + B^2}$$

Angle = ARC TAN (B/A)

Corrected Angle = Angle + SCA + Azimuth

Corrected A = MAG x COS (Corrected Angle)

Corrected B = MAG x SIN (Corrected Angle)

Depth	A	B	MAG	Angle	SCA + Azimuth	Corrected Angle	Corrected A	Corrected B
53	3001	-331	3019	-6.29	7.38	1.09	3018	57
55	3034	-389	3059	-7.31	7.56	0.25	3059	13
57	2964	-520	3009	-9.95	7.74	-2.21	3007	-116
59	2997	-423	3027	-8.03	7.88	-0.15	3027	-8
61	2973	-382	2997	-7.32	8.02	+0.70	2997	37

FIGURE 6 (2 of 2)

Spiral Data Sheet

Sheet ________ of ________

Site ______________________________

Installation No. ______________________________

Description ______________________________

____

Date ______________ Sensor S/N ______________

Indicator ______________ S/N ______________

Read ________ Calc ________ Checked ________

Zero Measurements		Averaged	Zero Offset
1st			
2nd			
3rd			
4th			

Depth	0°	180°	0°/90°	180°/270°	AVG	Corrected Data	Σ Spiral

Spiral Calculation Sheet

Sheet________ of ________

Site____

Installation No. __________________________________

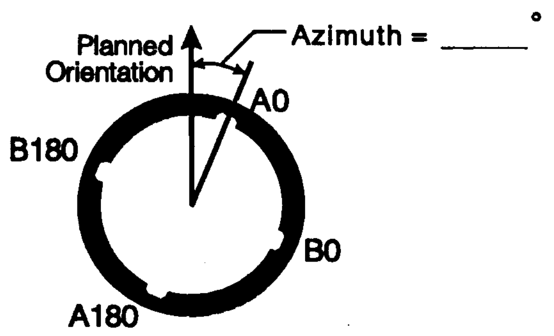
Description_______________________________________

____

Date ____________________Sensor S/N _______________

Indicator _________________S/N ____________________

Read____________ Calc ____________ Chkd____________



Spiral Survey		Inclinometer Depths			
Adj. Depth	Σ Spiral	Depth	SCA′ (minutes)	SCA° (degrees)	SCA° + Azimuth

Slope Indicator Co., Seattle WA USA

SINCO 70001480 1-92

Inclinometer Spiral Correction

Sheet ________ of ________

Site ____________________

Installation No. ____________________

Description ____________________

____

Date ____________ Sensor S/N ____________

Indicator ____________ S/N ____________

Read ________ Calc ________ Checked ________

$$\text{Mag} = \sqrt{A^2 + B^2}$$

Angle = ARC TAN (B/A)

Corrected Angle = Angle + SCA + Azimuth

Corrected A = MAG x COS (Corrected Angle)

Corrected B = MAG x SIN (Corrected Angle)

Depth	A	B	MAG	Angle	SCA + Azimuth	Corrected Angle	Corrected A	Corrected B