

The Gradient Control Mat (GCM)



OVERVIEW

The gradient control mat by DEI is designed to limit step and touch potentials due to lightning because such design will also keep step and touch potentials well below that required by IEEE 80 for power frequency voltages. The gradient control mat is made of 0.135" diameter steel wire with a 3" x 3" wire spacing with all wire intersections welded. After welding, the mat is hot dip galvanized. Mats are available in 4' x 8' sheets and are shipped flat on pallets. Each mat weighs 15 pounds (6.8kg). For larger mats, these sheets can be joined together to form any size mat required. Provision is made for thermit welding adjacent mat sections together to form an electrically continuous mat and for thermit welding lead connections to the mat.

DESIGN LIFE

To assure long life of the galvanized steel gradient control mat in all soil conditions, DEI has commissioned Correng Consulting to provide guidelines for cathodically protecting the mat using readily available magnesium anodes. The design life of the anodes protecting the mat is 20 years. Refer to the Correng Report COR-05-9508D "Guidelines for Cathodic Protection of Galvanized Steel Gradient Control Mats," a supplement to this document. In this report, see Table 2 to: (a) select the desired mat size, (b) to determine the anode type and quantity required for the soil resistivity and the size mat selected, and (c) to determine the mat layout configuration that applies

(Figure 1, 2, 3, or 4). Any larger size mat can be made from combining the sizes shown. The anodes required are to be purchased separately by the user from the supplier of choice per the criteria in Section 2.1 and 2.2 of the report. The anodes are to be ordered with the #6 AWG copper conductor size specified because this is required for connecting the anode lead to the mat with the thermit welding molds available from DEI for this purpose.

INSTALLED COSTS

Although auxiliary anodes and a decoupler are recommended, the total installed cost of the galvanized steel mat will normally be less than a pure zinc mat of any construction, particularly when an 8' x 8' or larger mat is required.

SAFE TOUCH AND STEP POTENTIALS

Specific technical data is provided for the touch and step potentials for the most difficult voltages to control, namely, voltage caused by lightning. Refer to Table 1 in DEI Application Note 8: Gradient Control Mats in Pipeline Applications for more information. To limit the touch potentials to safe levels, it is essential to make the connections between the pipe and the mat (whether directly or through a decoupler) with the shortest possible lead length, and preferably with multiple leads, to reduce lead inductance, and thereby reduce the inductive voltage drop in the leads.

DECOUPLING

While the DEI gradient control mat may be directly connected to the pipeline or decoupled, it is recommended that the mat be connected to the pipeline through a new, low cost Solid-State Decoupler (SSD) developed by DEI for this purpose as illustrated in Figure 1. A decoupled gradient control mat offers several distinct advantages:

- The galvanic potential of the mat material is irrelevant when it is decoupled from the cathodically protected pipeline
- CP readings can be taken in the vicinity of the gradient control mat
- Stray DC currents are prevented from accessing the pipeline, thereby preventing a corrosion problem where stray DC currents would exit the pipeline
- Any interaction between the CP system and the gradient control mat functions are eliminated
- When the mat is directly connected, the service life of the anodes is reduced by approximately 36% for the H1-Alloy magnesium anodes and 28% for the Hi-Potential magnesium anodes; hence, considerably longer anode life is achieved with a decoupled mat

ORDERING INFORMATION

1. Gradient Control Mat (4' x 8'): Order #GCM4-8. Specify quantity.
2. Anodes Required: Order from supplier of choice per Table 2 and Section 2.1 and 2.2 of the Correng Report referenced in this document.

3. Decoupler: For most applications, the SSD model suggested is SSD-2/2-1.2-75 which blocks +/- 2.0 volts (hence, polarity is not an issue when installing), has a 1.2kA fault current rating at 30 cycles, and a 75kA lightning current rating (4x10 µsec). Decouplers with higher AC fault and lightning current ratings are also available - See the SSD technical literature. Specify model number and quantity.

For large station mats, it is suggested that connections to the gradient control mat be made at the incoming and outgoing pipelines. Other pipe segments within a station may also need to be referenced to ground through additional decouplers.

4. Thermit Welding Molds:

(a) For mechanically and electrically bonding adjacent mat sections together (0.135" to 0.135" diameter galvanized steel wire), order "MOLD-135." and "WELD-135-15"(20/pack; industry standard #15 CP cartridge). Specify quantity of each.

It is recommended that mats be joined approximately every 18 inches (450mm).

(b) For bonding the #6 AWG decoupler and anode leads to the 0.135" diameter galvanized steel wire of the mat, order "MOLD-6" and "WELD-6-25"(20/pack; industry standard #25 CP cartridge). Specify quantity of each.

The life of either of the above molds is estimated at 50 welds nominal, 100 welds maximum.

c) All thermit welded decoupler and anode leads to the mat, plus all thermit welded connections to join adjacent mats, should be completely sealed. A recommended sealant is the Denso LT tape available in 4" wide x 33' long rolls, available from DEI or the distributor of choice. About a 2" length of this tape is required to seal each connection. Other user provided equivalent sealants may also be used.

