BRIDGE DECK PROTECTION SYSTEM

FINAL

CONSTRUCTION REPORT

by

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Project 1-10-84-562
(DTFH 71-83-3605-TX-10)

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
TRANSPORTATION PLANNING DIVISION
June 1989
This report concludes a study of three bridge deck protective systems which were utilized on a bridge deck constructed over the Brazos River on SH 67 south of Graham, Texas. As noted in the Interim Report of July, 1986, the protective systems applied were as follows:

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2. High molecular weight (11MW) **methacrylate** was applied as a surface dressing on two test spans as a means of restricting Cl ion penetration through membrane action (with epoxy coated reinforcement and with plain reinforcement), and

3. **Lime oil** surface dressing was also applied for the purpose of restricting Cl ion penetration through membrane action (with epoxy coated reinforcement and with plain reinforcement).

For reasons detailed within this report, current flow readings from corrosometer probes were not attainable, and removal (core drilling) of any test bars was determined to be premature. Also, surface friction with respect to each protective system is addressed. The report summary identifies future work to be conducted and documented in this regard.

**Key Words**
- bridge
decks
calcium nitrate
British pendulum test

**Distribution Statement**
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PREFACE

This report was prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

The contents of this report are experimental in nature and reflect the views of the author who is responsible for the facts and the accuracy of the data presented, which is published for informational purposes only.

The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the State Department of Highways and Public Transportation. Any discrepancies with official views or policies of the Texas State Department of Highways and Public Transportation should be discussed with the appropriate Austin Division prior to implementation of the procedures or results. This report does not constitute a standard, specification, or regulation.
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## METRIC CONVERSION FACTORS

### Approx. Conversions to Metric Measures

<table>
<thead>
<tr>
<th>Multiply</th>
<th>By</th>
<th>To Obtain</th>
<th>Multiply</th>
<th>By</th>
<th>To Obtain</th>
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<td>millimeters</td>
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<td>inches</td>
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### Approx. Conversions from Metric Measures

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<tr>
<td>inches</td>
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<tr>
<td>feet</td>
</tr>
<tr>
<td>yards</td>
</tr>
<tr>
<td>miles</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>sq. in.</td>
</tr>
<tr>
<td>sq. ft.</td>
</tr>
<tr>
<td>sq. yd.</td>
</tr>
<tr>
<td>sq. mi.</td>
</tr>
<tr>
<td>acres</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MASS (weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ounces</td>
</tr>
<tr>
<td>pounds</td>
</tr>
<tr>
<td>short tons</td>
</tr>
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<table>
<thead>
<tr>
<th>VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>teaspoons</td>
</tr>
<tr>
<td>Tbsp.</td>
</tr>
<tr>
<td>fluid oz.</td>
</tr>
<tr>
<td>cups</td>
</tr>
<tr>
<td>pints</td>
</tr>
<tr>
<td>quarts</td>
</tr>
<tr>
<td>gallons</td>
</tr>
<tr>
<td>cubic ft.</td>
</tr>
<tr>
<td>cubic yd.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>TEMPERATURE (exact)</th>
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<tbody>
<tr>
<td>Fahrenheit</td>
</tr>
<tr>
<td>Celsius</td>
</tr>
<tr>
<td>Fahrenheit</td>
</tr>
<tr>
<td>5/9 (after subtracting 32)</td>
</tr>
</tbody>
</table>
This report concludes a study of three bridge deck protective systems which were utilized on a bridge deck constructed over the Brazos River on SH 67 south of Graham, Texas. As noted in the Interim Report of July, 1986, the protective systems applied were as follows:

(1) *Calcium nitrate* was applied to a single test span as a concrete additive to inhibit steel reinforcement corrosion through pH adjustment of concrete (with non epoxy "plain" reinforcement),

(2) High molecular weight (HMW) *methacrylate* was applied as a surface dressing on two test spans as a means of restricting Cl⁻ ion penetration through membrane action (with epoxy coated reinforcement and with plain reinforcement), and

(3) *Linseed oil* surface dressing was also applied for the purpose of restricting Cl⁻ ion penetration through membrane action (with epoxy coated reinforcement and with plain reinforcement).

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SECTION 1

INTRODUCTION

1.1 GENERAL

As noted in the Interim Construction Report,

"The utilization of deicing salts on bridges has posed serious problems in long term bridge deck serviceability. Bridge deck steel reinforcement exposed to winter salt applications and which subsequently commences to rust has displayed serious concomitant concrete spalling and delamination distress. Protective systems to restrict chloride contamination have been employed with varying degrees of success. A major concern with protective systems which utilize asphaltic seals and an asphaltic concrete overlay is that any concrete distress which subsequently takes place is hidden from observation. Problems which could have been corrected by timely maintenance when they were minor are likely to be obscured until major distress becomes evident. Further, labor costs, traffic disruptions, and motorist and worker safety are factors which must also be evaluated when considering effective alternate protective systems."

The intent of this project was to address the application, benefits and any shortcomings associated with the utilization of several protective systems, including their potential impact to surface friction.

1.2 PROJECT BACKGROUND

This project was initiated in accordance with a Cooperative Agreement Work Order issued by the U.S. Department of Transportation Federal Highway Administration.

The originating scope of this project (September, 1983) was to evaluate the application, maintenance and effect of linseed oil as a protective system for the Spring Creek Relief Bridge, S.B., 195-1-166 on IH 35, south of Gainesville, Texas. Also, the decks were to be evaluated for potential loss in frictional resistance of the deck surface after routine linseed oil applications. Linseed oil, the proposed protective system, was and continues to be extensively used throughout Texas.

In a subsequent modification to the agreement in November, 1984, the scope of work was expanded to include the use of calcium nitrate as an additive to the concrete deck for the Spring Creek Relief Bridge.
The final agreement, in May 1985, further modified the scope of the work to include the use of a high molecular weight (HMW) methacrylate monomer surface dressing as a third bridge deck protective system. This agreement also changed the project location. In this agreement, the systems were scheduled for utilization on a bridge deck to be constructed over the Brazos River on SH 67 south of Graham, Texas. See Figure 1, Project Location Map.

To summarize, this project evaluates: (1) calcium nitrate as a concrete additive, (2) HMW methacrylate surface dressing and (3) linseed oil surface dressing as bridge deck protective systems, and potential loss of frictional resistance to the deck after routine applications.

1.3 EXCERPTS FROM INTERIM REPORT

Project Layout

1. The Brazos River Bridge decks were treated with three separate protective systems by District 3 of the Texas SDHPT in cooperation with the W.R. Grace and the Rohm and Haas Companies.

2. The primary construction activity occurred in August and September of 1985.

3. The bridge was open to traffic on December 18, 1985.

4. Control and test spans were set up as noted in Table 1, Surface Treatments (sand was also applied to spans 6 & 7).

<table>
<thead>
<tr>
<th>CONTROL* SPAN</th>
<th>STEEL REINF.</th>
<th>PROTECTIVE TREATMENT</th>
<th>SURFACE TEXTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>Epoxy</td>
<td>Linseed Oil</td>
<td>Tine</td>
</tr>
<tr>
<td>#4</td>
<td>Epoxy</td>
<td>Linseed Oil</td>
<td>Tine</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TEST SPAN</th>
<th>STEEL REINF.</th>
<th>PROTECTIVE TREATMENT</th>
<th>SURFACE TEXTURE</th>
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</thead>
<tbody>
<tr>
<td>#5</td>
<td>Epoxy</td>
<td>Linseed Oil</td>
<td>Saw Groove</td>
</tr>
<tr>
<td>#6</td>
<td>Epoxy</td>
<td>Methacrylate</td>
<td>Saw Groove w/sand</td>
</tr>
<tr>
<td>#7</td>
<td>Plain</td>
<td>Methacrylate</td>
<td>Saw Groove w/sand</td>
</tr>
<tr>
<td>#8</td>
<td>Plain</td>
<td>Linseed Oil</td>
<td>Saw Groove</td>
</tr>
<tr>
<td>#9</td>
<td>Plain</td>
<td>Calcium Nitrate</td>
<td>Saw Groove</td>
</tr>
</tbody>
</table>

*See Figure 2, Schematic Layout of SH 67 Brazos River Bridge

TABLE 1 SURFACE TREATMENTS
FIGURE 1 PROJECT LOCATION MAP
FIGURE 2  SCHEMATIC LAYOUT OF SH 67 BRAZOS RIVER BRIDGE
5. Spans 5 through 9 were saw grooved as part of a field change to compare benefits with tine textured surfaces. Saw grooves for spans 5, 8 and 9 were 3/16 inch in depth, span 6 saw grooves were 7/32 inch in depth and span 7 saw grooves were measured at 1/4 inch.

6. As part of a field change, plain rebars were installed in spans 7, 8, and 9 to compare with epoxy coated bars.

7. The deck is comprised of 4 inches of prestressed panels, with 3 1/2 inch thick reinforced concrete surface overlay.

8. With only a few exceptions, reinforcement steel concrete cover ranges from 2 to 2 3/8 inches.

Instrumentation

   a. Nine corosometer probes, of plain #5 reinforcing steel bars, six inches in length, were typically installed in each of the experimental spans as noted in Figure 3, Corrosometer Probe Installation Data.
   b. Two ground wires were Cadwelded to the deck reinforcing steel in each experimental span.
   c. All leads were fed into locking waterproof junction boxes attached to the outside of the east parapet wall for each span. Figure 4, Corrosometer Probe Circuit, illustrates the schematic diagram of the instrumentation contained in each junction box.
   d. The circuits incorporated an interchangeable precision resistor placed in series with a rotary selector switch.
   e. Eight fifteen amp breakers were used in each box as switches to compute the rebar circuit as electrical measurements were made.

2. Retrievable Reinforcement Specimens
   a. A set of paired reinforcing steel bars, 7 feet in length of plain and epoxy were installed in each span as noted in Figure 5, Location Schedule – Retrievable Reinforcing Bars.
   b. The retrievable bars were placed at steel mat level.
### Typical Span *

*Southernmost span is No. 9, northernmost is No. 5*

<table>
<thead>
<tr>
<th>Span</th>
<th>Date</th>
<th>Installed by</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>#8</th>
<th>#9</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>7/31</td>
<td>Canaday &amp; Reed</td>
<td>Red</td>
<td>Blu</td>
<td>Blk</td>
<td>Wht</td>
<td>Org</td>
<td>Pur</td>
<td>Grn</td>
<td>Gry</td>
<td>Brn</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Wht (knotted)</td>
</tr>
<tr>
<td>8</td>
<td>8/6</td>
<td>Canaday &amp; Reed</td>
<td>Red</td>
<td>Blu</td>
<td>Blk</td>
<td>Wht</td>
<td>Pur</td>
<td>Pur</td>
<td>Grn</td>
<td>Gry</td>
<td>Brn</td>
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<td></td>
<td></td>
<td></td>
<td>Wht (knotted)</td>
</tr>
<tr>
<td>7</td>
<td>8/13</td>
<td>Hustace &amp; Golding</td>
<td>Pur</td>
<td>Red</td>
<td>Brn</td>
<td>Wht</td>
<td>Gry</td>
<td>Blu</td>
<td>Blk</td>
<td>Grn</td>
<td>Blu</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wht (knotted)</td>
</tr>
<tr>
<td>6</td>
<td>8/16</td>
<td>Reed &amp; Braddock</td>
<td>Red</td>
<td>Blu</td>
<td>Blk</td>
<td>Wht</td>
<td>Grn</td>
<td>Pur</td>
<td>...</td>
<td>...</td>
<td>Wht</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>(tied)</td>
</tr>
<tr>
<td>5</td>
<td>9/9</td>
<td>Hustace</td>
<td>Gry</td>
<td>Blk</td>
<td>Lav</td>
<td>Wht</td>
<td>Grn</td>
<td>Brn</td>
<td>Red</td>
<td>Blk</td>
<td>Blu (knotted)</td>
</tr>
<tr>
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<td></td>
<td>Org</td>
</tr>
</tbody>
</table>

**Source:** PROJECT 562 INTERIM CONSTRUCTION REPORT, 1986

**Figure 3** CORROSOMETER PROBE INSTALLATION DATA
Corrosometer Voltage Drop Monitoring Procedure

1. Open all circuit breakers.

2. Rotate rotary switch three complete revolutions to clean contact points.

3. Check ground continuity.

4. Set rotary switch to corrosometer probe position and read voltage drop across precision resistor, R1 and R2.

5. Repeat measurement for each probe three times and record the data on the following format and forward it to File D-10R, State Department of Highways and Public Transportation, Austin, Texas 78763-5051.

