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Construction Engineering
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Remote Monitoring of Cathodic Protection and Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson

Final Report on Project AR-F-321 for FY05

L.D. Stephenson, Ashok Kumar, and J. Bushman

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Final Report on Project AR-F-321 for FY05

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Final report

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Abstract: This project demonstrated and implemented emerging corrosion protection technologies for utilities at Fort Carson, CO, consisting of six deep anode impressed current cathodic protection (ICCP) systems, 106 drive-by type remote monitoring units for existing test stations, and 26 drive-by type remote monitoring units for existing and new rectifiers. ICCP rectifiers and groundbeds were installed on one natural gas main, one steam main, one water storage reservoir, and three separate water supply mains. The remote monitoring units have reduced the amount of time that it takes the contractor who maintains the ICCP systems at Fort Carson to obtain readings from 2 months to 2 days. The automated data are saved in a format that allows him to establish trends for early signs of problems with the system that needs immediate attention.

Other Army and DoD Installations have experienced similar problems with the need to upgrade and maintain their cathodic protection systems. It is therefore, recommended that these installations implement cathodic protection upgrades and remote monitoring technologies to extend the service life of the utility system.

Contents

Introduction

The U.S. Army Engineer Research and Development Center (ERDC) contracted with S & K Technologies, St. Ignatius, MT (subcontractor Bushman Associates, Medina, OH) under FY05 OSD Project AR-F-321 to implement Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson. The remote monitoring technology implemented has reduced the time required to collect data. In addition six new CP systems, comprised of a rectifier unit and deep anode ground bed, were installed to upgrade the cathodic protection of various water, natural gas, and steam mains.

Principal subcontractors to Bushman Associates were: Cathodic Protection Management, Chicago, IL and Borin Manufacturing, Marina del Rey, CA. Quality assurance and economic (return on investment) analysis was provided by N.D. Burke Associates, Inc., Seattle, Washington.

The project was facilitated by the aid and cooperation of the Fort Carson Chief of Base Operations Division Directorate of Public Works, specifically Daniel Goldin (Fort Carson DPW Office) and Darrel Rowland (Fort Carson Corrosion Technician).

The Project Manager was Dr. Ashok Kumar. The Associate Project Manager was Dr. L. D. Stephenson. Martin Savoie was the Chief of the Engineer research and Development Center- Construction Engineering Research Laboratory (ERDC/CERL) Materials & Structures Branch. The stakeholders are Daniel Goldin (Fort Carson Directorate of Public Works), Paul Volkman (Headquarters-Installation Management Command), David Purcell (Headquarters- Assistant Chief of Staff for Installation Management), and Hilton Mills (Army Materiel Command), as well as Tri-Services Working Integration Process Team representatives, Nancy Coleal (Air Force Civil Engineering Support Agency), and Tom Tehada (Naval Facilities Engineering Systems Command).

At the time this report was published, COL Gary E. Johnston was the Commander and Executive Director of ERDC, and Dr. James R. Houston was the Director.

Executive Summary

Fort Carson is spread over a large area and has many potable water storage tanks that use cathodic protection (CP) systems to protect the waterside of the tank. The outer surfaces of underground pipes, such as water, or gas distribution systems, also must be protected from corrosion in the soil using similar CP systems. CP systems must be monitored in order to verify that they are operating and providing sufficient voltage and current to maintain the cathodic protection. Fort Carson has existing CP systems for water storage tanks, water mains, gas mains, and steam lines. Both galvanic and impressed CP are used for these structures. In total almost 900 monitoring stations require monitoring at least once per year.

This project implemented 6 deep anode impressed current cathodic protection systems (ICCP), 106 drive-by type remote monitoring units (TSDMU) for existing test stations, and 26 drive-by type remote monitoring units (RDMU) for existing and new rectifiers at Fort Carson.

Impressed current cathodic protection rectifiers and groundbeds were installed on one natural gas main, one steam main, one water storage reservoir, and three separate water supply mains. Selection of sites for ICCP installations included input by Fort Carson Directorate of Public Works staff.

The contractor who maintains the ICCP systems at Fort Carson said that previously it would take him 2 months to obtain readings from the 106 ICCP test stations and 26 rectifiers that supply the cathodic protection current for necessary corrosion protection of those utilities. Now he can accomplish the same task in 2 days, with automated data saved in a format that allows him to establish trends for early signs that there may be a problem with the system that needs immediate attention.

