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SANDIA NATIONAL LABORATORIES
CIVILIAN RADIOACTIVE WASTE MANAGEMENT
TECHNICAL PROCEDURE (TP)

TP-232

Installation of Vibrating Wire Strain Gages To Steel Sets

Revision 03

Effective Date: 08/27/03

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(Reviewer signatures above serve to document the review and resolution of comments)

REVISION HISTORY

Rev.	Summary of Changes
00	Initial Issue
01	Minor editorial changes and update to current requirements
02	Combined TP-232 Rev 01, *Installer Qualification For Strain Gage Spot Welder*, with TP-235 Rev 01, *Spot Welding Vibrating Wire Strain Gages To Steel Sets*; made editorial changes and corrections to update to current requirements.
03	Made editorial changes and corrections to update to current requirements. This revision is also in response to concerns raised in YMP Deficiency Report(DR) 167.

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1.0 SCOPE

Sandia National Laboratories (SNL) is responsible for field experiments that monitor and characterize activities in the Exploratory Studies Facility (ESF) in support of the Yucca Mountain Project (YMP). One of these activities consists of installing and monitoring instrumentation that measures the long term in situ stability of geo-mechanical rock units during and after excavation. Gages are installed in order to evaluate installation stress in steel sets and to continuously monitor the load in the steel sets over time.

This Technical Procedure (TP) applies to all YMP SNL personnel and contractors who will be trained and qualified to perform spot welds during the installation of vibrating wire strain gages(VWSG).

2.0 OBJECTIVE

This Technical Procedure defines the procedure for spot welding VWSG on steel sets to ensure all support loads carried by the steel set will be accurately measured. This includes specific instructions for locating, cleaning, and welding VWSG to steel sets. Movement or creep of the installed strain gage during its lifetime will render collected data inaccurate and misleading.

3.0 RESPONSIBILITIES

The Principal Investigator (PI) or the Designee has responsibility for ensuring that all information obtained in the ESF is in accordance with SNL's Quality Assurance Implementing Procedure's (QAIP's) and that all individuals installing VWSG are properly trained.

Individuals working on the project must understand the requirement for ensuring that they perform all activities in accordance with both good engineering practice and good safety practice consistent with the YMP & SNL Quality Assurance Program.

4.0 WORK INSTALLATION DESCRIPTION

Strain gage installation is accomplished by following the steps outlined below. An installation checklist (Appendix 1) is attached to this TP for field use and is completed in conjunction with Data Forms.

4.1 Test Coordination

Work planned for the YMP site must be scheduled with the Test Coordination Office (TCO) and a current Field Work Package (FWP) shall exist documenting the field operations associated with this activity.

4.2 Pre Welding Procedures

In advance of using the welder, charge the portable welding unit and the VW readout box overnight.

4.3 Preliminary Tests

4.3.1 The PI or designee will select the appropriate strain gages from the calibrated Measurement & Test Equipment stock for installation in the test. See the manufacturer's specifications to determine the calibrated range (i.e. 1250 μstrain to 3750 μstrain for the Geokon VK-4150). Record the calibrated range of the final reading on the appropriate Data Form (Appendix 2).

4.3.2 Use a DVM set to read ohms. Record on the appropriate Data Form in Appendix 2 the VWSG coil resistance and the resistance of the thermistor temperature element. See the manufacturers specifications for the wiring color codes and the nominal resistance values (i.e. $50 \pm 10\,\Omega$ between red/black wires for the Geokon VK-4150 coil, and $3000\,\Omega$ between white/green wires @ 25° C for the Geokon VK-4150 thermistor). Reject any faulty gages.

4.3.3 Place VWSG on a flat surface. Set the Vibrating Wire(VW) readout box's ON/OFF switch to ON and the DISPLAY switch to E. Connect the appropriate VWSG leads of the VW readout box. (i.e. Color matched, red-to-red, black-to-black, green-to-green, white-to-white).