Corrosometer Probe Measurements
Brazos River Bridge Site 67, Young County
Texas SDH&PT Project 1-10-84-562

<table>
<thead>
<tr>
<th>Bridge Span No.*</th>
<th>5, 6, 7, 8, 9 (circle one)</th>
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<tr>
<td>Ground continuity check</td>
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</table>

<table>
<thead>
<tr>
<th>Date Da/Mo/Yr</th>
<th>Precision Resistor Value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Recorded by:</th>
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</tbody>
</table>

Average

* Span #9 is southernmost span

6. Close all circuit breakers and rotate rotary switch to neutral position (N) until next scheduled reading.

SOURCE: PROJECT 562 INTERIM CONSTRUCTION REPORT, 1986

FIGURE 4 CORROSOMETER PROBE CIRCUIT
Typical Span

<table>
<thead>
<tr>
<th>Span</th>
<th>#</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
<th>(f)</th>
<th>(g)</th>
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<tr>
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<td>40</td>
<td>3.9</td>
<td>10.6</td>
<td>13.1</td>
<td>15.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>45</td>
<td>3.8</td>
<td>10.5</td>
<td>13.6</td>
<td>15.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>40</td>
<td>3.8</td>
<td>10.5</td>
<td>13.5</td>
<td>15.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>40</td>
<td>3.9</td>
<td>10.7</td>
<td>13.5</td>
<td>15.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
<td>3.9</td>
<td>10.7</td>
<td>--</td>
<td>--</td>
<td>17.55</td>
<td>27.8</td>
<td></td>
</tr>
</tbody>
</table>

SOURCE: PROJECT 562 INTERIM CONSTRUCTION REPORT, 1986

FIGURE 5 LOCATION SCHEDULE - RETRIEVABLE REINFORCING BARS
SECTION 2
EVALUATION

2.1 INTERIM REPORT FINDINGS

1. Pavement Surface

   a. Construction related problems which might influence expected performance comparisons between test spans were not apparent.

   b. Only two separate deicing salt applications were made to the structure in the first year.

   c. Table 2, Sand Patch Texture and Saw Groove Depth Measurements Record and Table 3, British Pendulum Tester Measurements reflect surface texture and friction. The results of the Sand Patch tests indicated that the tine texture was rougher than that of saw grooving. The British Pendulum tests also indicate greater frictional qualities with tine texture as opposed to that of saw grooving. While variations existed, the examination of this data indicated that all surfaces had an adequate frictional level when open to traffic and through all subsequent measurements.

2. Current Flow Measurements

   a. Since from the equation, $E = IR$, current is proportional to voltage, a high voltage indicates a high current flow. Control test probes suspended in tap water in the laboratory indicated potential between probes to be 10 to 15 millivolts with a current flow of $15 \times 10^{-6}$ amperes.

   b. Initial voltage measurements of test probes, taken on April 15, 1986, resulted in readings from 1.0 to 37.9 millivolts. These measurements, noted in Table 4, Corrosometer Probe Voltage Measurements, did not reflect decisive patterns.

3. Retrievable Reinforcement Bars

   In accordance with the project work order, recoverable reinforcing steel bars were to be examined at periodic intervals to verify comparative corrosion protection.
<table>
<thead>
<tr>
<th>Location</th>
<th>Protective Treatment</th>
<th>Measurements (inches)</th>
<th>Average (inches)</th>
<th>Texture T</th>
<th>Saw Groove Depth (in.)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Laminated</td>
<td>4.5 4.7 4.8 4.7</td>
<td>4.7</td>
<td>0.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2(a)</td>
<td>&quot; &quot;</td>
<td>5.9 5.8 5.9 5.7</td>
<td>5.8</td>
<td>0.87</td>
<td></td>
<td>smoother than typical</td>
</tr>
<tr>
<td>2(b)</td>
<td>&quot; &quot;</td>
<td>3.8 3.9 3.7 3.6</td>
<td>3.8</td>
<td>1.32</td>
<td></td>
<td>rougher than typical</td>
</tr>
<tr>
<td>2(c)</td>
<td>&quot; &quot;</td>
<td>4.5 4.8 4.6 4.5</td>
<td>4.6</td>
<td>0.90</td>
<td></td>
<td>typical</td>
</tr>
<tr>
<td>3</td>
<td>&quot; &quot;</td>
<td>4.9 4.5 4.7 4.8</td>
<td>4.7</td>
<td>0.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>&quot; &quot;</td>
<td>4.5 4.8 4.6 4.6</td>
<td>4.8</td>
<td>0.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&quot; &quot;</td>
<td>7.0 6.9 6.9 7.0</td>
<td>6.9</td>
<td>0.40</td>
<td>3/16</td>
<td></td>
</tr>
<tr>
<td>6(a)</td>
<td>Methacrylate</td>
<td>6.8 7.0 6.6 6.9</td>
<td>6.7</td>
<td>0.43</td>
<td>7/32</td>
<td>before methacrylate</td>
</tr>
<tr>
<td>6(b)</td>
<td>&quot; &quot;</td>
<td>6.0 5.8 5.8 5.9</td>
<td>5.9</td>
<td>0.55</td>
<td></td>
<td>after methacrylate</td>
</tr>
<tr>
<td>7(a)</td>
<td>&quot; &quot;</td>
<td>6.8 6.4 6.0 6.7</td>
<td>6.5</td>
<td>0.45</td>
<td>1:4</td>
<td>before methacrylate</td>
</tr>
<tr>
<td>7(b)</td>
<td>&quot; &quot;</td>
<td>6.3 6.6 6.0 6.1</td>
<td>6.1</td>
<td>0.41</td>
<td></td>
<td>after methacrylate</td>
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<td>0.41</td>
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<td>9</td>
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<td>6.7 7.3 6.8 6.8</td>
<td>6.9</td>
<td>0.40</td>
<td>3/16</td>
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</tr>
</tbody>
</table>

**SOURCE:** PROJECT 562 INTERIM CONSTRUCTION REPORT, 1986

**TABLE 2 SAND PATCH TEXTURE AND SAW GROOVE DEPTH MEASUREMENTS RECORD**
<table>
<thead>
<tr>
<th>Station</th>
<th>Friction Pad Surface Contact (in.)</th>
<th>Values</th>
<th>Sum</th>
<th>$\bar{x}$</th>
<th>$\sigma$</th>
<th>$\bar{X}$</th>
<th>Var</th>
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<tr>
<td>Control: Linseed Oil, True Texture</td>
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<td>Spans #3 &amp; 4</td>
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<td>388 + 63</td>
<td>4 15/16</td>
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<td>84</td>
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<td>Span #5: Linseed Oil, Saw Groove</td>
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<td>Span #6: High Molecular Weight Monomer (with Sand), Saw Groove</td>
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<td>391 + 64</td>
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<td>391 + 28</td>
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<td>Span #7: High Molecular Weight Monomer (with Sand), Saw Groove</td>
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<td>77</td>
<td>74</td>
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<td>392 + 16</td>
<td>4 15/16</td>
<td>73</td>
<td>73</td>
<td>73</td>
<td>72</td>
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<td>Span #8: Linseed Oil, Saw Groove</td>
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<td>69</td>
<td>69</td>
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<tr>
<td>392 + 72</td>
<td>4 15/16</td>
<td>66</td>
<td>67</td>
<td>68</td>
<td>68</td>
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<td>68</td>
</tr>
<tr>
<td>392 + 94</td>
<td>5</td>
<td>67</td>
<td>68</td>
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<td>69</td>
<td>70</td>
<td>70</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Span #9: Calcium Nitrate, Saw Groove</td>
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<td></td>
<td></td>
<td></td>
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<td>393 + 12</td>
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<td>64</td>
<td>67</td>
<td>68</td>
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<tr>
<td>393 + 54</td>
<td>4 7/8</td>
<td>64</td>
<td>65</td>
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<td>67</td>
<td>67</td>
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<td>393 + 74</td>
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<td>64</td>
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</tr>
</tbody>
</table>

**SOURCE:** PROJECT 562 INTERIM CONSTRUCTION REPORT, 1986

**TABLE 3 BRITISH PENDULUM TESTER MEASUREMENTS**
Corrosometer Probe Voltage Measurements
(millivolts)

<table>
<thead>
<tr>
<th>Span #9</th>
<th>1</th>
<th>4</th>
<th>7</th>
<th>2</th>
<th>5</th>
<th>8</th>
<th>3</th>
<th>6</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaNO₃₉₂ (plain bar)</td>
<td>22.9</td>
<td>18.6</td>
<td>10.9</td>
<td>10.7</td>
<td>13.1</td>
<td>6.7</td>
<td>6.0</td>
<td>6.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Span #8</td>
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<td>7.4</td>
<td>5.8</td>
<td>8.3</td>
<td>5.2</td>
<td>13.8</td>
<td>14.1</td>
<td>14.9</td>
<td></td>
</tr>
<tr>
<td>Enamelled (plain bar)</td>
<td>7.4</td>
<td>7.4</td>
<td>5.8</td>
<td>8.3</td>
<td>5.2</td>
<td>13.8</td>
<td>14.1</td>
<td>14.9</td>
<td></td>
</tr>
<tr>
<td>Span #7</td>
<td>2.6</td>
<td>2.6</td>
<td>1.0</td>
<td>18.5</td>
<td>13.8</td>
<td>14.7</td>
<td>19.9</td>
<td>26.7</td>
<td></td>
</tr>
<tr>
<td>HMWM (plain bar)</td>
<td>2.6</td>
<td>2.6</td>
<td>1.0</td>
<td>18.5</td>
<td>13.8</td>
<td>14.7</td>
<td>19.9</td>
<td>26.7</td>
<td></td>
</tr>
<tr>
<td>Span #6</td>
<td>1.3</td>
<td>1.3</td>
<td>1.0</td>
<td>10.4</td>
<td>4.8</td>
<td>10.4</td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HMWM (plastic bar)</td>
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<td>1.3</td>
<td>1.0</td>
<td>10.4</td>
<td>4.8</td>
<td>10.4</td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Measurements made 4.15.86 by
original signed by David Hustace

David Hustace

SOURCE: PROJECT 562 INTERIM CONSTRUCTION REPORT, 1986

TABLE 4  CORROSMETER PROBE VOLTAGE MEASUREMENTS
2.2 SUBSEQUENT FINDINGS

1. Pavement Surface

Visual observation conducted on January 25, 1989 shortly after a light rainfall revealed numerous, but minor (in appearance) surface cracks. Under dry conditions, these cracks were not apparent. There was also no visible evidence of pavement wear. The methacrylate (with sand) surface especially appeared to be in excellent condition.

The SH 67 structure experiences traffic volumes of 1700 AADT. Based on the minimal traffic volumes and the visual observations noted, further surface friction tests were not scheduled.