Recommendations will be provided for revisions to Unified Facilities Guide Specifications (UFGS) 13111A “Cathodic Protection System (Steel Water Tanks)” and UFGS 13112A “Cathodic Protection System (Impressed Current).” These revisions include the specifications and instructions for installing the advanced impressed current cathodic protection systems in conjunction with the “drive-by” remote monitoring units for utilities as demonstrated under this project.

Unit Conversion Factors

Multiply	By	To Obtain
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters

1 Background

Fort Carson is spread over a large area and has many water storage tanks that use special corrosion protection systems known as “cathodic protection (CP),” which protect the internal or “water-side” of the tank. The outer surfaces of underground pipes, such as water, or gas distribution systems, also must be protected from corrosion in the soil using similar CP systems. In either case, CP systems need to be monitored in order to make sure that they are providing enough voltage and current to maintain the cathodic protection.

An emerging cathodic protection technology called “drive-by” remote monitoring is available to provide easily obtained readings of the CP system rectifiers and test stations. The drive-by remote monitoring interrogation system allows remote monitoring of cathodic protection values on buried metallic pipelines and structures and rectifiers while driving or walking in the vicinity of the remote monitoring units for rectifiers and test stations.

Supervisory Control and Data Acquisitions (SCADA) Systems, used by many military installations to monitor water levels in potable water storage tanks and sewage lift station parameters, are also being used at some DoD Installations for CP systems monitoring. The SCADA system is wireless; transmitting its data to a central control and monitoring station and receiving control signals via radio frequency transmission. The SCADA system will transmit the CP data to a central location upon request, and also provides control of the rectifiers from a central location at any given time.

However, there are some limitations to the use of SCADA systems, beginning with the cost. The cost of implementation of the SCADA-based CP monitoring/control system is very different for locations where SCADA already exists versus those locations where it does not exist, such as at Fort Carson. The cost of installing additional SCADA transmitting stations at test station locations is $10,000 each, whereas the cost of installing drive-by systems is $2,000 each. Also, SCADA system transmitting units are limited to line-of-sight radio frequency (RF) transmissions. In some cases, the RF signals are attenuated by leaves on trees during the summer, preventing transmission of CP data.

Given that Fort Carson has approximately 132 monitoring points where no existing SCADA is located (nor anticipated to be required for other measurement purposes), the “drive by” system is currently the economically justifiable system available for automating the CP system data acquisition and recording process.

2 Lessons Learned

This project has shown that properly monitored CP systems help to prevent corrosion from occurring. Monitoring these systems using remote monitoring units (RMUs) can help ensure that proper attention is given to any problems with the CP system. For example, the RMUs may alert maintenance personnel to the initial stages of inadequate corrosion protection, so that corrective action may be taken.

Recommended revisions to existing UFGS 13111A "Cathodic Protection System (Steel Water Tanks)" and UFGS 13112A "Cathodic Protection System (Impressed Current)" are planned. These revisions will include the specifications and instructions for installing the advanced impressed current CP systems in conjunction with remote monitoring units for utilities.

3 Technical Investigation

Problem

Existing CP systems at Fort Carson are difficult to maintain. Because of the size of the installation and number of test stations and rectifiers that must be monitored, it is time consuming to take the necessary readings for validating that the system is providing adequate corrosion protection or for alerting personnel when corrective action must be taken.

Without proper CP, the water storage tanks, pipes, and gas systems will corrode, and fail prematurely. Water tanks, water well casings, and fire suppression pipelines provide mission-critical water for fire fighting, including fire suppression systems in buildings, fire hydrants, and aircraft deluge systems. Continuing deterioration of these systems can lead to frequent shutdowns, and eventually to premature failure. Inadequate CP can result in severe corrosion of gas lines and eventual failure, leading to fire and explosions that endanger people and mission-critical equipment and structures.

Objectives

The objectives of this project were to provide the benefits of additional CP and to reduce the time required for the monitoring effort of the Fort Carson CP systems, which consists of five main tasks. These tasks are consistent with the primary goals of this project to install and provide final system testing for CP upgrades and remote monitoring units for tanks and pipelines at Fort Carson.

Approach

Task 1. Conduct a potential survey of CP of tanks and pipelines for utilities systems at Fort Carson.

Task 2. For each of the designated utilities develop specifications, install, and provide final systems testing for remote monitoring systems to include interrogation and transmission hardware, instant-off potential measurement coupons, permanent reference electrodes, and all related software for collection of the data in Excel Spreadsheet format. Included in Task 2

was a system final test and commissioning to ensure that applicable National Association of Corrosion Engineers (NACE) standards are met.

