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Instruction Manual

Model 1300

(Model A9)
Retrievable Extensometer

(Doc. REV G. 8/11)

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1. INTRODUCTION

1.1. Theory of Operation

The Geokon Model A-9 Retrievable Extensometer is designed primarily for short term measurements of deformation in boreholes in concrete, rock, etc. The system is used in both precast and cast-in-place concrete piles in plate load tests in rock and anywhere where deformations need to be measured in boreholes, either drilled or cast in to the structure being analyzed.

The system consists of pneumatically actuated anchors with spring loaded transducers that are connected to one another in series by a single connecting rod. When installed, the anchors are fixed in place and the transducers measure the deformation between the anchor positions. The connecting rods are held in tension to eliminate errors due to bowing and friction. Connecting rods of fiberglass, graphite epoxy, and stainless steel are available. The standard system is designed to be used in a nominal 2" ID pipe; either plastic or steel.

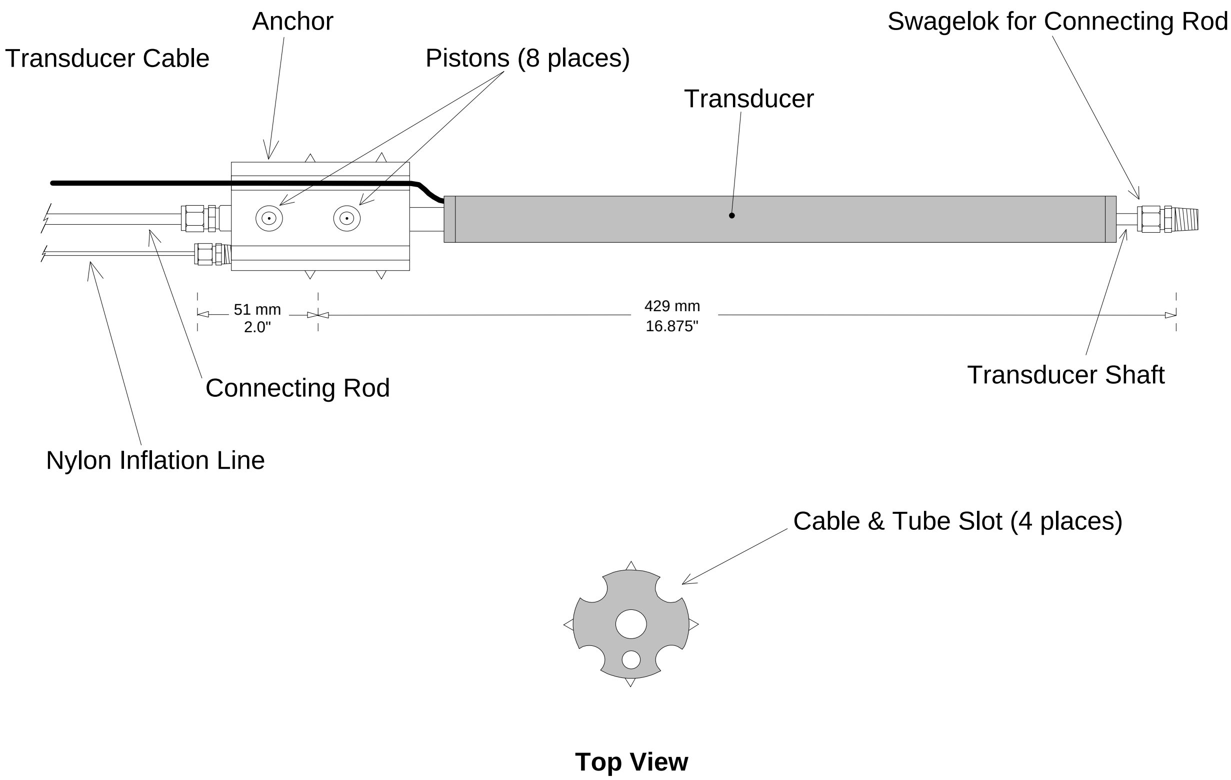

Figure 1 - Model A-9 Retrievable Extensometer Anchor

2. INSTALLATION

2.1. Preliminary Tests

Before assembly and installation of the extensometer the transducers should be checked for proper operation. See Section 3 for readout instructions. In position "B" of the GK-401, GK-403 and GK-404 Readouts the gage will read between 2000 and 2500. The transducer may need to be slightly extended to get a reading. Pull on the Swagelok affixed to the transducer shaft to do this (see Figure 1).

Checks of electrical continuity can also be made using an ohmmeter. Resistance between the gage leads should be approximately 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). Between the green and white should be approximately 3000 ohms at 25° (see Table B-1), and between any conductor and the shield or the case of the sensor should exceed 2 megohms.