The initial scope of the project (to determine potential loss of frictional resistance "after application") was, however, fully addressed in the interim report. The findings, as stated in Section 2.1.1, indicate that all surfaces had an adequate frictional level when opened to traffic.

2. Current Flow Measurements

Voltage and current measures taken subsequent to the Interim Report on September 23, 1986 are included in Tables 5A, 5B, 5C, 5D, and 5E, Voltage and Current Measurements. In virtually all instances, the recorded current flows indicated a transient condition where current values dropped over time and as with the initial readings of April 15, 1986, the values did not reflect decisive patterns. To emphasize the inconsistencies and variation in changes with time, a comparison (see Table 6) of the April and September readings is presented.

Based on these findings, there was minimal confidence in obtained values and in the established procedure.

On January 25, 1989, in a subsequent site investigation, it was apparent that the instrument boxes had been disturbed. Several resistors utilized during the initial readings were missing. Based on this finding and with the inconsistencies of previous values obtained, use of the test probes was not pursued in evaluating performance of the bridge deck protective systems.
Span #5 Linseed oil (epoxy bars)

<table>
<thead>
<tr>
<th>Milliamps</th>
<th>Parapet</th>
<th>Wheel Path</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 4 7 avg.</td>
<td>2 5 8 avg.</td>
<td></td>
</tr>
<tr>
<td>Initial*</td>
<td>6.9 12 15</td>
<td>19 16 23</td>
<td>14 - 17</td>
</tr>
<tr>
<td>@30 sec</td>
<td>3.4 5.6 7.3</td>
<td>10.5 9.6 12.0</td>
<td>7.7 - 9.2</td>
</tr>
<tr>
<td>Initial*</td>
<td>3.0 6.3 8.0</td>
<td>11.4 10.5 13.4</td>
<td>8.6 - 9.3</td>
</tr>
<tr>
<td>@1 min.</td>
<td>3.7 5.7 7.1</td>
<td>11.0 10.1 12.0</td>
<td>8.1 - 8.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Millivolts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial*</td>
</tr>
<tr>
<td>@30 sec</td>
</tr>
<tr>
<td>Initial*</td>
</tr>
<tr>
<td>@1 min.</td>
</tr>
</tbody>
</table>

*Note: initial current measurements all evidenced a substantial immediate drop from peak values.
Span #6 Methacrylate (epoxy bars)

<table>
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<th>Milliamps</th>
<th>Parapet</th>
<th>Wheel Path</th>
<th>Field</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>4</td>
<td>7 avg.</td>
</tr>
<tr>
<td>Initial*</td>
<td>26</td>
<td>51</td>
<td>-</td>
</tr>
<tr>
<td>@30 sec.</td>
<td>10.2</td>
<td>14.2</td>
<td>-</td>
</tr>
<tr>
<td>Initial*</td>
<td>22</td>
<td>47</td>
<td>-</td>
</tr>
<tr>
<td>@30 sec.</td>
<td>8.6</td>
<td>12.6</td>
<td>-</td>
</tr>
<tr>
<td>Initial*</td>
<td>23</td>
<td>46</td>
<td>-</td>
</tr>
<tr>
<td>@1 min.</td>
<td>6.3</td>
<td>9.6</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Millivolts</th>
<th>Parapet</th>
<th>Wheel Path</th>
<th>Field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8.9</td>
<td>20.6</td>
<td>-0.1</td>
</tr>
<tr>
<td></td>
<td>14.6</td>
<td>28.6</td>
<td>-0.1</td>
</tr>
<tr>
<td></td>
<td>18.2</td>
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<td></td>
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<td>38.0</td>
<td>-0.1</td>
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</tbody>
</table>

*Note: initial current measurements all evidenced a substantial immediate drop from peak values.

srm 39A

**TABLE 5B VOLTAGE AND CURRENT MEASUREMENTS**
Span #7 Methacrylate (plain bars)

<table>
<thead>
<tr>
<th>Milliamps</th>
<th>Parapet</th>
<th>Wheel Path</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 4 7 avg.</td>
<td>2 5 8 avg.</td>
<td>3 6 9 avg.</td>
</tr>
<tr>
<td>Initial*</td>
<td>2.7 1.7 3.0</td>
<td>- 7.0 3.5</td>
<td>5.5 14 -7.4 14</td>
</tr>
<tr>
<td>@30 sec.</td>
<td>1.5 0.5 0.8 2.4</td>
<td>- 2.2 1.1 1.7</td>
<td>1.6 7.1 - 4.4</td>
</tr>
<tr>
<td>Initial*</td>
<td>4.5 2.0 3.5</td>
<td>- 8.9 3.4</td>
<td>7.9 14 - 4.8</td>
</tr>
<tr>
<td>@30 sec.</td>
<td>2.1 0.5 0.8 1.1</td>
<td>- 2.6 1.1 1.9</td>
<td>1.8 7.8 - 4.8</td>
</tr>
<tr>
<td>Initial*</td>
<td>5.4 2.1 5.4</td>
<td>- 9.1 3.9</td>
<td>4.9 16.9 - 4.8</td>
</tr>
<tr>
<td>@1 min.</td>
<td>2.1 0.5 0.8 1.1</td>
<td>- 2.1 1.0 1.6</td>
<td>1.6 7.7 - 4.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Millivolts</th>
<th>Parapet</th>
<th>Wheel Path</th>
<th>C</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>7.9 3.1 3.5</td>
<td>-0.2 13.9 3.6</td>
<td>8.2 22.7 -0.3</td>
</tr>
<tr>
<td></td>
<td>8.0 3.2 3.5</td>
<td>-0.2 14.5 4.4</td>
<td>8.6 23.2 -0.3</td>
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<tr>
<td></td>
<td>8.2 3.3 3.8 5.0</td>
<td>-0.2 14.9 4.7 9.3</td>
<td>8.7 23.6 -0.3 15.8</td>
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*Note: initial current measurements all evidenced a substantial immediate drop from peak values.

srn-39B

**TABLE 5C  VOLTAGE AND CURRENT MEASUREMENTS**
Span #8 Linseed oil (plain bars)

<table>
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</tr>
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<td>Initial*</td>
<td>3.4 2.7 6.1</td>
<td>3.1 2.1 1.6</td>
<td>1.5 1.0 5.0</td>
</tr>
<tr>
<td>@30 sec.</td>
<td>2.0 1.0 2.7 1.9</td>
<td>1.3 0.6 0.6 0.8</td>
<td>0.5 3.4 2.6 2.2</td>
</tr>
<tr>
<td>Initial*</td>
<td>8.9 3.6 7.6</td>
<td>5.0 2.4 2.2</td>
<td>2.1 10.4 6.6</td>
</tr>
<tr>
<td>@30 sec.</td>
<td>3.5 1.3 3.1 2.6</td>
<td>1.9 0.7 0.6 1.1</td>
<td>0.6 4.1 2.9 2.5</td>
</tr>
<tr>
<td>Initial*</td>
<td>10.6 4.4 9.6</td>
<td>8.1 2.7 2.0</td>
<td>2.4 12.5 7.2</td>
</tr>
<tr>
<td>@1 min</td>
<td>3.0 1.2 2.9 2.4</td>
<td>1.8 0.7 0.6 1.0</td>
<td>0.6 3.8 2.7 2.4</td>
</tr>
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<td></td>
</tr>
<tr>
<td>17.2 6.9 10.9</td>
<td>11.5 5.0 3.4</td>
<td>3.5 16.8 7.4</td>
<td></td>
</tr>
<tr>
<td>17.6 7.1 11.3</td>
<td>11.8 5.1 3.6</td>
<td>3.6 17.3 8.2</td>
<td></td>
</tr>
<tr>
<td>17.9 7.3 11.6 12.0</td>
<td>12.1 5.2 3.7 6.8</td>
<td>3.6 17.8 8.7 9.7</td>
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</tr>
</tbody>
</table>

*Note: initial current measurements all evidenced a substantial immediate drop from peak values.*
Span #9 Calcium nitrate (plain bars)

<table>
<thead>
<tr>
<th>Milliamps</th>
<th>Parapet</th>
<th>Wheel Path</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 4 7</td>
<td>2 5 8 avg.</td>
<td>3 6 9 avg.</td>
</tr>
<tr>
<td>Initial*</td>
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<td>23 58 50</td>
<td>20.5 7.0 6</td>
</tr>
<tr>
<td>@30 sec.</td>
<td>20.9 25.1 5.7 17.2</td>
<td>10.8 28.3 21 20.0</td>
<td>7.1 2.7 2.4 4.1</td>
</tr>
<tr>
<td>Initial*</td>
<td>51 54 19</td>
<td>21 44 54</td>
<td>24 6.9 5.5</td>
</tr>
<tr>
<td>@30 sec.</td>
<td>22.3 23.9 5.2 17.1</td>
<td>10.8 27.9 22 20.2</td>
<td>8.0 2.5 2.2 4.2</td>
</tr>
<tr>
<td>Initial*</td>
<td>51 51 20</td>
<td>21 56 48</td>
<td>22 7.0 5.0</td>
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<tr>
<td>@1 min.</td>
<td>19.8 19.4 4.6 20.7</td>
<td>9.6 24.1 16.9 16.9</td>
<td>6.3 2.1 1.7 3.4</td>
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</tbody>
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<table>
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*Note: initial current measurements all evidenced a substantial immediate drop from peak values.
(5FT FROM PARAPET)  (-RT. WHEEL PATH-)  (DECK CENTER LINE)

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**TABLE 6 VOLTAGF COMPARISONS**

3. Retrievable Reinforcement Specimens

As previously noted, pavement surfaces for all decks appeared to be in satisfactory condition. Also, the interim report noted that only two separate deicing salt applications were made to the structure in the first year. As of January 25, 1989, only two additional applications had been made in the subsequent years. Three consecutive mild winters accounted for the limited deicing applications. Finally, as previously stated, the structure is being subjected to minimal traffic volumes (1700 AADT).

In regard to these findings, it was determined that removal of any of the retrievable reinforcement specimens (core samples) was premature, and therefore not pursued at the time.
SECTION 3
CONCLUSION

3.1 SUMMARY

As great efforts were taken in the planning and placement of numerous corrosometer probes, it is unfortunate that measured current and voltage values appeared to be unreliable.

This study has, however, concluded that proper application of linseed oil and high-molecular-weight methacrylate (with sand) surface dressings will not adversely affect surface friction.

While failure of the various protection treatments in regard to their ability to inhibit steel reinforcement corrosion is not evident at this time, the structures will need to be monitored for several more years, before final conclusions can be reached. It is recommended that core samples of the structure not be obtained for at least three years, unless visual disturbance is noted. These samples and samples taken beyond the three year period can continue to provide structural engineers with useful data in their analysis of steel reinforcement corrosion.

3.2 IMPLEMENTATION

Since additional observation of the structure is essential for deriving conclusive results, recommendations concerning the implementation of the protective systems used in this project cannot be made at this time.
Appendix A
STATE OF TEXAS
STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

PLANS OF PROPOSED
STATE HIGHWAY IMPROVEMENT

U.S. 87
HOWARD COUNTY
RAILROAD OVERPASS BRIDGE AT UNION PACIFIC
RAILROAD IN BIG SPRING
CATHODIC BRIDGE DECK PROTECTION

NO EQUATIONS
NO EXCEPTIONS
NO RAILROAD CROSSINGS

LAYOUT SCALE: 1 IN. = 100 FT.