4.3.4 The strain gage is usually supplied with the vibrating wire tension set at mid-range (i.e. 2500 μstrain, $\pm 200\mu$strain, for the Geokon VK-4150). If directed by the PI or his designee, follow the manufacturer's instructions to adjust the gage for greater range in either compression or tension. Record the range of the initial reading on the appropriate Data Form as directed by the PI. Take the initial NORMAL μstrain and temperature readings in an unloaded condition using the VW readout box. Record μstrain and temperature readings on the appropriate Data Form (Appendix 2) as the **Initial Reading**.

4.3.5 The PI or designee will identify the steel set to be instrumented, record instrumentation serial numbers on the appropriate Data Form. Fig. 1, Location of Gages, shows typical locations of strain gages on a typcial steel set.

4.4 Steel Set Surface Preparation

The surface of the steel member where the gages are to be attached should be flat and clean, free from grease, rust, scale, oxides, and surface irregularities for efficient welding.

4.4.1 Mark the gage positions for the following situations:

1. Steel sets laying horizontally on flat surface.

2. RIGHT SECTION. With the FACE-side down and the Dutchman end on the right, align the 'B' template with the right-most center spacer hole. With the FACE-side up and the Dutchman end on the left, align the 'A' template with the left-most center spacer hole.

3. CROWN SECTION. With the FACE-side down, and the Crown/Right end to the right, align the 'B' template with the right-most center spacer hole. With the FACE-side up and the Crown/Right end on the left, align the 'A' template with the left-most center spacer hole.

4. LEFT SECTION. With the FACE-side down and the Dutchman end on the left, align the 'B' template with the right-most center spacer hole. With the FACE-side up and the Dutchman end on the right, align the 'A' template with the left-most center spacer hole.

4.4.2 Surface Preparation

1. USE SAFETY GLASSES! Degrease the marked locations of the steel set metal surfaces, if necessary. Degrease the surface using an appropriate cleaning agent.

2. Remove rust and scale oxide from marked locations using a file, sandpaper, and/or a hand grinder. Leave smooth bright surfaces where the strain gages are to be welded and the welding unit's ground terminal is to be clamped.

3. Using the templates, scribe gage locations.

4. Thoroughly wash scribed locations with an appropriate solvent to remove all residues.

4.5 Equipment Functional Test (Proof Test)

At the start of each shift, it is necessary to test the spot welder to make sure that it is functioning properly and that the correct energy is used. Proof welds are performed by making a ½ inch wide horseshoe shaped grouping of fifteen welds to approximately simulate the welds of the strain gage flange attachment. A 0.006 stainless steel tab is welded to a 0.500 inch thick sample of A36 steel. (See Figure 2, Spot Welding Sequence)

4.5.1 Prepare the welding unit by following the operating instructions in the welding unit's instruction manual (i.e. Section 4.0, Operating Instructions, Measurements Group, Inc., Model 700, "Operation and Maintenance Manual"). Hold the stainless steel tab in firm contact with the A36 steel base, place the welding electrode firmly against the stainless specimen at the desired weld location and actuate the welder by depressing the trigger in the handpiece.

4.5.2 After completing the test pattern, peel the stainless material from the A36 base material with pliers or a screwdriver. Acceptable spot welds tear a hole through the stainless material.

4.5.3 The weld proof test demonstrates that acceptable production welds are being made if twelve of the fifteen spot welds tear the weld nugget from the stainless steel material leaving a hole. If welds are unacceptable, correct the problem and repeat the proof test cycle. Document optimum **WELD ENERGY** results on the field checklist.

4.6 Structural Steel Preparation

Use the 'Face' and 'Portal' templates to scribe gage locations onto steel set, then prepare steel set surface according to steps in Section 4.4.2.

4.7 Welding Unit Cable Connections

Follow the welding unit's operation manual to prepare the welder for use.

4.8 Welding VWSG to Structural Steel

4.8.1 During the welding of the VWSG you must monitor the VWSG output. Connect the VSWG to the VW readout box and set to display position E. Hold the VWSG in firm contact with the steel set material, place the welding electrode firmly against the stainless steel gage at the desired weld location and actuate the handpiece trigger. Spot-weld one end of the gage using the weld pattern and the sequence shown in Figure 2.