Checks on the actuation of the anchor pistons must be done with care. The anchor must first be positioned inside a piece of pipe or tubing with an inside diameter of approximately 50mm(2 inch), before the pistons are actuated by pneumatic pressure. If the pneumatic pressure is applied to the pistons while the anchor is not inside a tube, the pistons will over-range and in the process the O-ring seals will be damaged and the pistons will then be unable to hold pneumatic pressure without leaking

2.2. Extensometer Installation

If the transducers check out the assembly can proceed.

An adequate area must be located for the assembly of the extensometer. Preferably it should be as long as the extensometer, clear of debris and obstructions. When assembling the extensometer in the field be especially careful to keep dirt out of the Swagelok fittings for the inflation lines.

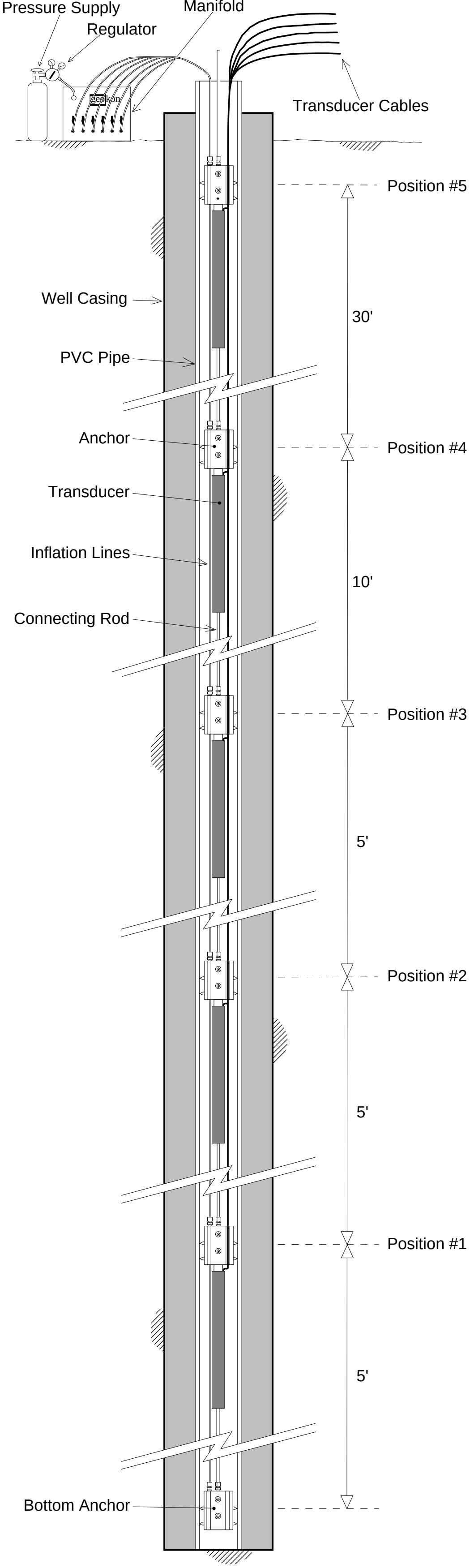

Figure 2 - Model A-9 Installation

1. Determine the anchor positions, i.e. the depth or position in the borehole for each anchor. Starting with the bottom, or deepest, anchor calculate the distance between it and the second anchor; this is the increment over which the measurement will be made. The connecting rod must now be cut to the proper length to make up this increment. For the standard 25 mm (1") transducer positioned at mid-range the length of the transducer assembly is 492 mm (19.375"). This length must be deducted from the increment length in order to make the correct rod length. For example, if the increment length is 3 meters the rod length is 2.508 meters (3.0 - 0.492). Calculate the rod lengths for all anchor positions and cut rods to length. Be careful when cutting the fiberglass rod that it does not splinter. Use a file to deburr the edges.

2. Connect the rod to the Swagelok fitting on the bottom anchor, pushing it in until it hits the shoulder. Tighten the Swagelok finger tight, then an additional 7 flats (1¼ turns). Use two wrenches to do this, one on the Swagelok nut, the other on the body. See Appendix D for additional Swagelok fitting assembly instructions.

   Connect the other end of the rod to the Swagelok fitting on the first transducer assembly using the same two wrenches. Repeat this for all the rods and sensors, leaving the instrument cables rolled up.

   Finally, attach an appropriate length of rod to the top anchor, this will allow for installation and removal of the system.

3. Cut nylon inflation tubing for each anchor position. Allow enough tubing to connect to the pressure manifold. Attach to the Swagelok fitting for the inflation line.