Barricades Type B(3) with signs G20-1
G20-2, G20-4, G20-5 at each end of
the project. Signs CM010/101 G20-2 at
all city street intersections that are
open to traffic during construction.
GENERAL NOTES AND SPECIFICATION DATA

BEFORE BEGINNING WORK ON THIS PROJECT, THE CONTRACTOR SHALL SUBMIT, FOR APPROVAL BY THE ENGINEER, A PLAN OF CONSTRUCTION OPERATIONS OUTLINING IN DETAIL A SEQUENCE OF WORK TO BE FOLLOWED SETTING OUT THE METHOD OF HANDLING TRAFFIC. IF AT ANY TIME DURING THE CONSTRUCTION THE CONTRACTOR'S PROPOSED PLAN OF OPERATION IN HANDLING TRAFFIC DOES NOT PROVIDE FOR SAFE, COMFORTABLE MOVEMENT, THE CONTRACTOR SHALL IMMEDIATELY CHANGE HIS OPERATIONS TO CORRECT THE UNSATISFACTORY CONDITION.

THE CONTRACTOR'S ATTENTION IS HEREBY DIRECTED TO UTILITIES EXISTING IN OR NEAR THE WORK AREAS OF THIS PROJECT. ANY ACTIVE UTILITIES THAT ARE ENCOUNTERED BY THE CONTRACTOR SHALL IMMEDIATELY BE BROUGHT TO THE ATTENTION OF THE ENGINEER.

ANY WORKSITE OUTSIDE THE RIGHT-OF-WAY AND CLOSE ENOUGH TO THE HIGHWAY FOR ITS CONDITION TO ADVERSELY AFFECT THE VIEW FROM THE HIGHWAY SHALL BE LEFT IN A NEAT AND PRESENTABLE CONDITION ACCEPTABLE TO THE ENGINEER.

---ITEM 421---
THE ENGINEER WILL SAMPLE ALL CONCRETE AND MAKE AND TEST ALL TEST BEAMS AND CYLINDERS IN ACCORDANCE WITH TEST METHODS TEX-418-A AND TEX-420-A. ALL TEST HOLES WILL BE Furnished BY THE ENGINEER AND THE CONTRACTOR SHALL MAINTAIN THEM IN THE PROPER CONDITION. IN ADDITION, THE CONTRACTOR SHALL BE RESPONSIBLE FOR FURNISHING PERSONNEL TO REMOVE THE TEST SPECIMENS FROM THE HOLES AND TO TRANSPORT THEM TO THE PROPER CURING LOCATION AT THE SCHEDULE Designated BY THE ENGINEER AND IN ACCORDANCE WITH THE GOVEMING SPECIFICATION. FOR ALL CONCRETE ITEMS THE CONTRACTOR SHALL HAVE A WHEELBARROW, OR OTHER CONTAINER ACCEPTABLE TO THE ENGINEER, AVAILABLE TO USE IN THE SAMPLING OF CONCRETE. ALL LABOR AND EQUIPMENT Furnished BY THE CONTRACTOR WILL BE CONSIDERED SUBSIDIARY TO THE VARIOUS BID ITEMS AND WILL NOT BE PAID FOR DIRECTLY.

---ITEM 437---
HIGH RANGE WATER REDUCERS WILL BE USED ONLY TO MEET SPECIAL REQUIREMENTS AND WILL REQUIRE THE WRITTEN APPROVAL OF THE ENGINEER ON EACH SPECIFIC PROJECT. A SATISFACTORY WORK PLAN FOR CONTROL SHALL BE SUBMITTED BY THE CONTRACTOR FOR APPROVAL AND AN EVALUATION OF THE CONCRETE CONTAINING THE ADMIXTURE WILL BE PERFORMED BY THE ENGINEER.

---ITEM 446---
PAINt PURCHASED FROM THE DEPARTMENT WILL BE CHARGED AS FOLLOWS:
PROTECTION SYSTEM I PRIME COAT $63.08/5 GAL.
PROTECTION SYSTEM II PRIME COAT $24.39/1/4 GAL.

---ITEM 442---
NEW STRUCTURE STEEL ARMOR JOINTS SHALL RECEIVE PROTECTIVE SYSTEM 1.

---ITEM 512---
FOR THIS PROJECT THE STATE SHALL FURNISH 1415 FEET OF PORTABLE CONCRETE TRAFFIC BARRIER (PCTB) SECTIONS AND 2 TERMINAL SECTIONS, STOCKPILED ON 1 KM AT EAST HUARD FIELD ROAD, NEAR THE MITCHELL COUNTY LINE. UPON REMOVAL THE PCTB AND TERMINAL SECTIONS SHALL BE RETURNED TO THE STORAGE AREA. THE CONTRACTOR SHALL MAKE ARRANGEMENTS FOR THE LOADING AND UNLOADING OF THE PCTB AT THE STORAGE AREA.

ITEM 518---
ALL CONDUIT RUNS CROSSING THE BRIDGE SHALL BE SECURELY ATTACHED TO THE SUBSTRUCTURE OF THE BRIDGE. CLAMPS EQUIVALENT TO APPEIIPON CH-5051(2-3/4") AND CH-12551(4") SHALL BE USED. THE NUMBER OF CLAMPS REQUIRED IS THEIR SPACING SHALL BE DETERMINED BY THE ENGINEER. THIS WORK SHALL NOT BE PAID FOR DIRECTLY. BUT SHALL BE CONSIDERED AS SUBSIDIARY TO ITEM 4642, "CATHODIC BRIDGE DECK PROTECTION SYSTEM".

---ITEM 644---
IF ABBREVIATED PAVEMENT MARKINGS ARE NEEDED FOR TEMPORARY ALIGNMENT ON ON A FINAL SURFACE, THESE MARKINGS SHALL BE APPLIED IN A MANNER THAT WILL ALLOW EASY AND COMPLETE REMOVAL WITH NO UNDUE INJURY TO THE FINAL SURFACE.
YELLOW ABBREVIATED PAVEMENT MARKINGS SHALL BE USED TO SEPARATE TRAFFIC FLOW IN OPPOSITE DIRECTIONS. WHITE ABBREVIATED PAVEMENT MARKINGS SHALL BE USED TO SEPARATE TRAFFIC FLOW IN THE SAME DIRECTION.

---ITEM 676---
BITUMINOUS ADHESIVE SHALL BE USED ON THIS PROJECT.

---ITEM 9003---
SURFACE TEXTURE AND SURFACE TEXTURE TESTS WILL NOT BE REQUIRED.

---GENERAL---
ALL PAVEMENT MARKING SHALL BE IN ACCORDANCE WITH THE M.U.T.C.O.

---ITEM 4685---
A 90 DAY TEST PERIOD IS REQUIRED AFTER INSTALLATION OF THE CATHODIC PROTECTION SYSTEM IS COMPLETED.
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SECTION THRU FINGER JOINT
AT BENT 4

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SECTION THRU ARMOR JOINT
AT ABUTMENTS 1 AND 7

PROPOSED ARMOR JOINT ELEVATION

ARMOR JOINT CONNECTION DETAIL

STIFFENER DETAIL

BRIDGE DETAILS

Show of E
TRAFFIC BUTTONS (NON-REFLECTORIZED)

TOP VIEW

TRAFFIC BUTTONS

PAVEMENT MARKERS (REFLECTORIZED)

NOTE

ALL DIMENSIONS ARE 6. W" UNLESS OTHERWISE SHOWN

GENERAL NOTES:

THE PAVEMENT UPON WHICH THE TRAFFIC BUTTONS, PAVEMENT MARKERS, ADHESIVE TILES, ADHESIVE TILES & BAR TILES ARE TO BE PLACED SHALL BE PREPARED SUBJECT TO THE APPROVAL OF THE ENGINEER TO ENSURE PROPER CLEANING OF THE PAVEMENT SURFACE. IPMS SHALL BE APPLIED TO THE PAVEMENT SURFACE WITH ADHESIVE CONTAINING WITH A SPECIFIED STRENGTH.

SPECIAL NOTE:

THE PAVEMENT UPON WHICH THE TRAFFIC BUTTONS, PAVEMENT MARKERS, ADHESIVE TILES, ADHESIVE TILES & BAR TILES ARE TO BE PLACED SHALL BE PREPARED SUBJECT TO THE APPROVAL OF THE ENGINEER TO ENSURE PROPER CLEANING OF THE PAVEMENT SURFACE. IPMS SHALL BE APPLIED TO THE PAVEMENT SURFACE WITH ADHESIVE CONTAINING WITH A SPECIFIED STRENGTH.

ADHESIVE TILES & BAR TILES SHALL ALSO BE PLACED AT EACH OTHER LOCATIONS AS DIRECTED BY THE ENGINEER. ADHESIVE TILES & BAR TILES SHALL ALSO BE PLACED PERPENDICULAR TO THE ROADWAY.

ADHESIVE TILES & BAR TILES ARE FOR ILLUSTRATION PURPOSES ONLY. THEY ARE NOT INTENDED TO SPECIFY ANY PARTICULAR PRODUCT.

1. TYPE OF PAVEMENT MARKINGS REFLECTORIZED PERMITTED ON THIS PROJECT IS AT THE CONTRACTOR'S OPTION

2. ALL PAVEMENT MARKINGS PROVIDED SHALL BE OF THE SAME MANUFACTURER.
UPDATE NO. 7

ALL INDIVIDUAL UNIT MARKINGS PLACED IN DASHED LINES SHALL BE PLACED IN LINE WITH AND HORIZONTAL TO THE STREETS.

PRINT AND LEFT INDIVIDUAL UNIT MARKINGS IN MIRROR IMAGE ON THE CENTERLINE MARKING OF THE LEFT SHOULDER OF THE STREETS.

BUTTON MARKINGS FOR CENTER LINES AND LANE LINES MAY BE 2 FEET IF DIRECTED BY THE ENGINEER.

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

INDIVIDUAL UNIT PAVEMENT MARKINGS USED TO SIMULATE STANDARD PAVEMENT MARKINGS FOR CENTER LINES AND LANE LINES

PM(3)

- SOLID LINE

- SKIP LINE

PATTERN DETAIL
The plan shown above is to be used when local traffic is permitted through project or permitted to use the road around the construction and new temporary roads. Other signs and barricades Types A & B may be required under the project being opened upon the contractor's issuance of work and other conditions.

Where conditions will permit, minimum length of barricade on each side of roadway shown is 12 feet.

Type I or II barricades (see Sheet BC-3) are for temporary use in normal traffic. Use these in areas where it is necessary to control traffic in a specific area between some particular points.

Type III barricades have more restrictive uses. They are intended to use on temporary and temporary or other type road.

Type IIA barricades and accompanying signs are to be used in each end of construction projects shown in this drawing or before.

Type III B barricades and accompanying signs may be used at all ends of construction projects shown in this drawing.

Type III B barricades and accompanying signs may be used at the ends of construction projects shown in this drawing.

There is a minimum length of 12 feet required on each side of roadway shown is 12 feet.

GENERAL NOTES FOR TYPES I, II & III BARRICADES

1. Type I or II barricades are to be used where local traffic is permitted through the project or permitted to use the road around the construction and new temporary roads. Other signs and barricades Types A & B may be required under the project being opened upon the contractor's issuance of work and other conditions.

Type III barricades have more restrictive uses. They are intended to use on temporary and temporary or other type road.

Type IIA barricades and accompanying signs are to be used in each end of construction projects shown in this drawing or before.

Type III B barricades and accompanying signs may be used at all ends of construction projects shown in this drawing.

Type III B barricades and accompanying signs may be used at the ends of construction projects shown in this drawing.

There is a minimum length of 12 feet required on each side of roadway shown is 12 feet.

GENERAL NOTES FOR TYPES I, II & III BARRICADES

1. Type I or II barricades (see Sheet BC-3) are for temporary use in normal traffic. Use these in areas where it is necessary to control traffic in a specific area between some particular points.

Type III barricades have more restrictive uses. They are intended to use on temporary and temporary or other type road.

Type IIA barricades and accompanying signs are to be used in each end of construction projects shown in this drawing or before.