5. SSD Decoupler Mounting Options:

(a) Banding may be utilized as illustrated in Figure 2. The banding is to be purchased by the user. Contact DEI for banding material sources.

This mounting option requires that leads be run from one decoupler bus to the pipeline and from the other decoupler bus to the mat. Two leads to each bus are recommended for a total of four leads. The following kits contain two leads each: #MTL-6-12 with 12"(300mm) leads or #MTL-6-36 with 36"(900mm) leads. #6 AWG copper leads are furnished with terminals attached to one end. Bolts, nuts, and washers for securing the terminal end of the lead to the SSD bus are furnished with the SSD. The other lead end is unfinished. Order the mold and weld metal in Item 4(b) for welding the leads to the mat. The user is responsible for the lead connection to the pipeline. (Custom molds can be acquired for welding the leads to the pipeline upon request provided the pipe diameter is given and it is specified whether the weld is to a vertical pipe wall or on the top side of a horizontal pipe.) All leads should be cut to the shortest possible length during installation to minimize touch potential.

(b) Attachment via pin brazing M8 studs to a steel pipe is illustrated in Figure 3. The user must have the required pin brazing equipment and consumable items (i.e., the M8-1.25 threaded studs with a 16mm threaded section furnished with two washers and a locknut and ceramic ferrules). Equipment and studs are available from several manufacturers - contact DEI for assistance if required. The desirability of this option is that it virtually eliminates the inductance of one lead connection because one SSD terminal is directly connected to the pipe via the pin brazed stud. For each decoupler installed using pin brazed stud mounting, order one #HCN-M8 (the Hex Coupling Nut plus M8 bolt and washers required) plus one set of leads, #MTL-6-12 for 12" (300mm) leads or #MTL-6-36 for 36"(900mm) leads.

ORDERING INFORMATION CHECKLIST:

- 1) Gradient control Mat: GCM4-8
 - 2) Anodes: By user-order per Section 2 and Table 2 in attached Correng Report
 - 3) Decoupler: Model SSD-2/2-1.2-75 unless other model selected
 - 4) Thermit Welding Molds/Charges:
 - For joining adjacent mats:
 - MOLD-135
 - WELD-135-15 (20/pack)
 - For joining anode and decoupler leads to mat:
 - MOLD-6
 - WELD-6-25 (20/pack)
- Note:** If anodes with #10 or #12 conductor leads are used then thermit weld to the mat using MOLD-135 and WELD-135-15.

5) Denso LT Tape in 4" x 33' roll

- 6) Decoupler Mounting Options:
 - Leads: MTL-6-12 or MTL-6-36
 - Banding: Material by others
 - Pin Brazing: Equipment/studs/ceramic ferrules by others. Order HCN-M8 kit from DEI.