   Finger tighten and then turn an additional 7 flats (1¼ turns) to engage the ferrule. See Appendix D for additional Swagelok fitting assembly instructions.

4. Lay out all the transducer cables and inflation lines next to the anchors and attached rods. Position the lines and cables in the slots of the anchors and tape on either side of the anchors,

i.e. tape above the anchor around the connecting rod and below the anchor around the transducer body. Continue this procedure at each anchor position from the deepest up to the top. Be sure the inflation lines and transducer cables are clearly labeled. Allow enough slack, at least the range of the instrument, (≈25mm, 1") between anchor positions for the movement of the anchors.

5. The assembly is now ready for installation in the borehole. Lower into the borehole with the bottom anchor first. Bend the connecting rod through a large arc, as needed to lower the extensometer. Be careful not to permanently bend the rods.

6. Once the assembly is installed attach the inflation lines to the pressure manifold. Attach the transducer cables to the terminal box or multiplexer.

7. Make sure all the valves of the pressure manifold are in the off position. Attach the air supply to the pressure manifold. Carbon dioxide, compressed air or nitrogen may be used for the pressure supply. The recommended pressure for setting the extensometer is 300 psi (20 bar). Appendix C illustrates the relationship between applied pressure and pull-out of the anchor. The maximum recommended applied pressure is 750 psi (50 bar).

8. Turn on the air for the deepest position of the extensometer. Attach the readout to the instrument cable from the first transducer position. To set the transducer anchor pull on the extension rod coming out of the borehole until the desired reading is obtained and then turn on the valve for that position. To set the instrument at mid-range the reading should be around 5000 digits. To measure mostly tensile strains the reading should be around 3000. To measure mostly compressive strains the reading should be around 7000. Repeat this procedure for each transducer position of the extensometer. Installation complete.

2.3. Cable Splicing

Cables may be spliced to lengthen them, without affecting gage readings. Always waterproof the splice completely, preferably using an epoxy based splice kit such the 3M Scotchcast™, model 82-A1. These kits are available from the factory. When making splices, use solder connections wherever feasible or crimp connectors if not.

2.4. Initial Readings

All readings are referred to an initial reading so it is important that this initial reading be carefully taken. Conditions should be noted at the time of all readings, especially during curing, i.e., temperature, time after placement, local conditions, etc.

2.5. Electrical Noise

Care should be exercised when installing instrument cables to keep them as far away as possible from sources of electrical interference such as power lines, generators, motors, transformers, arc welders, etc. **Cables should never be buried or run with AC power lines!** The instrument cables will pick up the 50 or 60 Hz (or other frequency) noise from the power cable and this will likely cause a problem obtaining a stable reading.

3. TAKING READINGS

3.1. Operation of the GK-401 Readout Box

The GK-401 is a basic readout for all vibrating wire transducers used in the Model A-9 Retrievable Extensometer.

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the green or blue clip for the shield drain wire. The GK-401 cannot read the thermistor (see Section 3.4).

1. Turn on the Readout. Turn the display selector to position "B". Readout is in "digits" (see Equation 1).

2. Turn the unit on and a reading will appear in the front display window. The last digit may change one or two digits while reading. Record the value displayed. If zeros are displayed or the reading is unstable see section 6 for troubleshooting suggestions.

3. The unit will automatically turn itself off after approximately 4 minutes to conserve power.

3.2. Operation of the GK-403 Readout Box

The GK-403 can store gage readings and also apply calibration factors to convert readings to engineering units. Consult the GK-403 Instruction Manual for additional information on Mode "G" of the Readout. The following instructions will explain taking gage measurements using Mode "B".

Connect the Readout using the flying leads or in the case of a terminal station, with a connector. The red and black clips are for the vibrating wire gage, the white and green clips are for the thermistor and the blue for the shield drain wire.

1. Turn on the Readout. Turn the display selector to position "B". Readout is in digits (see Equation 1).

2. Turn the unit on and a reading will appear in the front display window. The last digit may change one or two digits while reading. Press the "Store" button to record the value displayed. If the no reading displays or the reading is unstable see section 6 for troubleshooting suggestions. The thermistor will be read and output directly in degrees centigrade.

3. The unit will automatically turn itself off after approximately 2 minutes to conserve power.

3.3. Operation of the GK404 Readout Box

The GK404 is a palm sized readout box which diplays the Vibrating wire value and the temperature in degrees centigrade.
The GK-404 Vibrating Wire Readout arrives with a patch cord for connecting to the vibrating wire gages. One end will consist of a 5-pin plug for connecting to the respective socket on the bottom of the GK-404 enclosure. The other end will consist of 5 leads terminated with alligator

clips. Note the colors of the alligator clips are red, black, green, white and blue. The colors represent the positive vibrating wire gage lead (red), negative vibrating wire gage lead (black), positive thermistor lead (green), negative thermistor lead (white) and transducer cable drain wire (blue). The clips should be connected to their respectively colored leads from the vibrating wire gage cable.