Type III B barricades and accompanying signs may be used at all ends of construction projects shown in this drawing.

Type III B barricades and accompanying signs may be used at the ends of construction projects shown in this drawing.

No dimensions of barricade panels see Sheet BC-3.

NOTES:
1. Where possible, reflective capability is provided, and barricades may be used throughout the project.
2. On highways or roads with speed limits of 35 mph or less, Type II barricades may be used in lieu of temporary or other signs necessary for protection.
The Advance Warning Flashing Arrow and Sequencing Arrow Panels are intended to supplement existing traffic control devices. They provide additional advance warning and directional information to motorists moving through construction or maintenance activities being conducted on or adjacent to the traveled way.

The Advance Warning Panel may be used for two or more consecutive advance warning panels to serve as permanent, temporary or auxiliary signs on the traveled way, or extremely hazardous high density and speed conditions.

The Sequencing Arrow Panel may be used for temporary high density and speed conditions.

The Advance Warning Panel may be used in conjunction with the Advance Warning Arrow Panel.}

Arrow panels should be placed at the beginning of a curve or ramp. It should be preceded by an appropriate curve sign when required.

**TYPICAL ILLUSTRATION OF SIGNING FOR A CURVE**

**TYPICAL ILLUSTRATION OF SIGNING FOR A TURN**

**USAGE OF CWI-6, CWI-6A, AND CWI-8 SIGNS**

Notes:
- CWI-6, CWI-6A, and CWI-8 signs may be mounted on temporary appurtenances.
- CW-6A Alignment signs, when used, should be placed on the traveled way of a curve, ramp, or on the side of a roadway.
- CW-6B and CW-6C signs are used to supplement the alignment signs to provide additional information.
- For temporary traffic, the same arrangement of signs on a pedestal of curve for each direction of travel.
- Appropriate Advance Warning Turn or Curve signs with Associated Speed Signs should be used when required.
Appendix B
I. JOB DESCRIPTION: Five impressed current cathodic protection systems will be installed on the U.S. 87 overpass in Big Spring, Texas in Howard County. There shall be 5 separate systems. Each system will utilize a different type of anode material. These five systems shall be further sub-divided into zones. Each zone shall be separately energized from an enclosed rectifier assembly.

A. Terms and definitions

Resident Engineer: The representative of the state who shall have the final decision in all matters concerning this job.

Contractor: The company or business that this job is awarded to.

Cathodic Protection Engineer: A professional Engineer supplied by the contractor who shall be licensed and fully accredited in the area of bridge deck cathodic protection systems. (The Cathodic Protection Engineer shall assist the Resident Engineer in all aspects of the complete cathodic protection installation).

Manufacturer: The company that manufactures the anode material used in each system.

Technical Representative: A representative chosen by each anode material manufacturer to assist in the installation of the represented material.

B. General Information

1. Material suppliers should attend the pre-letting conference at the Resident Engineer’s office in Big Spring on September 16, 1987 at 10:00 a.m.

2. The contractor shall furnish, install, and put into operation five complete impressed current cathodic protection systems as described in these plans and specifications. The contractor shall have a technical representative qualified in the field of Cathodic Protection of bridge decks to supervise the installation, energizing and adjusting of the complete systems.
3. The contractor shall have a technical representative from each manufacturer of the anode materials used in traffic lanes to advise in the installation of the represented material.

4. The contractor shall coordinate installation of the cathodic protection systems with all other construction operations. Special caution and scheduling may be required to prevent damage to installed components by subsequent operations.

5. The contractor shall contact the Resident Engineer prior to installing each system.

6. The contractor shall hold a preconstruction conference with the subcontractors installing the cathodic protection systems at least seven days before the installations. The Resident Engineer, Cathodic Protection Engineer, and the cathodic protection system manufacturer's representative(s) shall be present at the conference.

7. The cathodic protection systems shall include all the materials identified in these plans and specifications. Substitutions may be made only with the written permission of the Resident Engineer.

7. The cathodic protection systems shall be of the impressed current type and shall consist of the following:

   a. Direct current power supply (rectifier) with at least seventeen (17) separate voltage and current regulated outputs meeting the requirements of the plans and specifications.

   b. Seventeen (17) zones of cathodic protection consisting of five different types of anode material meeting the requirements of the plans and specifications.

   c. A negative ground return (cathode) wiring system connected to the reinforcing bars as described in these plans.

   d. Bonding of the following to the reinforcing bars:

      (1) armor joints (2) guard rail supports (3) dowel bars used to connect adjacent deck slabs (4) steel diaphragms and girder supports under or contacting a cathodically protected member (5) illumination poles, clamps, conduit, electrical enclosures, supports or metallic members in contact with a cathodically protected member.

   e. Reference cells in each zone with continuous lead wires terminating at rectifier enclosure.

9. The electrical installation shall in all applicable ways conform with the National Electrical Code and all local codes.
10. The contractor shall arrange for power service and the connection to the system. The contractor shall arrange for all inspections and obtain all necessary permits.

11. The contractor shall furnish all material to the Resident Engineer for inspection and samples for testing when specified or requested. The Resident Engineer may accept material on the basis of the manufacturer's certification when testing is performed by a qualified independent laboratory. A copy of the independent laboratory report documenting the test results and testing procedures shall accompany the certification. The Engineer may accept or reject these materials on the basis of these certifications or other tests performed by or for the Department.

12. SPECIAL NOTE:

THE RESIDENT ENGINEER SHALL BE INFORMED OF ANY FUTURE SLAB WORK OR EQUIPMENT MOUNTING ON THE NEW OVERLAY SURFACE. CONCRETE CHIPPINGS, HOLE DRILLING OR CORING, DETECTOR LOOP SAWCUTTING AND OTHER SUCH OPERATIONS MUST NOT BE PERFORMED UNLESS THE ENGINEER HAS BEEN CONSULTED.

13. The Contractor shall purchase the following instruments for use by State personnel for taking measurements of the performance of the various cathodic bridge deck protection systems being installed on the bridge structures:

Portable "Three Electrode Linear Polarization Rate of Corrosion Device", complete package with single portable probe and twenty (20) permanent probes.

The device purchased shall include training for at least three personnel into the operation and use of the device and any related computer programs.

Currently the only known portable device of this type is a "3LP" unit made by Ken Clear, Inc. The permanent probes to be used with this unit are "3LP" permanent probes and must be installed according to the manufacturer's specifications. Complete package by Ken Clear, Inc. is as follows:

(1) Three Electrode Linear Polarization Device (Portable)
(2) PC-8 Pocket Computer with Printer
(3) "Corrate II" Program for use on IBM PC
(4) Single Portable Probe
(5) Permanent Probes as Required
(6) Training for Personnel

Two permanent probes shall be provided by the Contractor in each zone on the bridge deck traffic lanes. A total of twenty (20) permanent probes will be provided by the Contractor for the complete cathodic protection installation.

Two areas per zone will be provided for portable rate of corrosion measurements in zones not in the traffic lanes. These measurement areas consist of locations on the sidewalks, median and on a bent below the bridge deck.
II. Structural Integrity of Bridge

A. After scarification of the deck surface, the contractor shall verify that the concrete surface is sound. The contractor shall correct unsatisfactory conditions before continuing with the installation of the cathodic protection systems. The Resident Engineer will determine that the structure is sound and has been prepared according to specification.

B. Removal of concrete will be necessary to:

1. Expose the top and bottom (or outer and inner) rebar mats for continuity testing
2. Install reference electrodes
3. Install instrument and system negatives
4. Install rebar bonds
5. Install rebar probes
6. Install "3-LP" probes

C. The contractor shall be responsible for the physical concrete removal and bar exposure. The contractor shall ensure all exposed steel is cleaned to bare gray metal and all debris is removed from the cavities.

D. The reference electrodes, rebar probes, instrument negative and system negative installation cavity shall be located within ten (10) feet of the location marked on the drawings, or as determined by the Cathodic Protection Engineer and approved by the Resident Engineer. An existing cavity from delamination removal may be used if approved by the Cathodic Protection Engineer and Resident Engineer.

E. The contractor shall be responsible for proper repair of all concrete of the bridge structure. An anode system will not be installed until repairs have been completed on the area of installation.

III. Rebar Preparation and Connections

A. The contractor shall have the responsibility of making sure that the entire bridge structure has been made electrically continuous.

B. Following the continuity survey and before any anode materials are installed, it is the responsibility of the contractor to ensure that all conduits, signs, markings, drains, and other embedded or surface mounted metallic fixtures within the area of protection are electrically continuous with the reinforcing steel.

1. Rebar bond wiring is not shown in the plans. Rebar bond wiring shall be installed as directed by the Cathodic Protection Engineer and approved by the Resident Engineer.
2. REBAR BOND WIRES SHALL BE COPPER WIRE WITH WHITE INSULATION. WHITE INSULATED WIRE MAY NOT BE USED FOR ANY OTHER CONNECTIONS. (Except where local electrical codes specify otherwise.)

3. Wherever possible the bond wires shall be thermite brazed to the rebar or metallic fixtures. Where this is not possible the bond shall be established as directed by the Cathodic Protection Engineer and approved by the Resident Engineer.

4. Rebar bonds shall be made to reinforcing bars having no more than 5% section loss at the connection location.

5. Rebar bond wires do not have to be labeled except for the wires within the rectifier enclosure.

6. The length of the bond wire shall be kept to a minimum.

7. Bond wiring shall be well secured to the structure using cable ties.

8. Bond wires shall be anchored within six (6) inches of their termination (thermite braze).

9. Bond wires may not be spliced.

10. All reinforcing steel lead wire and other metal to metal permanent lead wire connections, except those in the junction boxes and rectifier enclosure shall be made using the thermite welding process in accordance with the manufacturer's instructions.

11. The discontinuous objects must be connected (bonded) to a rebar which is electrically continuous with the rest of the structure using copper wire with white insulation.

12. All mats not electrically connected shall be connected together using copper wire and thermite bonding.

13. A discontinuous rebar or metallic fixture shall be bonded to a nearby continuous rebar.

14. Bonding shall be provided for all of the following to the reinforcing bars:
   a. Armor joints
   b. Guard rail supports
   c. Dowel bars used to connect adjacent deck slabs
   d. Steel diaphragms and girder supports under the deck or other structures contacting a cathodically protected member
8. Each reference cell lead wire and corresponding instrument negative lead wire shall be brought through a 1/2 inch diameter hole drilled in the deck. The hole shall be filled with a non-conductive epoxy approved by the Engineer.

9. The reference cells shall be positioned as determined by the Cathodic Protection Engineer and approved by the Resident Engineer. The reference cells shall be located within one (1) inch, but not in direct contact with top-mat reinforcing steel.

10. Each reference cell shall be cast in an air-entained portland cement concrete patch with a chloride content about equal to that of the surrounding concrete and a water-cement ratio of about 0.50.

11. Rebar probes shall be installed by the contractor as necessary.

V. Wiring

A. The contractor shall be responsible for installation of all wiring concerning the five cathodic protection systems, system negatives and related instrumentation.

B. The Cathodic Protection Engineer shall consult each of the anode material manufacturers and prepare a complete wiring diagram subject to the Resident Engineer's approval. All wiring changes made during the project shall be documented and subject to the Resident Engineer's approval.

1. Wiring shall run according to plans prepared by the Cathodic Protection Engineer and approved by the Resident Engineer.

2. All wires shall be properly labeled. Labels used shall have a long life expectancy and be resistant to destruction by insects local to the region. Each label used shall not easily separate from the wire that it has been attached to.

3. Wiring shall be run in conduit or saw cuts as determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

4. Wiring run in saw cuts shall be fastened down every twenty (20) feet.

5. Wiring connected to reinforcing steel shall be securely anchored to the rebar with a cable tie within six (6) inches of the thermite braze.