4.8.2 Start welding at the centerline on the opposite edge from the wire leads using the row of dots marked on the mounting tab. Complete the back row, working in a direction away from the starting point. Welds should have a slight depression and be uniform in appearance.

4.8.3 Use the welding electrode to position the unwelded end of the VWSG against the steel set and to adjust the VWSG μstrain reading to within the desired range as displayed on the VW readout box. Start welding at the centerline and complete the weld pattern. Tap each end of the VWSG four or five times to relieve local stresses induced by the welding process. Read and record μstrain and temperature readings on the installation Data Form as the **Post Weld Reading**. If this reading is not within the calibrated range, remove the VWSG, select another VWSG and go to 4.3, Preliminary Tests.

4.8.4 Cover weld points with a cyanoacrylate (Super Glue) sealant.

4.8.5 Place the metal housing cover over the VWSG instrument and inject an RTV type sealant into the housing. Record μstrain and temperature readings on Data Form as the **Final Reading**.

4.8.6 Always keep the hand probe weld tip clean and burr free. Periodically sand the tip gently with 400 grit sand paper. The surface of the tip shall be maintained to a well-rounded point. Proper dressing of the tip will prevent it from sticking to the welding media during welding.

5 QA Records

QA records, and any corrections or changes generated as a result of implementing this procedure will be prepared and submitted as inclusionary QA records (QA:QA) by the PI or designee in accordance with AP-17.1Q, Record Source Responsibility for Inclusionary Records.

1. These records include: Installation Checklist – Appendix 1

2. Data Form for Vibrating Wire Strain Gage Manual Readouts – Appendix 2

6 REFERENCES

6.1 Implementing Documents

QAIP 20-1, Technical Procedures

AP15.2Q, Control of Non-Conformances

AP16.1Q, Management of Conditions Adverse to Quality

AP-17.1Q, Records Source Responsibility for Inclusionary Records

6.2 Applicable Standards, Criteria, and Manufacturer's Guidance

1. "Instruction Manual VK-4100/4150 Vibrating Wire Strain Gage," Geokon, Inc., 1983, 1996 (Doc rev F 12/01).

2. Portable Strain Gage Welding/Soldering Unit — Model 700, "Operation and Maintenance Manual," Measurements Group, Inc., May 1994.

7 APPENDICES

Appendix 1. Installation Checklist (2 pages)

Appendix 2. Data Form – Vibrating Wire Strain Gage Manual Readouts (3 pages)

Appendix 3. Geokon Resistance vs. Temperature Table (1 page)

8 FIGURES

Figure 1. Location of Gages

Figure 2. Spot Welding Sequence

INSTALLATION CHECKLIST

(TP-232, Rev. 03, Appendix 1, page 1 of 2)