Use the **POS** (Position) button to select position **B** and the MODE button to select **Dg,** (digits). Other functions can be selected as described in the GK404 Manual.

The GK-404 will continue to take measurements and display the readings until the OFF button is pushed, or if enabled, when the automatic Power-Off timer shuts the GK-404 off.

The GK-404 continuously monitors the status of the (2) 1.5V AA cells, and when their combined voltage drops to 2V, the message **Batteries Low** is displayed on the screen. A fresh set of 1.5V AA batteries should be installed at this point

3.4. Measuring Temperatures

The vibrating wire transducers used in the Model A-9 Retrievable Extensometer is equipped with a thermistor for reading temperature. The thermistor gives a varying resistance output as the temperature changes. Usually the white and green leads are connected to the internal thermistor.

1. Connect an ohmmeter to the two thermistor leads coming from the transducer. (Since the resistance changes with temperature are so large, the effect of cable resistance is usually insignificant.)

2. Look up the temperature for the measured resistance in Table B-1 (Appendix B). Alternately the temperature could be calculated using Equation B-1 (Appendix B). For example, a resistance of 3400 ohms equivalent to 22° C. When long cables are used the cable resistance may need to be taken into account. Standard 22 AWG stranded copper lead cable is approximately 14.7Ω/1000' or 48.5Ω/km, multiply by 2 for both directions.

Note: The GK-403 and GK-404 readout boxes will read the thermistor and display temperature in °C automatically.

4. DATA REDUCTION

4.1 Digits

The basic units utilized by Geokon for measurement and reduction of data from the vibrating wire displacement transducers used in the Model A-9 are "digits". The units displayed by the GK-401, GK-402, and GK-403 in position "B" are digits. Calculation of digits is based on the following equation;

$$\text{Digits} = \left(\frac{1}{\text{Period}}\right)^2 \times 10^{-3} \quad \text{or} \quad \text{Digits} = \frac{\text{Hz}^2}{1000}$$

Equation 1 - Digits Calculation

To convert digits to deformation the following equation applies;

$$\mathbf{D = (R_1 - R_0) \times G \times F}$$

Equation 2 - Deformation Calculation

Where; D is the calculated deformation.
R_1 is the current reading.
R_0 is the initial reading usually obtained at installation (see section 2.4).
G is the calibration factor, usually in terms of millimeters or inches per digit taken from the calibration sheet an example of which is shown in Figure 3
F is an engineering units conversion factor (optional), see Table 1.

From→ To↓	Inches	Feet	Millimeters	Centimeters	Meters
Inches	1	12	0.03937	0.3937	39.37
Feet	0.0833	1	0.003281	0.03281	3.281
Millimeters	25.4	304.8	1	10	1000
Centimeters	2.54	30.48	0.10	1	100
Meters	0.0254	0.3048	0.001	0.01	1

Table 1 - Engineering Units Conversion Multipliers

For example, the initial reading (R_0) with no load on the pile of a Model A-9 transducer is 5102 digits. The reading with a 100 ton load on the pile, the current reading (R_1), is 4523. The calibration factor, G, is 0.0001755 inches/digit. The deformation change is;

$$D = (4523 - 5102) \times 0.0001755 = -0.1016 \textit{ inches}$$

Note that decreasing readings (digits) indicate compression.

To calculate strain divide the deformation by the distance between the anchors. For example, if the deformation change between two anchors spaced 12 feet apart was -0.1016 inches. The strain change for that segment of the pile, uncorrected for temperature, would be -0.1016/144 x 10^6 = -706 µstrain (compression).

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Vibrating Wire Displacement Transducer Calibration Report

Range: 25 mm

Serial Number: 05-8389

Cal. Std. Control Numbers: 529, 406, 344, 057

Calibration Date: September 01, 2005

Temperature: 23.6 °C

Calibration Instruction: CI-4400 Rev: C

Technician: Elice

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2230	2228	2229	-0.055	-0.22	-0.008	-0.03
5.0	3369	3368	3369	5.024	0.10	5.014	0.06
10.0	4494	4492	4493	10.04	0.14	9.999	0.00
15.0	5615	5613	5614	15.03	0.13	15.00	-0.02
20.0	6729	6729	6729	20.00	0.01	19.99	-0.03
25.0	7841	7841	7841	24.96	-0.17	25.01	0.02