6. Care shall be taken during cathodic protection system installation and concrete overlay installation to avoid damaging the wiring.

7. Any damaged wiring shall be repaired or replaced as directed by the Cathodic Protection Engineer prior to placing the concrete overlay. All repaired or replaced wiring shall be documented and approved by the Resident Engineer.
e. Illumination poles, clamps, conduit, electrical enclosures, supports or metallic members in contact with a cathodically protected member.

C. All wire to rebar connections shall be made using thermite brazing techniques unless otherwise directed by the Cathodic Protection Engineer and approved by the Resident Engineer.

1. Specific attention shall be directed to the processes of connecting lead wires to reinforcing steel and other metallic components.

2. Each project thermite weld shall be made to the satisfaction of the Resident Engineer and may be hammer impact tested.

3. Slag from the thermite weld operation shall be removed and the weld approved by the Resident Engineer before a coating is applied.

4. All thermite brazing connections shall be coated with a non-conductive epoxy as directed by the Cathodic Protection Engineer and approved by the Resident Engineer.

IV. Reference Cells

A. The contractor shall install reference cells in each zone. Locations for reference cells are to be determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

1. At least one reference cell shall be installed in each zone in an area of high chloride content.

2. Reference cells shall be silver-silver chloride furnished in an ion trapping, chloride rich backfill or equal approved by the Resident Engineer.

3. The reference cell assembly shall be approximately five (5) inches long and one (1) inch in diameter.

4. The reference cells shall not be placed in direct contact with reinforcing steel or other metallic embedments.

5. The reference cell lead wires shall be No. RG-58U coax-cable or approved equal. The lead wires shall be continuous from the reference cell to the rectifier enclosure.

6. An instrument negative lead wire will be attached to the reinforcing steel by a thermite weld not more than twelve (12) inches from the cell location, coated with non-conductive epoxy. No splices shall be allowed in the instrument negative lead wire.

7. Instrument negative lead wire shall be made only to reinforcing bars having no more than 5% section loss at the connection location.
8. Wiring shall be spliced only at locations determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

9. All direct current and instrumentation conduit shall be PVC. PVC conduit size shall be 1.5 inch inside in diameter for all runs except as otherwise designated in the plans.

10. All PVC used on the project shall be Polyvinyl-chloride (PVC) conduit conforming to NEMA TC-2, Schedule 40.

11. PVC conduit expansion and contraction sections shall be placed at all appropriate locations and not to exceed 75 feet apart. These sections shall provide at least 4 inch of movement.

12. Rectifier power supply (AC) shall be run in Galvanized Rigid Steel conduit (RSC) which conforms to ANSI C 80.1 and bears the U.L. Label. RSC conduit size shall be 1 inch diameter with RSC fittings unless otherwise determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

13. All components of conduit hangers and clamps shall be made of stainless steel or galvanized steel approved by the Engineer. Conduit clamps for PVC conduit shall permit movement of the conduit and shall be placed at 4 foot maximum spacing.

14. CARE SHALL BE TAKEN TO MAKE SURE THAT CONDUIT HANGERS AND CLAMPS DO NOT CAUSE SHORT CIRCUITS WITHIN THE CATHODIC PROTECTION ZONES.

15. All connections and splices shall be made in junction boxes approved by the Resident Engineer.

16. All wires within junction boxes shall be properly labeled.

17. Junction boxes shall be constructed of the same material as joining conduit, of sufficient size to house wiring and splices and shall be sealed against entry by nest building insects and have provisions to prevent water retention.

18. All wires within the rectifier enclosure shall be properly and thoroughly labeled.

19. All conduit shall enter the rectifier enclosure from the bottom with provisions for drainage of conduit water at a level beneath the rectifier. The drainage site shall be sealed against entry by nest building insects.

B. Size of wire to be used will be determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

C. All wiring shall conform to the following specifications for color, minimum size and insulation type.

1. White = Cathode leads for System negative and Rebar bond wiring.
a. Minimum 8 AWG stranded copper
b. Type HMWPE on the deck or within structures
c. Type XHHW or approved equal below deck to the rectifier inclosure

2. Red = Anode leads
   a. Minimum 8 AWG stranded copper
   b. Type HMWPE on the deck or within structures
   c. Type XHHW or approved equal below deck to the rectifier inclosure

3. Brown = Reference cell rebar grounds
   a. Minimum 14 AWG stranded copper
   b. Type HMWPE on the deck or within structures
   c. Type XHHW or approved equal below deck to the rectifier inclosure

4. Black = Reference cell lead wires and rebar probe lead wires
   a. RG-58U or equivalent

5. Green = Rectifier cabinet ground
   a. Minimum 4 AWG
   b. Type XHHW or approved equal

D. Color code for AC line power shall be per all applicable National and Local codes.

VI. Rectifier Specifications

A. The contractor shall locate the rectifier enclosure in an area accessible to maintenance personnel.

B. The rectifier enclosure shall be attached to a controller box support as shown in the plans.

C. The contractor shall take care to avoid damaging the rectifier. Any damage caused by the contractor's operations shall be repaired at the contractor's expense.

D. The contractor shall connect the rectifier as determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

1. All wiring shall be fully documented. A copy of the final wiring diagram with all corrections noted shall be stored in the rectifier enclosure for future reference by maintenance personnel.

E. The rectifier shall conform to the following specifications:
1. The rectifier shall be suitable for cathodic protection of a bridge. It shall operate from 120/240 VAC single phase 60 Hz mains and provide seventeen (17) independent and individually controlled outputs for connection to seventeen (17) independent anode zones.

2. The unit shall be designed for a 20 year minimum working life under continuous operation. The unit shall be convection cooled with no fans or moving parts and shall operate at full capacity in ambient temperatures from 0 degrees F to 110 degrees F.

3. Each zone shall be controlled independently using modular DC controllers.
   A. Output DC controllers shall be of modular plug in construction for simple field replacement.
   B. Each module shall be removed and replaced from the front of the rectifier enclosure.
   C. Each module shall have a method of current limiting which does not require manual resetting.
   D. Each module shall be independently controlled.
   E. Output adjustment of one circuit must not effect the output of any other module and must be continuous over the entire rated range of output current.
   F. Each module shall be capable of supplying continuous full-rated output at temperatures from 10 F to 140 F.
   G. Each module shall be air cooled by natural convection.
   H. Each module shall be provide with lightning protection separate from AC power lightning protection.
   I. The rectifying elements shall be silicon diodes. The diodes shall be protected against high voltage surges with metal oxide varistors.
   J. The peak inverse voltage rating of the SCR's shall be no less than 600 volts. Protection.
   K. Following assembly of the modules, each module shall have been individually tested over the full range of its rated current to insure proper operation. The card shall then be coated with a heavy coating of Dow Corning 2577 or equivalent conformal coating.

4. An LCD meter coupled with suitable switching arrangement shall be provided to monitor DC voltage, current, structure to electrolyte and rebar to probe potentials. A power on/off switch shall be provided to remove AC power from the meter when it is not in use. Meter jacks shall be provided which enable all readings to be taken using a portable handheld meter.
5. An AC circuit breaker shall be provided. It shall be of the manually reset type.

6. The state of the AC circuit breaker shall be indicated by a light visible from outside the enclosure that can be seen from traffic lanes on the bridge.

7. Protection against lightning surges shall be provided to protect against 1) AC line to ground overvoltage, 2) ground to structure overvoltage, and 3) structure to anode overvoltage.

8. A service manual shall be provided with each unit which explains operation, operating principles, maintenance, installation, and schematics.

9. The rectifier shall be equipped with compression type connectors for all positive and negative output cables and be sized for up to No. 6 AWG wire.

10. Acceptable line input voltage shall be 120 VAC or 240 VAC ±10% -5%, 60 HZ, single phase.

11. The instrument panel shall be clearly labeled as to the functions it performs.

12. All switches and instruments shall be clearly labeled as to their functions.

13. A light shall be provided which is easily visible from the traffic lanes. This light shall indicate the status of the AC circuit breaker within the rectifier assembly. The light shall be armor encased for protection from vandalism.

F. Rectifier Enclosure

1. The enclosure shall meet all the requirements of NEMA STANDARD MR-20-1958, "CATHODIC PROTECTION RECTIFIER UNITS".

2. The enclosure shall be NEMA 4 water tight and dust tight with conduit access in the bottom to accommodate AC and DC wiring.

3. The enclosure shall have a front opening door.

4. Provisions for padlocking shall be provided.

5. The rectifier cabinet shall be constructed of one of the following materials or equal approved by the Resident Engineer:

   A. One-eighth inch aluminum sheet (5052-H32) and one-quarter inch aluminum back panel or

   b. Minimum 11 gauge galvanized steel and coated with white baked on enamel.
6. A grounding lug for connecting No. 4 AWG wire to earth ground shall be provided on the enclosure exterior.

7. All components shall be mounted on the back panel easily removable through the front opening door.

8. Mounting bolt holes shall allow for 3/8" diameter bolts.

9. A hinged door with over-center latches and locking hasp shall be provided. A neoprene gasket 1/5" thick and 1" wide shall seal the door opening against moisture and dust. When closed, the door shall form a dust tight, water tight closure and shall be equipped with lift off type hinges providing easy removal of the door for access to internal components.

10. Each rectifier shall have provisions for permanent storage of the manual, schematic, and system wiring diagram in the door of the rectifier.

11. The cabinet and door shall be essentially "square and true" such that the door does not sag when opened and does not require force when opening or closing.

12. The cabinet shall be equipped with panel support brackets with hinges and panel stops which are of sufficient strength to support the instrument panel in both the closed and open positions.

13. All welds and sharp edges shall be completely deburred and rounded.

C. Transformers

1. Power transformers shall provide rated output over the full range of input voltages, be of E-I laminated construction to provide isolated secondary voltages appropriate for circuit operation, and have independent primary and secondary windings. Adjustment of output by tap bars is not acceptable. Varnish impregnation and Faraday shield between primary and secondary must be provided. Transformer efficiency shall be at least 95% and the regulation shall not exceed 3% when measured from 1/4 to full load.

2. Control transformers for module power shall be of E-I lamination construction and shall have primary power supplied from the power transformer secondary for line surge isolation.

H. Filter Chokes

1. Filter chokes of E-I lamination or other suitable core construction shall be used in each rectifier output circuit to:  

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a) Improve efficiency

b) Provide some surge protection from transients externally generated

c) Provide full output current capability at low output voltage

d) To reduce R.F.I. in the load circuit.

I. Circuit Breaker

1. A two (2) pole fully magnetic circuit breaker shall be provided as an input power switch and for protection to the line against rectifier fault.

2. The breaker shall be rated for 240 volt AC.

3. The breaker must hold 101% rated current and must trip at 125% of rated current.

J. Meter

1. Metering shall be provided for monitoring the operating current, operation voltage, and reference electrode potentials.

2. A 3 1/2 digit L.C.D. (Liquid crystal display) meter with 200 MV 2000 count sensitivity shall be provided to take readings.

2. The meter shall have input impedance sufficiently high to cause no appreciable (1 micro amp max) loading of circuits connected to it such as sensitive half cell.

3. Appropriate scaling and switching circuits shall be provided to give direct meter displays in amperes and volts.

4. Structure potentials shall be displayed in volts up to 1,999 either positive or negative with respect to the half cell.

5. The meter shall have the capability of being removed from the circuit when readings are not being taken.

6. The meter shall have the capability of monitoring reference electrodes when the rectifier is shut off.

K. Wiring inside the enclosure

1. Wiring shall be sized for a minimum of 500 CM/ampere for power circuits and No. 28 AWG minimum for signal circuits.

2. Power wires shall have 600 volt insulation and be stranded copper wire such as MTW or similar.

3. Wires shall be neatly bundled, tied and clamped as necessary to provide a clean neat appearance.
4. Signal wires shall be stranded copper and routed separately from power leads wherever possible.