FIGURE 1 Typical Procedure For Decoupling A Gradient Control Mat

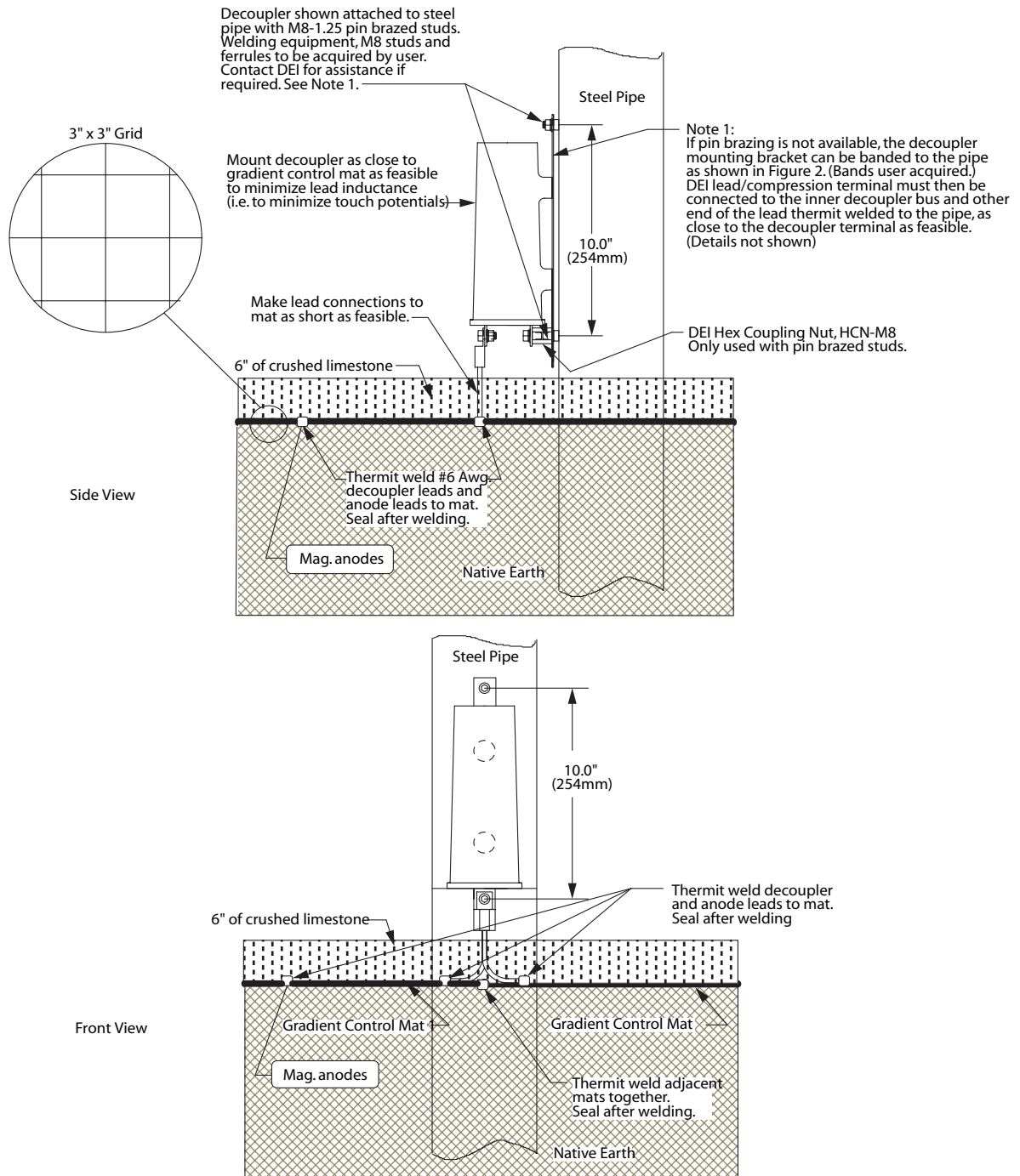


FIGURE 2 Banding SSD to a Test Station or Pipe Wall

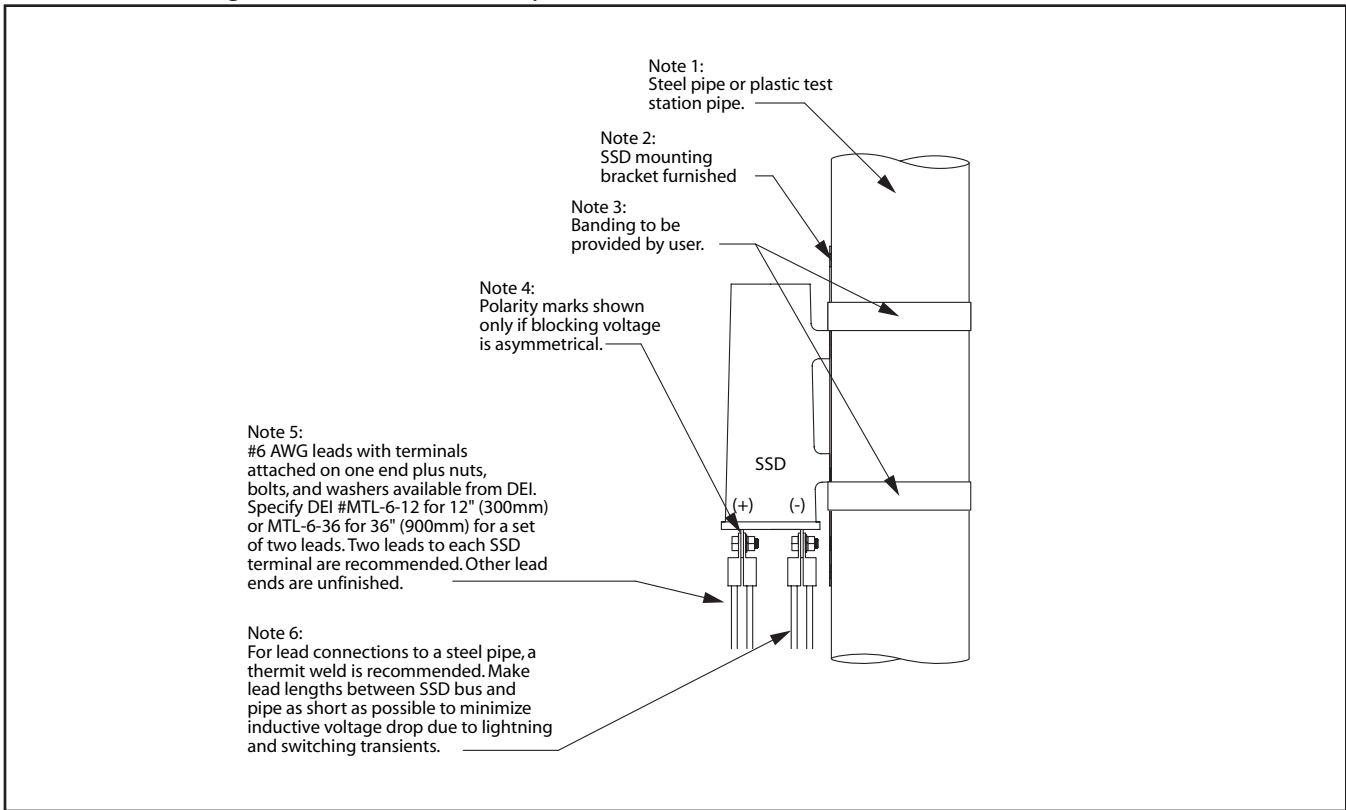
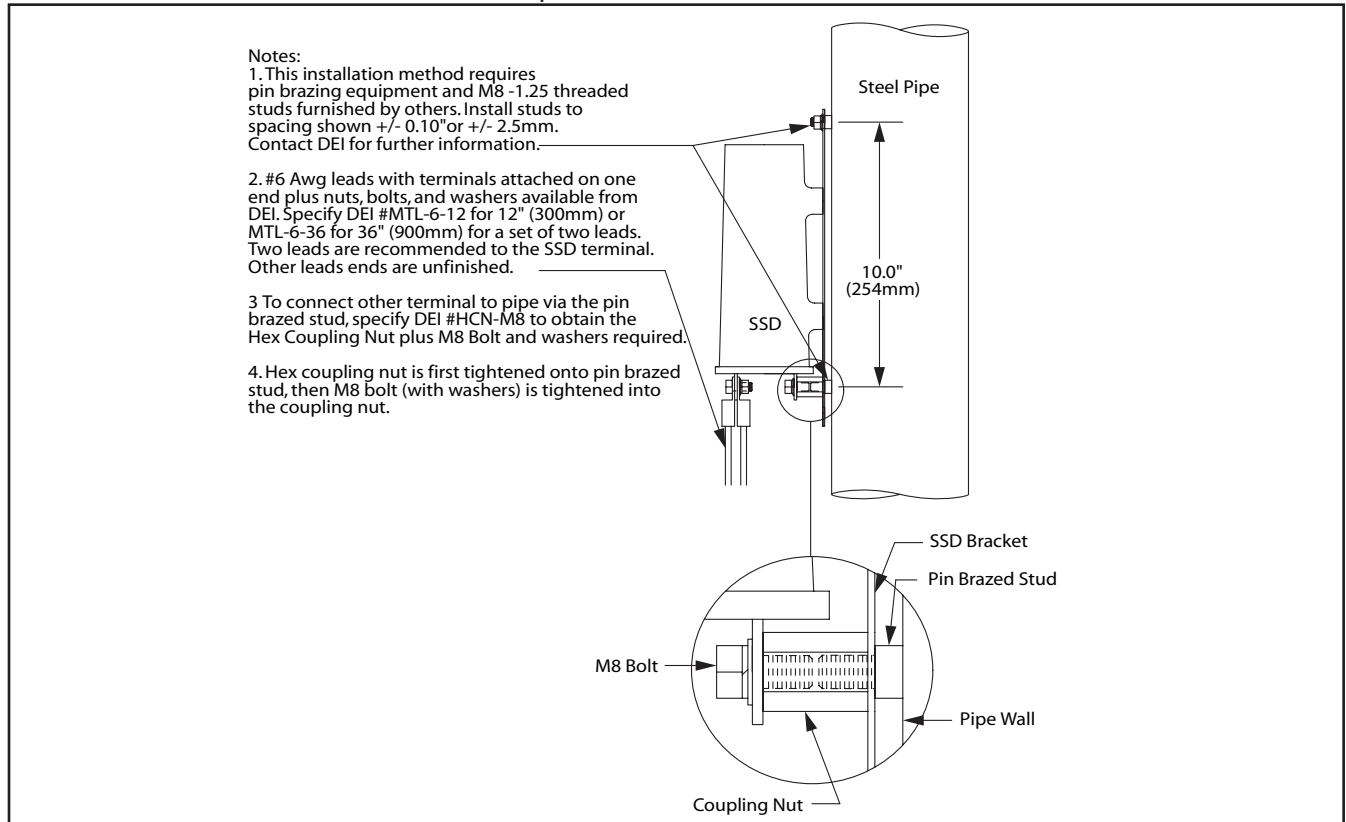


FIGURE 3 Pin Brazed Stud Connection to a Pipe Wall





GUIDELINES FOR CATHODIC PROTECTION OF GALVANIZED STEEL GRADIENT CONTROL MATS

1.0 APPLICABILITY

- 1.1 These guidelines apply to cathodic protection of galvanized steel gradient control mats installed at pipeline appurtenances to reduce electrical step and touch potentials in areas where persons could come into contact with a pipeline appurtenance subject to hazardous potentials.
- 1.2 These guidelines do not apply when the gradient mat is connected to other grounding systems, either directly or indirectly through the pipeline appurtenance. These applications require consultation with a cathodic protection specialist.
- 1.3 If the pipeline is not cathodically protected, the galvanized steel mat should be connected only via a decoupling device, or provision should be made to protect both the pipe and the mat in consultation with a cathodic protection specialist.