(mm) Linear Gage Factor (G): 0.004457 (mm/ digit) **Regression Zero: 2241**

Polynomial Gage Factors: A: 1.11026E-08 B: 0.004345 C: -9.7486

(inches) Linear Gage Factor (G): 0.0001755 (inches/ digit)

Polynomial Gage Factors: A: 4.37111E-10 B: 0.0001711 C: -0.38380

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 4795 Temp(T_0): 23.7 °C Date: September 19, 2005

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.
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Figure 3 Typical Calibration sheet

4.2. Temperature Correction

The Model 4430 Deformation Meter used in the Model A9 Extensometer has a vibrating wire transducer with a small coefficient of thermal expansion and the body of the transducer contracts and expands slightly with changes in temperature. The interconnecting rods also expand and contract so in most cases correction is advisable. Note also that in situations where temperature changes are large (more than 10 degrees C) it may be prudent to use carbon graphite rods which have very low coefficients of expansion. The following equation applies;

$$\mathbf{D_{corrected} = (R_1 - R_0) \times G + (T_1 - T_0) \times K + L_C + L_R}$$

Equation 3 - Thermally Corrected Deformation Calculation

Where; R_1 is the Current Reading.
R_0 is the Initial Reading.
G is the Calibration Factor.
T_1 is the Current Temperature.
T_0 is the Initial Temperature.
K is the calculated Thermal Coefficient,
L_C is the correction for the change in gage length.
L_R is the correction for the change in rod length

Tests have determined that the Thermal Coefficient, K, of the transducer changes with the position of the transducer shaft. Hence, the first step in the temperature correction process is determination of the proper Thermal Coefficient based on the following equation;

Thermal Coefficient = ((Reading in Digits × Multiplier) + Constant) × Calibration Factor
or

$$\mathbf{K = ((R_1 \times M) + B) \times G}$$

Equation 4 - Thermal Coefficient Calculation

See Table 2 for the Multiplier and Constant values used in Equation 4. The Multiplier (M) and Constant (B) values vary for the stroke of the transducer used in the Deformation Meter.

Model:	4430-6mm 4430-0.25”	4430-12mm 4430-0.5"	4430-25mm 4430-1"	4430-50mm 4430-2"	4430-100mm 4430-4”	4430-150mm 4430-6”	4430-300mm 4430-12”
Multiplier (M):	0.00073	0.000295	0.000301	0.000330	0.000192	0.000216	0.000250
Constant (B):	0.583	1.724	0.911	0.415	0.669	0.491	0.450
Def, Meter Length (L):	267mm 10.5”	267 mm 10.5"	267 mm 10.5"	292 mm 11.5"	393mm 15.49”	510.5mm 20.1”	715.2mm 28.2”

Table 2 - Thermal Coefficient Calculation Constants

The Model 4430 deformation meter length temperature correction (L_C) is calculated using Equation 5.

$$\mathbf{L_C = 17.3 \times 10^{-6} \times L \times (T_1 - T_0)}$$

Equation 5 – Deformation Meter Length Correction

Where L is the length of deformation meter in millimeters or inches, (see Table 2),

The rod length correction (L_R) is calculated from the equation 6

$$\mathbf{L_R = K_R \times S \times (T_1 - T_0)}$$

Equation 6 – Rod Length Temperature Correction

Where S is the distance between anchor points minus the length of the transducer in mm or inches and K_R is the coeficient of expansion of the rod material from Table 3

Rod Material	K_R Thermal Coefficient Per º C
Stainless Steel	17.3×10^{-6}
Graphite	0.2×10^{-6}
Fiberglass	6.0×10^{-6}

Table 3. Thermal coefficients of expansion for various rod materials

Example for the same 25mm range transducer as before where the anchor spacing is 144 inches and the rods are fiberglass

R_1 = 4523
T_o= 15 degrees C
T_1 = 30 degrees C
S= 144-10.5 = 133.5 inches

Then K = [4523 x 0.000301 +0.911] x 0.0001755 = 0.00040

And the total temperature correction $\mathbf{(T_1\text{-}T_0)\ [\ K + L_C + L_R\ ]}$ =

$$(30 – 15) \times [\ 0.00040 + 10.5 \times 17.3 \times 10^{-6} + 133.5 \times 6.0 \times 10^{-6}\ ] = +0.0207 \text{ inches}$$

And the Total deformation, temperature corrected, is -0.1016 + 0.0207 = -0.081 inches and the measured strain is -0.081/144 x 10^6 = - 562 microstrain in compression

5. TROUBLESHOOTING

Consult the following list of problems and possible solutions should difficulties arise. Consult the factory for additional troubleshooting help.