5. All wiring shall be of sufficient length to avoid tension at terminal connections.

6. All connections either electrical or mechanical shall be tightly secured with lock washers.

7. Any electrical connection through the instrument panel shall not rely on pressure to the panel to maintain good connection.

L. Cable Entry

1. All wiring shall enter through the bottom of the cabinet.

2. AC INPUT AND DC OUTPUT BE KEPT SEPARATE.

3. Reference cell leads shall be kept separate from all other anode and cathode wiring.

M. Complete Rectifier Dialectric Test

The insulation and spacings of a rectifier unit shall be capable of withstanding without breakdown, for a period of one minute, the application of a 60 cycle alternating-current rms voltage of 1000 volts plus twice the rated primary voltage between current-carrying parts of the primary circuit and (1) non-conductive-carrying metal parts which may be grounded and (2) current-carrying metal parts of an insulated secondary circuit. When operating below 60 volts, an insulated secondary circuit shall be capable of withstanding an alternating-current rms test voltage of 600 volts to any non-current-carrying metal parts which may be grounded; when operating within the range of 60 to 90 volts, the alternating-current rms test voltage shall be 900 volts.

If the rectifier unit includes devices which normally fall within the scope of other recognized standards requiring dielectric test voltages lower than the foregoing, such devices shall be disconnected before the remainder of the equipment is subjected to the test. The disconnected devices shall be tested separately for dielectric strength in accordance with the applicable standards.

N. Circuit Operation Test

Each circuit shall be tested to insure that all of its components are properly interconnected and function normally at 5% low and 10% high AC input line voltage. The unit shall then be tested with all circuits energized and operating at rated output current to insure normal operation at 5% low and 10% high input line voltages. If the rectifier is designed for more than one input line voltage, the test shall be run at each.
With all circuits energized, an adjustment of one or more of the circuits' output current shall not effect any of the other circuits' output amps. Any circuit must be able to be adjusted over its full range without changing the output of any other circuit.

V. Current Regulation

The current regulation of each circuit shall be checked and shall not exceed ±1% when the load resistance is varied between 0 and rated load resistance. The current regulation of the entire unit with all circuits energized shall not exceed ±1% when the total load resistance is varied between 0 and total rated load resistance.

VII. Post Installation Tests

The contractor shall be responsible for performing the following tests as detailed in this specification and will be required to document results, procedures and train at least three State employees to conduct subsequent required tests as directed by the Resident Engineer.

A. E log I tests shall be performed prior to system energizing at each of the reference locations in each zone. The data shall be plotted and explanations of the data shall be provided to State personnel. The system will be adjusted based on this data.

B. Two sets of polarization tests shall be performed by the contractor and adjustments made if the system is not within a minimum of 100 millivolts to a maximum of 150 millivolts range.

1. The first set of tests shall be performed after 45 days of continuous system operations. Adjustments to the system shall be made as necessary by the contractor and explanation of the adjustments shall accompany the data.

2. The second set of tests shall be performed after 90 days of continuous system operations. Adjustments to the system shall be made as necessary by the contractor and explanation of the adjustments shall accompany the data.

C. Rate of corrosion tests shall be performed by the contractor prior to system energizing and upon each depolarization test. The rate of corrosion test shall be performed for each of the two areas per zone. The data from these tests shall be documented and analyzed using the Corrate II computer program.

VIII. System "A"

A. This system shall utilize an anode of expanded titanium metal mesh anode as manufactured by Eltech or equivalent. The installation will be on the bridge deck main lanes between Station 8+18.49 and Station 10+24.62.
B. Zones

There shall be four separately energized zones in this system. The areas of coverage for these zones shall be determined by the anode manufacturer's representative and approved by the Resident Engineer.

C. General Information

1. Traffic on the Deck

After installation of the anode strands, traffic on the deck shall be limited to vehicles required for delivery and installation of the overlay. Recesses or grade changes of greater depth that one (1) inch must be temporarily bridged for vehicles with gross vehicle weight greater than two (2) tons.

2. Gasoline and Oil on the Deck

When cathodic protection material are exposed, the contractor shall ensure that gasoline and oil do not drip onto the cathodic protection materials from equipment being used. Refueling and servicing of the equipment shall be performed off any deck covered with exposed anode materials.

3. Installation

a. Anode material installation shall not begin until all concrete surface preparation is complete and installation of all the cathodic protection instruments is complete.

b. The Resident Engineer shall determine that the concrete surface is sound and has been prepared according to specification. The contractor responsible for concrete work shall correct unsatisfactory conditions before installation of the anode material.

C. Prior to installing the anode material, the contractor shall verify that all conduits, signs, markings, drains, and other embedded or surface mounted metallic fixtures within the area of protection are electrically continuous with the reinforcing steel.

d. Where concrete cover over the steel reinforcement is one-quarter (1/4) inch or less, one of the following procedures must be followed:
   (1) Epoxy coat the exposed rebar surface.
   (2) Add one-quarter (1/4) inch maximum layer of cementitious material.
   (3) Insert insulating spacers.
   (4) Route the anode material to avoid the area with shallow cover.

The appropriate procedure shall be specified by the Cathodic Protection Engineer and approved by the Resident Engineer. The Cathodic Protection Engineer shall ensure that the minimum anode to cathode separation is one-quarter (1/4) inch.

e. Anodes shall be fastened to the deck with insulating fasteners supplied with the anode material and approved by the Resident Engineer.
to not more than one-half (1/2) inch (may be more or less depending on the thickness of the overlay) from the surface of the deck. At least one fastener shall be used for every five (5) square feet of deck surface.

f. As directed by the Resident Engineer, fasteners may need to be attached to the concrete to ensure the anode mesh lies flat during concrete overlay placement.

g. The contractor shall take care to prevent damage to the anode mesh during anode installation and concrete overlay placement. Damaged anode mesh shall be repaired or replaced as directed by the Resident Engineer.

h. Anode fasteners and installation aids shall be supplied by the anode material manufacturer.

i. Anodes shall be terminated within two (2) inches of the expansion joint, fixed joint or other integral steel members at the surface of the deck. Layout of anodes and anode zones shall be determined by the anode manufacturer's representative after scarification of the bridge deck and approved by the Resident Engineer.

j. Current shall be distributed to the anodes via titanium current distributor bars or equal approved by the Resident Engineer.

k. Current distributors shall be attached to the anode mesh by resistance welded metallurgical bonds. There shall be at least one weld for every three linear inches of distributor bar.

l. Current distributors shall be at locations determined by the anode manufacturer's representative and approved by the Resident Engineer.

m. Current distributors shall be bent to extend through a one inch diameter hole to junction boxes located beneath the deck as shown by the plans. Current distributors shall be covered within this hole by an insulating heat-shrinkable sleeve approved by the Resident Engineer. Holes shall then be filled with a non-conductive epoxy approved by the Resident Engineer.

n. Insulated anode lead wires shall be AWG No. 10 stranded copper wire with THHN insulation or approved equal. Anode lead wires shall be attached to current distributors external to the concrete using spade lug connectors, and connections shall be coated with an epoxy approved by the Resident Engineer. Wires shall be tagged to indicate their position. No splices shall be allowed.

IX. System "B"

A. This system shall utilize Ferex 100 anode strand as manufactured by Raychem Corporation or equivalent. The installation will be on the bridge deck main lanes between Station 10+24.62 and Station 12+30.74.
B. Zones

There shall be four separately energized zones in this system. The areas of coverage for these zones shall be determined by the anode manufacturer's representative and approved by the Resident Engineer.

C. General Information

1. Traffic on the Deck

After installation of the anode strands, traffic on the deck shall be limited to vehicles required for delivery and installation of the overlay. Recesses or grade changes of greater depth that one (1) inch must be temporarily bridged for vehicles with gross vehicle weight greater than two (2) tons.

2. Gasoline and Oil on the Deck:

When cathodic protection material are exposed, the contractor shall ensure that gasoline and oil do not drip onto the cathodic protection materials from equipment being used. Refueling and servicing of the equipment shall be performed off any deck covered with exposed anode materials.

3. Installation

a. Anode strand installation shall not begin until all concrete surface preparation is complete and installation of all the cathodic protection instruments is complete.

b. The Resident Engineer shall determine that the concrete surface is sound and has been prepared according to specification. The contractor responsible for concrete work shall correct unsatisfactory conditions before installation of the anode material.

C. Prior to installing the anode strand, the contractor shall verify that all conduits, signs, markings, drains, and other embedded or surface mounted metallic fixtures within the area of protection are electrically continuous with the reinforcing steel.

d. Where concrete cover over the steel reinforcement is one-quarter (1/4) inch or less, one of the following procedures must be followed:

(1) Epoxy coat the exposed rebar surface.
(2) Add one-quarter (1/4) inch maximum layer of cementitious material.
(3) Insert plastic cleats or rebar clips as spacers.
(4) Route the anode material to avoid the area with shallow cover.

The appropriate procedure shall be specified by the Cathodic Protection Engineer and approved by the Resident Engineer. The Cathodic Protection Engineer shall ensure that the minimum anode to cathode separation is one-quarter (1/4) inch.
e. The contractor shall fasten each anode strand end loop to the concrete. The anode strand shall be fastened to the concrete a minimum of every five (5) feet at cleat locations between end loops.

f. As directed by the Resident Engineer, additional cleats may need to be fastened to the concrete to ensure the anode strand lies flat during concrete overlay placement.

g. The contractor shall take care to prevent damage to the anode strands during anode installation and concrete overlay placement. Anode strands shall not be bent through a radius smaller than two (2) inches. Damaged anode strands shall be repaired or replaced directed by the Resident Engineer.

h. Anode splicing shall be done in accordance with the anode manufacturer's representative and shall be subject to the Resident Engineer's approval. Anode splicing material shall be supplied by the anode manufacturer.

i. Anode to anode or anode to insulated wire splices shall be covered with a heavy wall heat shrinkable tubing internally coated with a specialized meltable sealant as supplied by the manufacturer. Substitutions shall be made only with the anode manufacturer representative's recommendation and the Resident Engineer's approval. Only the appropriate heat shrinkable splice seal shall be used.

j. Anode strand fasteners and installation aids shall be supplied by the anode material manufacturer.

k. Anodes shall be terminated within two (2) inches of the expansion joint, fixed joint or other integral steel members at the surface of the deck. Layout of anodes and anode zones shall be determined by the anode manufacturer's representative after scarification of the bridge deck and approved by the Resident Engineer.

l. Insulated anode lead wires shall be AWC No. 10 stranded copper wire with THHN insulation or approved equal. Anode lead wires shall be attached to current distributors external to the concrete using connectors supplied by the anode manufacturer and approved by the Engineer. Connections shall have non-conductive coatings approved by the Engineer. Wires shall be tagged to indicate their position. No splices shall be allowed in the anode lead wires.

X. Bu System "C"

A. This system shall utilize an anode of platinized primary wire, carbon filament secondary strands and anodecrete backfill. The installation will be on the bridge deck main lanes between Station 12+30.74 and Station 13+99.49.
B. Zones

There shall be two separately energized zones in this system. The areas of coverage for these zones shall be determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

C. General Information

1. Traffic on the Deck

After installation of the platinized wire and anode strands, traffic on the deck shall be limited to vehicles required for delivery and installation of the overlay. Recesses or grade changes of greater depth that one (1) inch must be temporarily bridged for vehicles with gross vehicle weight greater than two (2) tons.