2.0 ANODES

- 2.1 The magnesium anodes used to protect the mats should be either high potential packaged magnesium anodes (Alloy M1C) or H1-Alloy (Standard) packaged magnesium anodes, as indicated in Table 1.

Table 1. Magnesium Anode Data

Anode Type	Alloy (ASTM B843-93)	Weight (Lbs.)	Standard Package Dimensions
17S4	H-1 Alloy Grade A	17	6.5" x 19"
17D4	M1C (High Potential)	17	6.5" x 19"
32S5	H-1 Alloy Grade A	32	8" x 30"
32D5	M1C (High Potential)	32	8" x 30"

- 2.2 The packaged anodes should be provided with 10 ft. of AWG 6/7 RWU 90 cable. The backfill should be a mix of 75% hydrated gypsum, 15% bentonite, and 5% sodium sulphate.



CP of Galvanized Steel Gradient Control Mats

2.3 The type and quantity of the packaged anodes should be in accordance with Table 2. Contact DEI if the size of the mat exceeds 16' x 16'.

Table 2. Required Type and Number of Magnesium Anodes

Mat Size	Soil Resistivity (Ω -cm) ^[1]	Anode Type	Required No. of Anodes	Calculated Anode Service Life		Layout
				Decoupled GCM	Directly Connected GCM ^[2]	
4' x 8'	Low (1000 to 2000)	32S5	1	>20 years	>18 years	Figure 3
	Moderate (Over 2000)	17S4	1	>20 years	>20 years	Figure 3
8' x 8'	Low (1000 to 2000)	32S5	1	>20 years	>17 years	Figure 1
	Moderate (Over 2000)	17D4	1	>20 years	>20 years	Figure 1
8' x 16'	Low (1000 to 2000)	17S4	2	>20 years	>19 years	Figure 4
	Moderate (Over 2000)	32D5	1	>20 years	>20 years	Figure 3
12' x 16'	Low (1000 to 2000)	32S5	2	>20 years	>20 years	Figure 4
	Moderate (Over 2000)	32D5	2	>20 years	>20 years	Figure 4
16' x 16'	Low (1000 to 2000)	32S5	2	>20 years	>19 years	Figure 2
	Moderate (Over 2000)	32D5	2	>20 years	>20 years	Figure 2

^[1] The cathodic protection system was designed to provide an anode life in excess of 20 years in soil resistivities as low as 1000 Ω -cm and to provide the required protection current at soil resistivities up to 15,000 Ω -cm. Soils with resistivities higher than 15,000 Ω -cm are not considered corrosive.

^[2] If the gradient control mat is directly connected to a pipe appurtenance, then the polarized potential of the protected structure is expected to drop from -1100mV_{CSE} to -850 mV_{CSE} and the service life of the anode would be reduced by 28% for high potential anodes and by 36% for H1-Alloy anodes.



3.0 ANODE INSTALLATION

- 3.1 The anodes should be installed horizontally approximately 3 ft. below the mat, as indicated in Figures 1 to 4.
- 3.2 The anode wire should be run to a close mat wire. The radius of bends should be at least 8".
- 3.3 The #6 AWG anode wire connections to the 0.135" diameter galvanized steel wire of the gradient control mat and the mechanical/electrical bonding of the galvanized steel wires in adjacent gradient control mats should be done by thermit welding. Custom molds and the weld metal for each case are available from DEI (Dairyland Electrical Industries, Inc.) All thermit welded connections should be sealed with two or more layers of Denso LT tape.