Symptom: 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 transducer on a different readout position. For instance, channel A of the GK-401 and GK-403 might be able to read the transducer. To convert the Channel A period display to digits use Equation 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.
- ✓ Has the transducer gone outside its range? This may happen in either compression or extension. Check the previous readings for any trends. The extensometer may be need to be re-installed in the borehole, see section 2.
- ✓ Does the readout work with another transducer? If not, the readout may have a low battery or be malfunctioning. Consult the appropriate readout manual for charging or troubleshooting directions.

Symptom: 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.

Sympton: Transducer will not hold pressure

✓ Check all the fittings on the pneumatic lines using a soap solution and observe for bubbles. If no leaks are found then the O-ring on the anchor piston may be cut or nicked. Replace the O-ring using one of the spares from the accessories supplied with the equipment. The piston is held inside the anchor by a small “ding” made by a prick punch. This has to be filed off with a round file so that the piston can be pushed out. Replace the O-ring and then push the piston back into place and again “ding” the end of the hole with a hammer and screwdriver so that the piston is once again held in place.

APPENDIX A - SPECIFICATIONS

A.1. Model A-9 Retrievable Extensometer Transducer

Ranges Available:[1]	12, 25, 50 mm 0.5, 1, 2"
Overrange:	100% (none)
Accuracy:	0.1% (with polynomial expression)
Resolution:	0.025% FSR
Linearity:	0.25% FSR
Thermal Zero Shift:	< 0.05% FSR/°C
Stability:	< 0.2%/yr (under static conditions)
Temperature Range:	-40 to +60°C -40 to 120° F
Frequency Range:	1200 - 2800 Hz
Coil Resistance:	180 Ω, ±10 Ω
Cable Type:[2]	2 twisted pair (4 conductor) 22 AWG Foil shield, PVC jacket, nominal OD=4.8 mm (0.1875")
Weight:	1 kg. 2.2 lbs.
Rod Types:	Stainless steel, fiberglass, graphite

Table A-1 Model A-9 Transducer Specifications

Notes:
[1] Consult the factory for other ranges available.
[2] Consult the factory for alternate cable types.

A.2 Thermistor (see Appendix B also)

Range: -80 to +150° C
Accuracy: ±0.5° C

APPENDIX B - THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3

Resistance to Temperature Equation:

$$T = \frac{1}{A + B(\text{LnR}) + C(\text{LnR})^3} - 273.2$$

Equation B-1 Convert Thermistor Resistance to Temperature

Where; T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance
A = 1.4051×10^{-3} (coefficients calculated over the −50 to +150° C. span)
B = 2.369×10^{-4}
C = 1.019×10^{-7}

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	**3000**	**25**	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Table B-1 Thermistor Resistance versus Temperature

APPENDIX C - ANCHOR PULL OUT TEST RESULTS

Pull out tests were conducted with the Model A-9 anchors installed in stainless steel and PVC pipes to determine the force necessary to fail the anchors.

The results are presented in the following chart.