Date:		
STEP	**ACTION**	**COMMENTS/INITIALS**
1.0 2.0	Notify TCO of planned work activity. Locate Strain Gages, Welding Tools, Supplies, and Monitoring equipment. The PI or designee has identified the steel set(s) to be instrumented.	Notified:
3.0	Pre Welding Procedures.	Charging complete:
3.1	Use PPEs as required. The portable welding unit and the vibrating wire readout box are charged. Calibrated equipment have valid calibration stickers and the information is documented on Data Form.	
3.2	Adjust VWSG tension to desired range per the manufacturer's instruction.	
3.3	VWSG Coil Ω (ohms) and Thermistor Ω. Set DVM to read ohms. Connect the DVM to the VWSG coil leads (Red & Black) Record the VWSG coil Ω on Data Form Connect the DVM to the VWSG temperature leads (White & Green) Record VWSG temperature Ω on Data Form	
3.4	Set the VW readout box's ON/OFF switch to ON. Set the readout box's DISPLAY switch to E. Connect the VWSG leads to the respective leads of the VW read out box.	
3.5	Initial Reading. Place strain gage on flat surface. Take the μstrain and temperature Initial Reading using the VW readout box and record on Data Form.	
3.6	When installing strain gages on steel sets on the surface, tag the selected steel set sections (Right, Crown, and Left)	
3.7	Steel Set Surface Preparation. Surfaces are free of grease, rust, scale, oxides, and surface irregularities.	
3.8	Mark the gage positions for the following situations. RIGHT SECTION. FACE-side down – Dutchman end on the right, align the 'B' template with the right-most center spacer hole. FACE-side up – Dutchman end on the left, align 'A' template with the left-most center spacer hole. CROWN SECTION. FACE-side down – Crown/Right end to the right, align the 'B' template with the right-most center spacer hole. FACE-side up – Crown/Right end on the left, align the 'A' template with the left-most center spacer hole. LEFT SECTION. FACE-side down – Dutchman end on the left, align the 'B' template with the right-most center spacer hole. FACE-side up – Dutchman end on the right, align 'A' template with the left-most center spacer hole.	
3.9	Degrease marked locations on the steel surfaces, if necessary.	
3.10	At strain gage and welding unit ground clamp locations: Remove rust and scale oxide using a hand grinder. Leave smooth bright surfaces.	
3.11	Use template to scribe gage locations.	
3.12	Thoroughly wash scribed locations with an appropriate solvent to remove residue.	

INSTALLATION CHECKLIST

(TP-232, Rev. 03, Appendix 1, page 2 of 2)

Before welding the gage, it is necessary to test the spot welder to make sure that it is functioning properly and that the correct energy is used. Proof welds are assured by making a ½ inch wide horseshoe shaped grouping of fifteen welds to approximately simulate the welds of the strain gage flange attachment. A 0.006 stainless steel tab is welded to a 0.500 inch thick sample of A36 steel.

STEP	ACTION	COMMENTS/INITIALS
	Date:	
4.0	Equipment Functional Test (Proof Test)	
4.1	Steel Sample Surface Preparation. Degrease and remove rust.	
4.2	Follow the welding unit's operation manual to prepare the welder for use.	
4.3	Set WELD ENERGY (approximately 25 joules for Measurement Group Model 700).	
4.4	Hold the stainless steel tab in firm contact with the steel base, place the welding electrode firmly against the stainless specimen at the desired weld location and actuate the welder by depressing the hand piece trigger. After completing the test pattern, peel the stainless material from the A36 Base material with pliers or a screw driver. Acceptable proof test spot welds: • Twelve of the fifteen spot welds will tear the weld nugget from the stainless steel material leaving a hole. If welds are unacceptable, adjust WELD ENERGY and repeat proof test. Document results at right.	Proof test results: Weld energy = _____

Proof Test performed by:_____

LEFT STEEL SET SECTION

VIBRATING WIRE STRAIN GAGE MANUAL READOUTS

DATA FORM TP-232, REV. 03, Appendix 2, page 1 of 3

STATION LOCATION _____ (Meters) **STEEL SET #: _____**

STEEL SET SECTION	VERTICAL POSITION	HORIZONTAL POSITION		OPERATING RANGE FROM	TO	CALIBRATION EQUIPMENT USED Equipment Name	SNL #	Recall Date
				μStrain	μStrain			
L = Left Section	**I** = Inside	**F** = Face	Initial Reading			1		
	O = Outside	**P** = Portal	Final Reading			2		
						3		
						4		

* Use equipment line number with each data entry.

Proof test performed by : _____

CH	DATE	TIME	Cable Length	Gage SN	Welder's Initials	VWSG μStrain	VWSG Temp°C	*	COMMENTS	*	Recorders Initials
1 LOF						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
1 LOF						E-			**Post Weld Reading** – After gage welded		
1 LOF						E-			**Final Reading** – After VWSG cover installed		
2 LOP						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
2 LOP						E-			**Post Weld Reading** – After gage welded		
2 LOP						E-			**Final Reading** – After VWSG cover installed		
3 LIF						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
3 LIF						E-			**Post Weld Reading** – After gage welded		
3 LIF						E-			**Final Reading** – After VWSG cover installed		
4 LIP						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
4 LIP						E-			**Post Weld Reading** – After gage welded		
4 LIP						E-			**Final Reading** – After VWSG cover installed		