2. Gasoline and Oil on the Deck

When cathodic protection material are exposed, the contractor shall ensure that gasoline and oil do not drip onto the cathodic protection materials from equipment being used. Refueling and servicing of the equipment shall be performed off any deck covered with exposed anode materials.

4. Anode Materials and Backfill

a. Composition of Primary Anode Wire

Each primary anode wire shall be a continuous length of 0.062 inch diameter platinized niobium copper core wire. The wire shall have a minimum coating of 25 micro-inches of platinum. At least 35% of the wire cross sectional area shall be niobium (outside the copper core). Electrical resistance of the wire shall not exceed 4.0 milliohms per foot.

B. Composition Secondary Anode Strands

Secondary anode strand shall be a 20,000 filament high purity carbon strand (99% minimum carbon) with a tensile strength of at least 250,000 P.S.I., a cross sectional area of 240 x 10 exp -5 inches squared, a resistivity of .00075 ohm-em and a maximum electrical linear resistance of 2.0 ohms per foot. The strand shall be wrapped with Dacron or equivalent thread, to prevent fraying during handling.

C. Anode Backfill

(1) The anode backfill material shall be extremely resistant to degradation by acid, chlorine, freezing, thawing, and thermal cycling while bonded to concrete, and shall have the following properties:

(A) compressive strength, more than 4,000 psi (4 hrs. @ 70 F)
(b) electrical resistivity, less than 10 ohm-cm
(c) water absorption (24 hrs.), less than 0.5%

(2) Composition

The composition of the anode backfill shall be as follows unless otherwise approved by the Engineer.

% by wt.

<table>
<thead>
<tr>
<th>Component</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin - Vinyl Ester Resin D-1115 Hetron as manufactured by Ashland Chemical Co., Columbus, Ohio.</td>
<td>35.</td>
</tr>
<tr>
<td>Silane Coupling Agent - A-174</td>
<td>0.35</td>
</tr>
<tr>
<td>Wetting Agent - S-440</td>
<td>0.35</td>
</tr>
<tr>
<td>Cobalt Naphthenate (Con)</td>
<td>0.35</td>
</tr>
<tr>
<td>Titanium Dioxide (TiO2) RHD 6x</td>
<td>0.70</td>
</tr>
<tr>
<td>Coke Breeze DWl</td>
<td>65.</td>
</tr>
<tr>
<td>Methyl Ethyl Ketone Peroxide (MEXP)</td>
<td>0.70</td>
</tr>
</tbody>
</table>

4. Installation of the Anodes

a. The deck surface shall be cleaned immediately prior to placing the anodes. The deck surface shall be free of moisture, dirt, grease, oil, asphalt, or other foreign matter when laying out anode materials. Anodes shall be held in place by a method approved by the Resident Engineer until placement of the anodecrete backfill.

B. All exposed reinforcing bars and other metallic material shall be covered with a non-conductive epoxy, approved by the Engineer.

c. Testing to prevent shorts in the anode system shall be conducted by the contractor to insure that no reinforcing steel or other material continuous with the reinforcing steel is within 1/2 inch of the primary or secondary anode materials. Areas found to be in such condition shall be covered with non-conductive epoxy prior to placing the anode system.

d. Primary anodes, secondary anodes and anodecrete shall be terminated within two (2) inches of the expansion joint, fixed joint or other integral steel members at the surface of the deck. Layout of anodes and anode zones shall be determined by the Cathodic Protection Engineer after scarification of the bridge deck. Layouts shall be approved by the Resident Engineer.

e. The primary anode wire shall not be kinked or scored. Damage to the anode wire shall be grounds for rejection.
f. Current shall be distributed to the anodes via platinized wire approved by the Resident Engineer. The current distributors shall be laid perpendicular to the carbon strands. At the end opposite the current distributor for the carbon strands, another platinized wire shall be placed. The platinized wire shall be attached at each end of the carbon filaments.

g. Current distributors shall be at locations determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

h. Current distributors shall be bent to extend through a 1 inch diameter hole to junction boxes located beneath the deck as shown by the plans. Current distributors shall be covered within this hole by an insulating heat-shrinkable sleeve approved by the Resident Engineer. Holes shall then be filled with a non-conductive epoxy approved by the Resident Engineer.

i. Insulated anode lead wires shall be AWG No. 10 stranded copper wire with THHN insulation or approved equal. Anode lead wires shall be attached to current distributors external to the concrete using methods specified by the Cathodic Protection Engineer and approved by the Resident Engineer. Connections shall have non-conductive coatings approved by the Resident Engineer. Wires shall be tagged to indicate their position. No splices shall be allowed in the anode lead wires nor in the primary anodes.

5. Installation of the Backfill Material

a. The anodecrete backfill shall be packaged in kits sized for the project.

b. The quantity of backfill material mixed at any time shall not be in excess of the amount that can be used within 30 minutes.

c. The backfill material shall be installed only when the deck temperature is expected to be about 40 degrees Fahrenheit for at least four (4) hours following the installation.

d. The manufacturer's instructions, including likely safety and handling measures, must be followed explicitly.

e. The deck surface shall be free of moisture, dirt, grease, oil, asphalt, or other foreign matter when covering the anodes with anodecrete backfill.

f. The anodecrete backfill shall be mounded over the primary and secondary anodes immediately after the anodes have been placed and any drill holes are completely sealed.

g. The backfill material must not come in contact with the reinforcing rods or any other metallic object of the bridge.

h. The anodecrete backfill mounded over the anodes shall be approximately one (1) inch wide and three-eights (3/8) inch high.
i. The mounded anodecrete backfill shall have dry, fine silica sand broadcast to excess over them within 15 minutes of pouring. The excess sand shall be broomed from the surface after the material has set.

6. Laboratory Tests

a. Prior to contract approval the contractor must submit independent laboratory tests certifying that the material proposed for use on this project meets the requirements as specified.

b. A sample shall be obtained from every fourth batch of material produced in the field. The sample shall be evaluated by an independent engineering laboratory to assure compliance with the resistivity and water absorption requirements. The test results shall be submitted to the Resident Engineer for approval.

c. The independent laboratory shall not be owned or connected in any way with the contractor, material supplier or Cathodic Protection Engineer.

XI. System "P"

A. This system shall utilize an anode of hot sprayed zinc, 20 mils plus or minus 3 mils thick. The installation will be on the bridge sidewalks and median between Station 8+18.49 and Station 12+30.74.

B. Zones

There shall be six separately energized zones in this system. The areas of coverage for these zones shall be determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

C. General Information

1. Gasoline and Oil on the Sidewalks and/or Median

2. When cathodic protection material are exposed, the contractor shall ensure that gasoline and oil do not drip onto the cathodic protection materials from equipment being used. Refueling and servicing equipment shall be performed away from the area of coverage by the anode material.

3. Installation

a. Anode material installation shall not begin until all concrete surface preparation is complete and installation of all the cathodic protection instruments is complete.

b. The Resident Engineer shall determine that the concrete surface is sound and has been prepared according to specification. The contractor responsible for concrete work shall correct unsatisfactory conditions before installation of the anode material.
c. Prior to installing the anode material, the contractor shall verify that all conduits, signs, markings, drains, and other embedded or surface mounted metallic fixtures within the area of protection are electrically continuous with the reinforcing steel.

d. Where concrete cover over the steel reinforcement is one-quarter (1/4) inch or less, one of the following procedures must be followed:

(1) Epoxy coat the exposed rebar surface.
(2) Add one-quarter (1/4) inch maximum layer of cementitious material.
(3) Use approved masking to avoid the area with shallow cover.

The appropriate procedure shall be specified by the Cathodic Protection Engineer and approved by the Resident Engineer.

e. The contractor shall take care to prevent damage to the anode material during the installation. Damaged anode areas shall be repaired or resprayed as directed by the Resident Engineer.

f. Areas not to be sprayed shall be masked off with an appropriate masking material. Anode material application shall be terminated within two (2) inches of the expansion joint, fixed joint or other integral steel members at the surface of application area. Layout of masking for anode zones shall be determined by the Cathodic Protection Engineer after any repairs have been made. Layout approval by the Resident Engineer must be obtained.

G. Current distributors shall as determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

h. Insulated anode lead wires shall be AWG No. 10 stranded copper wire with THHN insulation or approved equal. Wires shall be tagged to indicate their position. No splices shall be allowed in the anode distributor lead wires.

i. The Cathodic Protection Engineer shall be responsible for determining what type of coating (if any) is required to alleviate any hazards to pedestrian traffic as a result of the installation of the cathodic protection material.

j. The contractor is required to take all necessary precautions to protect contractor personnel and pedestrians.

XII. System "E"

A. This system shall utilize an anode of Porter DAC-85 Conductive coating or equivalent. The installation will be on bent 4 located at Station 12+30.74 of the bridge.

B. Zones

There shall be one zone in this system. The areas of coverage for this zone shall be all surfaces of the bent.
C. General Information

1. Gasoline and Oil on the Bent

2. When cathodic protection material are exposed, the contractor shall ensure that gasoline and oil do not drip onto the cathodic protection materials from equipment being used. Refueling and servicing of the equipment shall be performed away from the area of coverage by the anode material.

3. Installation

   a. Anode material installation shall not begin until all concrete surface preparation is complete and installation of all the cathodic protection instruments is complete.

   b. The Resident Engineer shall determine that the concrete surface is sound and has been prepared according to specification. The contractor responsible for concrete work shall correct unsatisfactory conditions before installation of the anode material.

   c. Prior to installing the anode material, the contractor shall verify that all conduits, signs, markings, drains, and other embedded or surface mounted metallic fixtures within the area of protection are electrically continuous with the reinforcing steel.

   d. Where concrete cover over the steel reinforcement is one-quarter (1/4) inch or less, one of the following procedures must be followed:

      1. Epoxy coat the exposed rebar surface.
      2. Add one-quarter (1/4) inch maximum layer of cementitious material.
      3. Use approved masking to avoid the area with shallow cover.

   The appropriate procedure shall be specified by the Cathodic Protection Engineer and approved by the Resident Engineer.

E. The contractor shall take care to prevent damage to the anode material during the installation. Damaged anode areas shall be repaired or re-applied as directed by the Resident Engineer.

F. Areas not to be coated shall be masked off with an appropriate masking material. Anode material application shall be terminated within two (2) inches of the expansion joint, fixed joint or other integral steel members at the surface of the bent. Layout of masking for anode zones shall be determined by the Cathodic Protection Engineer after any repairs have been made. Approval of layouts by the Resident Engineer must be obtained.

G. Current distributors shall as determined by the Cathodic Protection Engineer and approved by the Resident Engineer.

H. Insulated anode lead wires shall be AWG No. 10 stranded copper wire with THHN insulation or approved equal. Wires shall be tagged to

25-26
4685.000
9-87
indicate their position. No splices shall be allowed in the anode distributor lead wires.

I. The Cathodic Protection Engineer shall be responsible for determining what type of coating (if any) may be required to alleviate possible shorting of the system due to small debris falling onto the bent. (Note: The current configuration of the finger joint immediately above the bent allowed a significant amount of trash to collect on the top surface of the bent - ie. Cans, bottle tops)

4. The conductive coating system shall employ platinum wire primary anodes layered on the surface and covered with fiberglass screen adhesive tape.

5. The conductive coating shall be graphite/acrylic consisting of 42% solids.

6. The conductive coating shall have a resistivity of 1 ohm-cm. or less after curing.

7. The applied dry film thickness shall not be less than 16 mils.

XIII. MEASUREMENT. The complete Cathodic Protection System as indicated on the plans and as described herein when completely installed will be measured by the complete Cathodic Protection System.

XIV. PAYMENT. Payment shall be made at the contract lump sum bid for "Cathodic Protection System", which price shall be full compensation for all tools, labor, equipment, and incidentals necessary to complete the work.