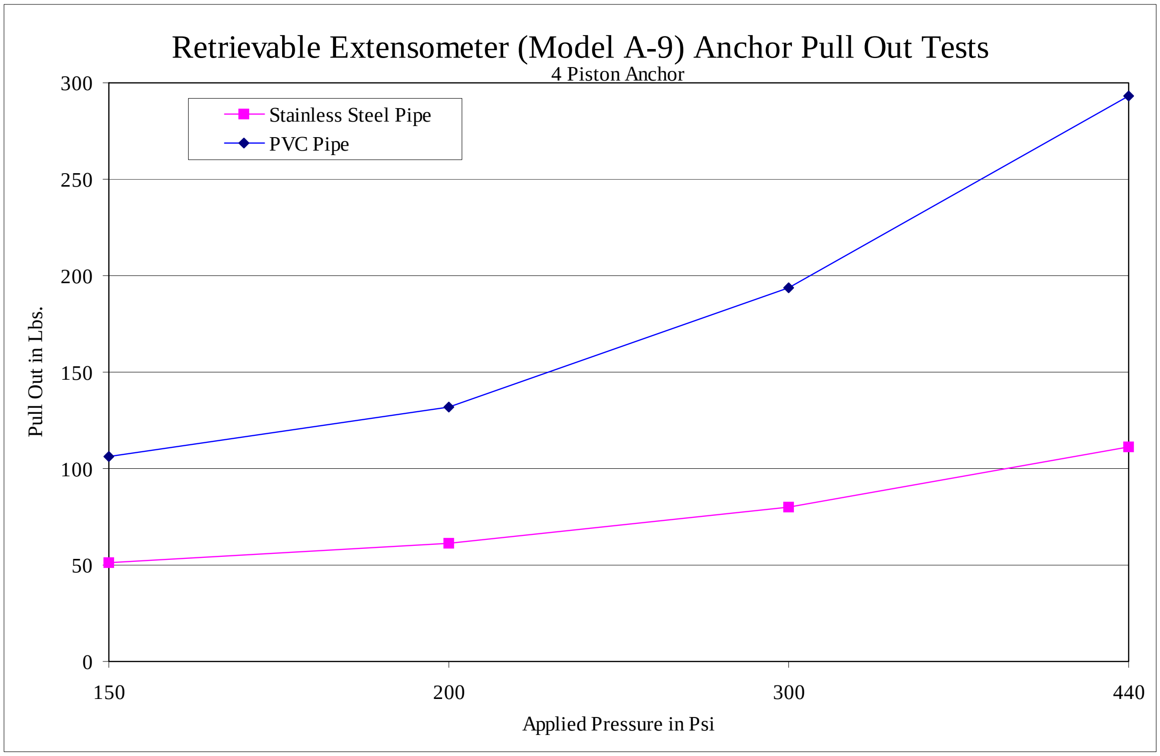


Figure C-1 Anchor Pull Out Test Results

APPENDIX D - SWAGELOK FITTING ASSEMBLY INSTRUCTIONS

INSTALLATION INSTRUCTIONS

SWAGELOK Tube Fittings

SWAGELOK Tube Fittings come to you completely assembled, finger-tight. They are ready for immediate use.

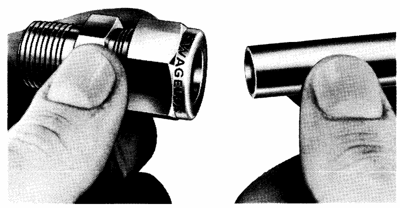
Disassembly before use is unnecessary and can result in dirt or foreign material getting into fitting and causing leaks.

High Pressure Applications or High Safety Factor Systems

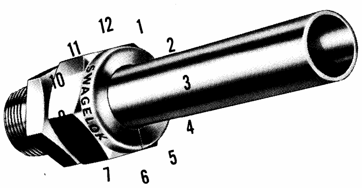
Due to variations in tubing diameters, a common starting point is desirable. Using a wrench, tighten the nut to the SNUG position. Snug is determined by tightening the nut until the tubing will not rotate freely (by hand) in the fitting. (If tube rotation is not possible, tighten the nut approximately 1/8 turn from the finger-tight position). At this point, scribe the nut at the 6 o'clock position and tighten the nut 1-1/4 turns.* The fitting will now hold pressures well above the rated working pressure of the tubing.

Use of the individual Gap Inspection Gage (1-1/4 turns* from snug end) ensures sufficient pull-up.

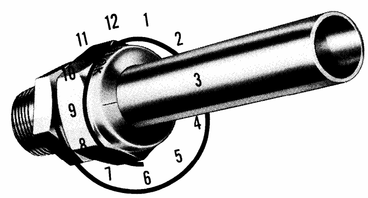
SWAGELOK Tube Fittings are installed in three easy steps:



Simply insert the tubing into the SWAGELOK Tube Fitting. ***Make sure that the tubing rests firmly on the shoulder of the fitting and that the nut is finger-tight.***



Before tightening the SWAGELOK nut, scribe the nut at the 6 o'clock position.



Now, while holding the fitting body steady with a backup wrench, tighten the nut 1-1/4 turns.* Watch the scribe mark, make one complete revolution and continue to the 9 o'clock position.

By scribing the nut at the 6 o'clock position as it appears to you, there will be no doubt as to the starting position. When tightened 1-1/4 turns* to the 9 o'clock position you can easily see that the fitting has been properly installed.

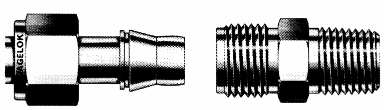
Use of the Gap Inspection Gage (1-1/4 turns* from finger-tight) assures sufficient pull-up.

*For 1/16," 1/8" and 3/16" size tube fittings, only 3/4 turn from finger-tight is necessary.

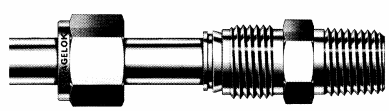
RE-TIGHTENING INSTRUCTIONS

Connections can be disconnected and re-tightened many times. The same reliable, leak-proof seal can be obtained every time the connection ~~is~~ remade.

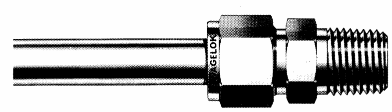
Fitting shown in disconnected position.