CROWN STEEL SET SECTION

VIBRATING WIRE STRAIN GAGE MANUAL READOUTS

DATA FORM TP-232, Rev. 03, Appendix 2, page 2 of 3

STATION LOCATION _____ (Meters) **STEEL SET #: _____**

STEEL SET SECTION	VERTICAL POSITION	HORIZONTAL POSITION		OPERATING RANGE FROM	TO		CALIBRATION EQUIPMENT USED Equipment Name	SNL #	Recall Date
				μStrain	μStrain	1			
C = Crown Section	**I** = Inside	**F** = Face	Initial Reading			2			
	O = Outside	**P** = Portal	Final Reading			3			
						4			

* Use equipment line number with each data entry.

Proof test performed by : _____

CH	DATE	TIME	Cable Length	Gage SN	Welder's Int	VWSG μStrain	VWSG Temp°C	*	COMMENTS	*	Recorders Initials
5 COF						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
5 COF						E-			**Post Weld Reading** – After gage welded		
5 COF						E-			**Final Reading** – Strain gage cover installed		
6 COP						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
6 COP						E-			**Post Weld Reading** – After gage welded		
6 COP						E-			**Final Reading** – Strain gage cover installed		
7 CIF						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
7 CIF						E-			**Post Weld Reading** – After gage welded		
7 CIF						E-			**Final Reading** – Strain gage cover installed		
8 CIP						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
8 CIP						E-			**Post Weld Reading** – After gage welded		
8 CIP						E-			**Final Reading** – Strain gage cover installed		

RIGHT STEEL SET SECTION

VIBRATING WIRE STRAIN GAGE MANUAL READOUTS

DATA FORM TP-232, REV. 03, Appendix 2, page 3 of 3

STATION LOCATION _____ (Meters) STEEL SET #: _____

STEEL SET SECTION	VERTICAL POSITION	HORIZONTAL POSITION	OPERATING RANGE	FROM	TO	CALIBRATION EQUIPMENT USED	Equipment Name	SNL #	Recall Date
				μStrain	μStrain	1			
R = Right Section	**I** = Inside	**F** = Face	Initial Reading			2			
	O = Outside	**P** = Portal	Final Reading			3			
						4			

* Use equipment line number with each data entry.

Proof test performed by : _____

CH	DATE	TIME	Cable Length	Gage SN	Welder's Int.	VWSG μStrain	VWSG Temp °C	*	COMMENTS	*	Recorders Initials
9 ROF						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
9 ROF						E-			**Post Weld Reading** – After gage welded		
9 ROF						E-			**Final Reading** – Strain gage cover installed		
10 ROP						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
10 ROP						E-			**Post Weld Reading** – After gage welded		
10 ROP						E-			**Final Reading** – Strain gage cover installed		
11 RIF						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
11 RIF						E-			**Post Weld Reading** – After gage welded		
11 RIF						E-			**Final Reading** – Strain gage cover installed		
12 RIP						E-			**Initial Reading** – Prior to Installing VWSG Coil Ω_____ Thermistor Ω_____	*	
12 RIP						E-			**Post Weld Reading** – After gage welded		
12 RIP						E-			**Final Reading** – Strain gage cover installed		

Geokon, Inc.
(TP-232, Rev. 02, Appendix 3)

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

Baseline Equation:

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

Where : T = Temperature in $^{\circ}$C.
LnR = Natural Log of ThermistorResistance

$A = 1.4051 \times 10^{-3}$

$B = 2.369 \times 10^{-4}$

$C = 1.019 \times 10^{-7}$

Note Coefficients calculated over –50 to + 150 $^{\circ}$C span.