3.0 ANODE INSTALLATION CONT'D

3.3 Cont'd

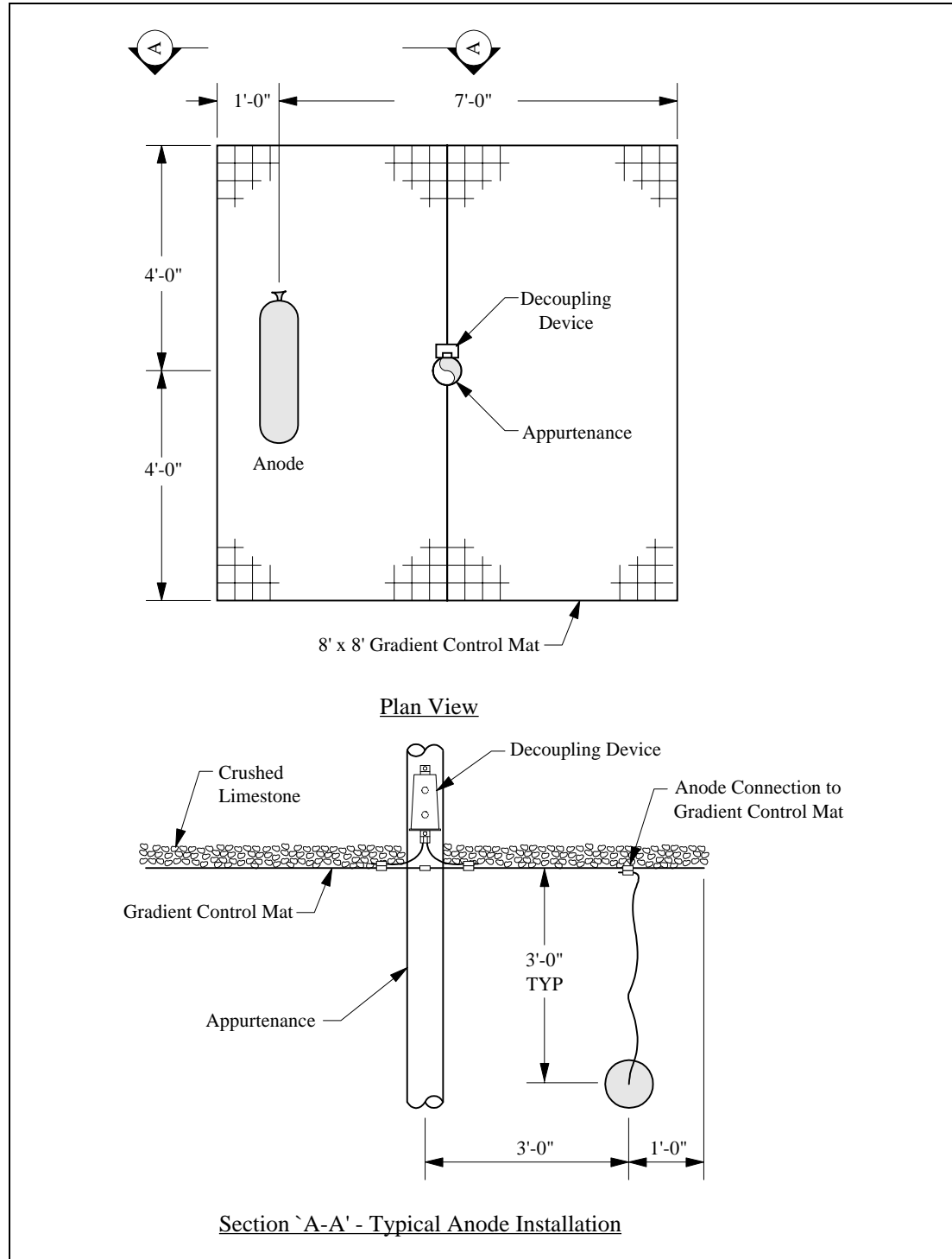


FIGURE 1 • Square Gradient Control Mat with One Anode

3.0 ANODE INSTALLATION CONT'D

3.3 Cont'd

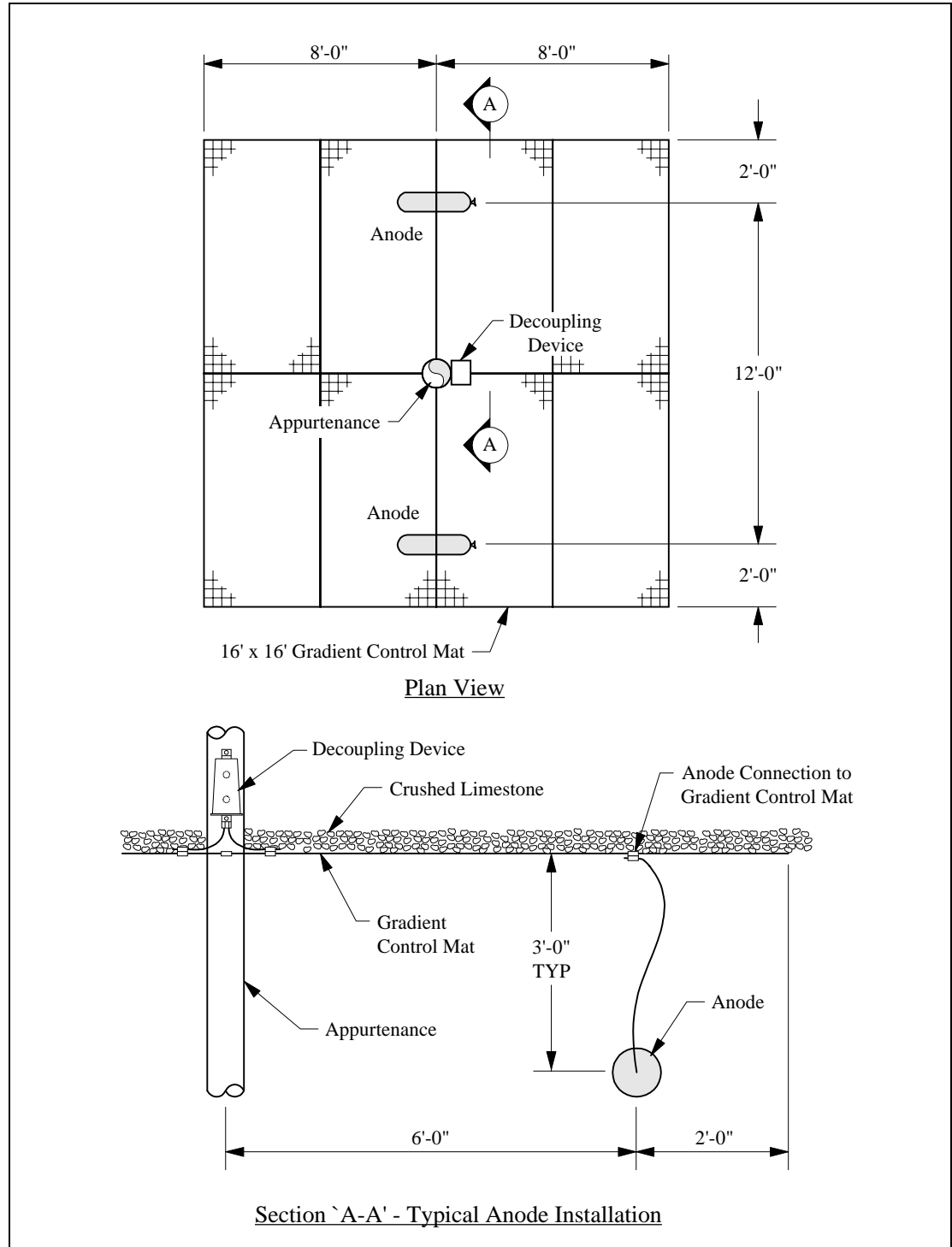


FIGURE 2 • Square Gradient Control Mat with Two Anodes