Tubing with pre-swaged ferrules inserted into the fitting until front ferrule seats in fitting.



Tighten nut by hand. Rotate nut to the original position with a wrench. (An increase in resistance will be encountered at the original position). Then tighten slightly with the wrench. (Smaller tube sizes will take less tightening to reach the original position, while larger tube sizes will require more tightening. The wall thickness will also have an effect on tightening).



GAP INSPECTION GAGES

The SWAGELOK Gap Inspection Gage is placed in the gap between the nut and body hex. If the gage **will not** fit, the fitting nut is tightened sufficiently.

For multiple sizes

This gage works on five (5) sizes of SWAGELOK Tube Fittings: 1/4," 3/8," 1/2," 6mm, and 12mm.

Ordering Number: MS-IG-468

For individual sizes

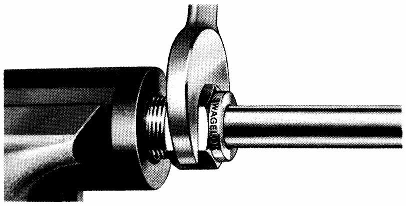
Fitting Size (Inches)	Series
1/16*	100
1/8*	200
3/16*	300
1/4	400
5/16	500
3/8	600
1/2	810
5/8	1010
3/4	1210
7/8	1410
1	1610

*For 1/16," 1/8," and 3/16" size tube fittings, only 3/4 turn from finger-tight is necessary.

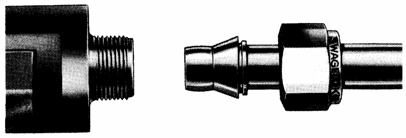
PRE-SWAGING INSTRUCTIONS

When installing SWAGELOK Tube Fittings in cramped quarters or where ladders must be used, it may be advantageous to use a pre-swaging tool. It allows the pre-swaging of ferrules onto the tube in a more open or safe area. After using the tool, simply follow the re-tightening instructions.

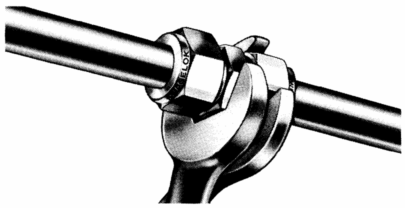
Oversized or very soft tubing may occasionally stick in the tool after pull-up. If this happens, remove the tube by gently rocking back and forth. DO NOT TURN the tube with pliers or other tools as this may damage sealing surfaces.



Assemble SWAGELOK nut and ferrules to pre-swaging tool. Insert tubing through ferrules until it bottoms in the pre-swaging tool, and tighten nut 1-1/4 turns.*



2 The nut is loosened and the tubing with pre-swaged ferrules is removed from the pre-swaging tool.



3 The connection can now be made by following the *Re-tightening Instructions.*

Tube O.D. Size	Part Number
1/16"	[illegible]
1/8"	[illegible]
3/16"	[illegible]
1/4"	[illegible]
5/16"	[illegible]
3/8"	[illegible]
1/2"	[illegible]

While pre-swaging tools can be used many times, they do have a finite life. After frequent use, ask your Authorized Sales & Service Representative to have them checked.

Hydraulic Swaging Units are available in 1/2," 5/8," 3/4" and 1" sizes. See below for further information.

*For 1/16," 1/8" and 3/16" size tube fittings, only 3/4 turn from finger-tight is necessary.

SWAGELOK Hydraulic Swaging Unit

FOR INSTALLING SWAGELOK TUBE FITTINGS

A Hydraulic Swaging Unit is available for making up to 1/2," 5/8," 3/4" and 1" size SWAGELOK Tube Fittings. The Swaging Unit is ideal for installations where large numbers of SWAGELOK Tube Fittings are made up. The unit is designed to swage the ferrules on the tubing prior to final assembly into a fitting. It assures a safe and reliable, torque-free, leak-proof seal on different tube materials.

The unit consists of a Swaging Tool and a sturdy metal Accessory Case containing a hydraulic pump, hose and service equipment. Advantages include:

- Portable and easy to use by one person
- Requires little physical effort by the installer, reducing installation time
- Ensures proper and sufficient swaging of the ferrules onto the tubing
- Does not place any initial strain on the nut c fitting body threads, or on body seal surfaces

Consult your Authorized Sales & Service Representative for a demonstration.

HOW TO ORDER

	For
	1/2" SWAGELOK Fittings
	5/8" SWAGELOK Fittings
	3/4" SWAGELOK Fittings
	1" SWAGELOK Fittings

Units are also available for 1-1/4," 1-1/2" and 2" SWAGELOK Fittings.