Resistance versus Temperature Table

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	1999	35	444.0	75	133.6	115
132.2K	-42	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	9795	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
56.15K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	6971	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

Location of Gages

(Figure 1)

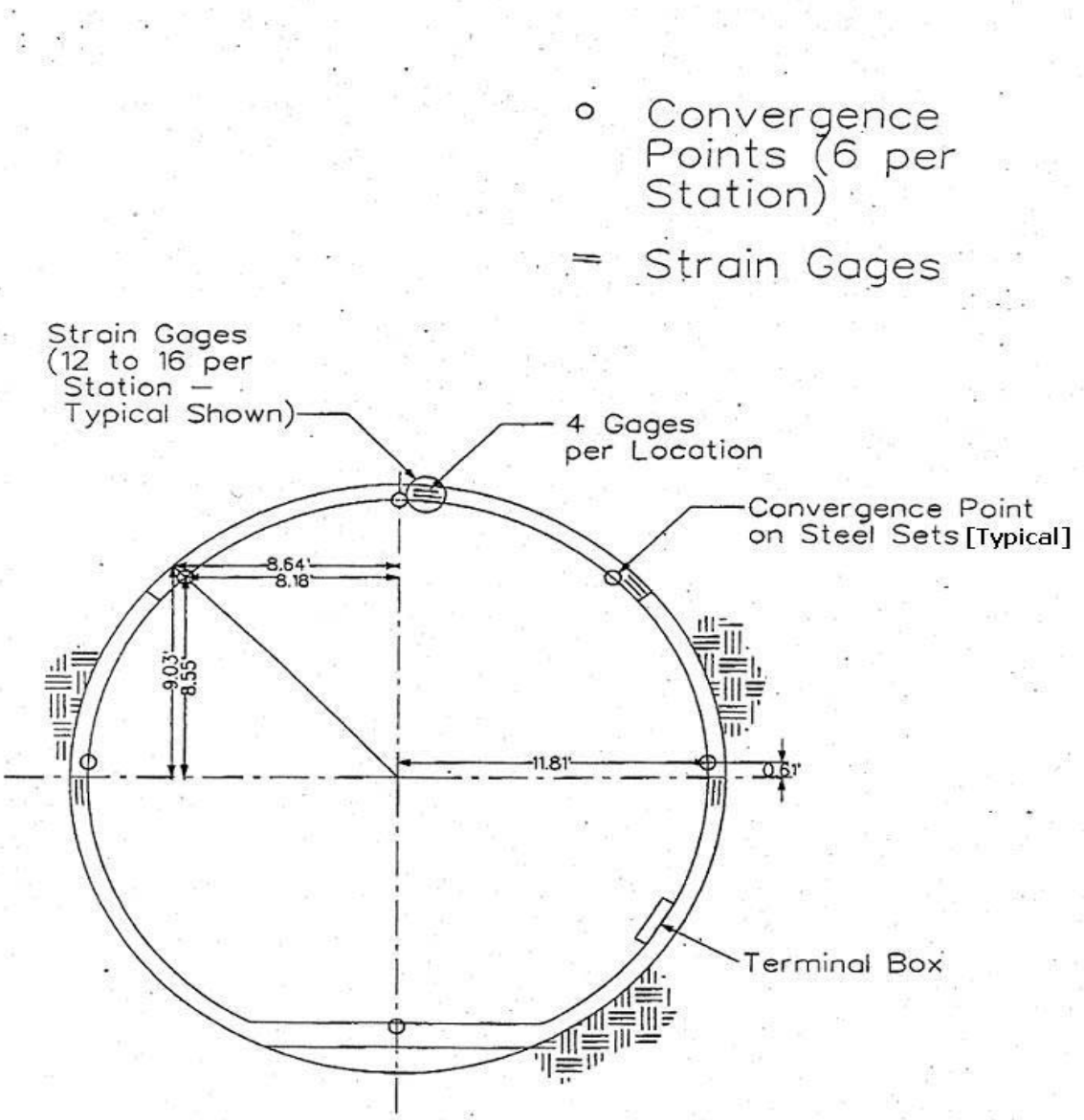

Figure 3. Typical Station "S" - Location of Gages on Steel Sets

Spot Welding Sequence

(Figure 2)