3.0 ANODE INSTALLATION CONT'D

3.3 Cont'd

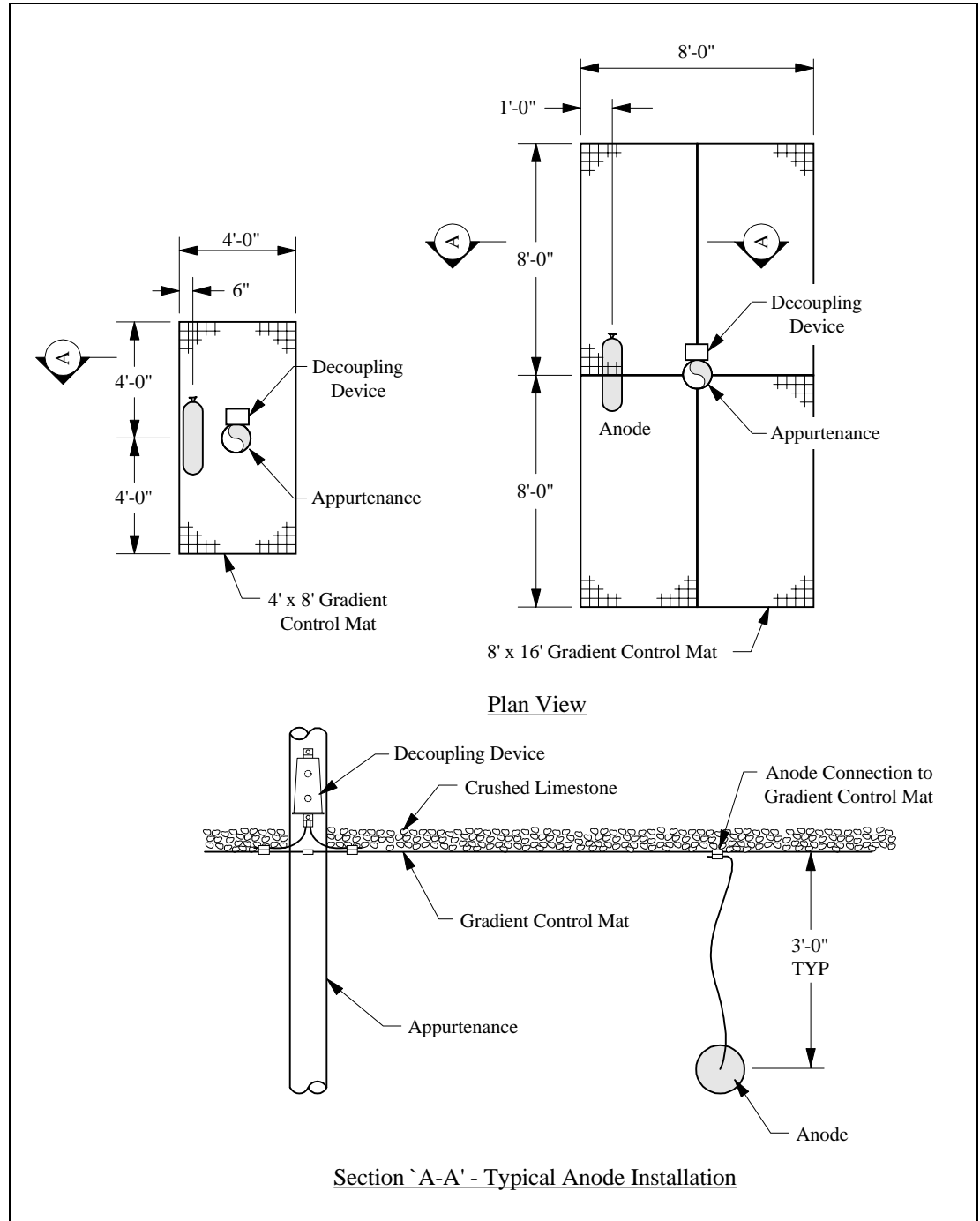


FIGURE 3 • Rectangular Gradient Control Mat with One Anode

3.0 ANODE INSTALLATION CONT'D

3.3 Cont'd

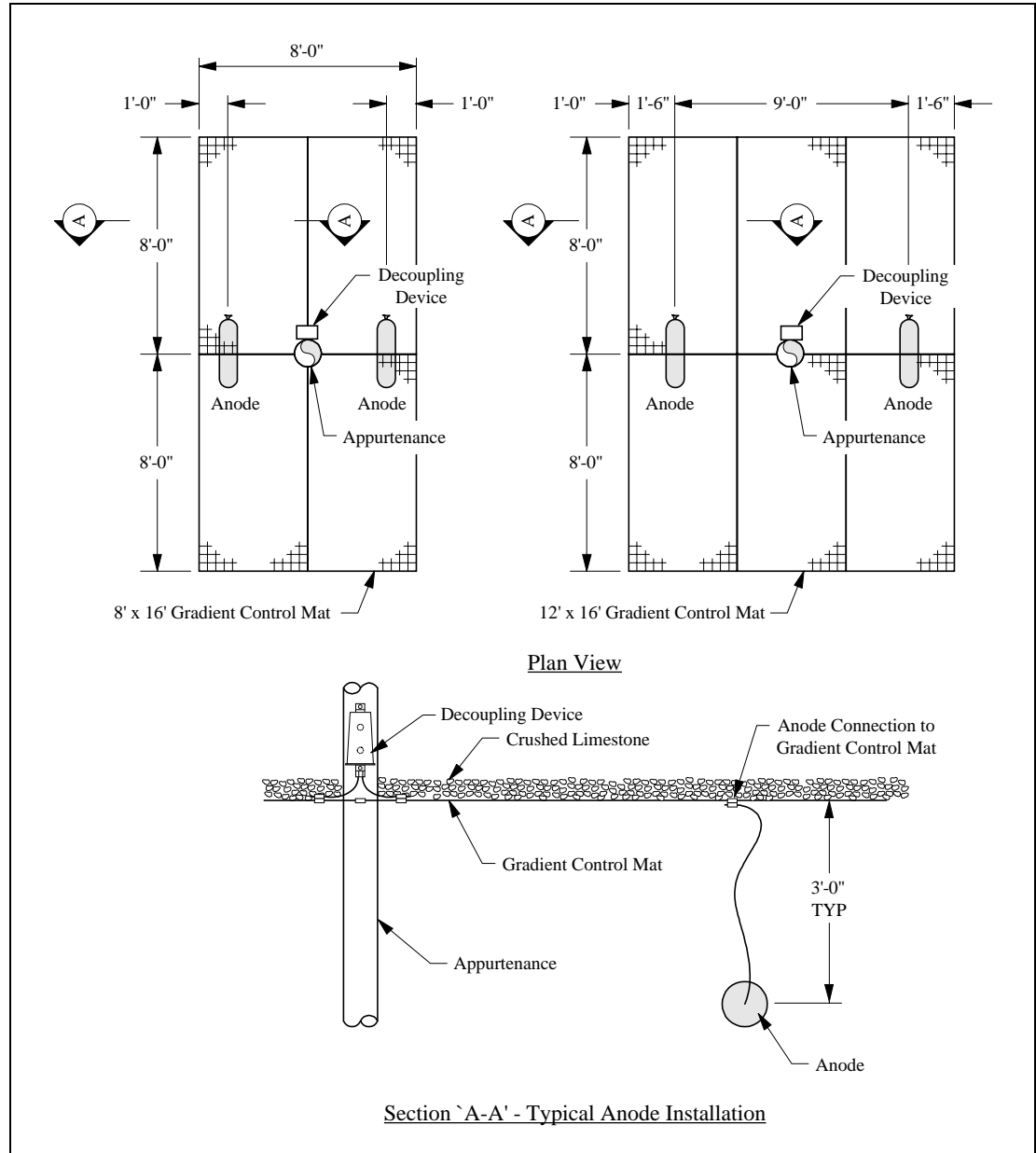


FIGURE 4 • Rectangular Gradient Control Mat with Two Anodes



4.0 ADDITIONAL RECOMMENDATIONS

- 4.1 It is recommended to use crushed limestone as the high resistivity layer to be installed on top of the safety mat, in order to minimize the attack of acid rain on the galvanized steel.