Task 3. Develop specifications, install, and provide final systems testing for six pole-mounted deep anode ICCP rectifier with associated ceramic anodes and hardware. Each of the six rectifiers were to be equipped with remote monitoring interrogation/transmission units with system DC voltage, amperage and instant-off potential measurement and all related software for collection of the data in Excel Spreadsheet format. Included in Task 3 was a system final test and commissioning to ensure that applicable NACE Standards are met.

Task 4.Provide on-site training for Fort Carson maintenance personnel on the systems installed in Tasks 2 and 3.

Task 5. Perform final inspection of all project work, analyze and summarize results of all equipment installations, including photo documentation of all project major components; document and analyze all individual component costs for detailed project compliance cost and performance report. Include cost/benefits information in format similar to that given at the following website http://www.estcp.org/documents/guidance/CP_CP.pdf, which will assist in developing return-on-investment (ROI) calculations (Appendix A) for the project.

Commensurate with the requirements of Project AR-F-321 Bushman and Associates, Inc. provided the consultation, design and installation services to complete the defined tasks. The work performed to complete each task is presented in this section of the report.

Results

A potential study was performed for portions of the facilities presently having CP applied. These facilities included natural gas and water mains and water storage tanks. In addition to the survey performed by Bushman & Associates, Inc., a review of the results of the past annual surveys conducted by the Public Works contractor for these facilities was conducted. The results of the potential study were previously reported to ERDC-CERL and are included in Appendix B of this report.

The drive-by concept was selected to provide remote monitoring of the Fort Carson CP systems. Each monitoring location is equipped with a

transducer to convert analog to digital information and transmit the data via a radio frequency from each monitoring location to a receiving unit. This concept was chosen because it can use a long-life battery power source for the measuring and transmitting functions and eliminate the need to provide commercial power to each location. Because of the large number of monitoring locations typically associated with CP systems, the cost of installing and maintaining commercial power precludes the economic use of remote monitoring for a significant number of individual locations.

The drive-by remote monitoring interrogation system allows remote monitoring of CP values on buried metallic pipelines and structures and rectifiers while driving or walking in the vicinity of the remote monitoring units. The system consists of three basic components:

1. The DART™ Drive-by Remote Monitoring Unit (TSDMU) and the Rectifier Drive-by Remote Monitoring Unit (RDMU).
2. The Stelth® HT "High-Tech" reference electrode.
3. The DART™ Remote Monitoring Interrogator (RMI) comprised of PDA/GPS/RADIO. The RMI unit running version 6.00b will read both the TSDMU and RDMU.

Remote monitoring unit requirements were established as follows:

1. Provide rectifier model units at the six new rectifiers and at existing rectifier locations.
   a. New Rectifier Locations
      (1) Reservoir Road for 600,000 Gallon Reservoir Exterior
      (2) Titus Blvd and Harr Ave, Fire Protection Main and Steam Lines
      (3) Butz Field Bldg 9601, Steam Lines
      (4) Wetzel Road, Twin Reservoirs to Prussman Road 16-in. Water Main
      (5) Brown Road, Twin Reservoirs to Special Forces16-in. Water Main
      (6) Gas Pit 4 to Gas Pit 6 8-in. Gas Main
   b. Existing Rectifier Locations
      (1) Butz Airfield Steam Plant
      (2) Evans Hospital (two existing rectifiers)
      (3) Harr Ave at Fort Carson golf course
      (4) Sheridan Ave and Titus Ave
      (5) Titus Ave at St. Lo (Senior Officers Housing)
      (6) Down Range water well casings (three existing rectifiers)

(7) Twin Reservoirs (four existing rectifiers)
(8) Single 1,000,000 Gallon Reservoir (two existing rectifiers)
(9) Single 600,000 Gallon Reservoir (two existing rectifiers)
(10) Building 8000, Motor Pool (two existing rectifiers)

2. Provide Rectifier Test Station Model remote monitoring equipment at selected existing test station locations.
3. Provide Rectifier Test Station Model remote monitoring equipment at 16 selected locations around the circumferences of the four steel water reservoirs.
   a. Starting at 62 feet from the existing rectifier place rectifier test station model at the reference cells installed at 62 feet spacing around circumference of 1,000,000 gallon storage reservoirs.
   b. Starting at 40 feet from the existing rectifier units, place rectifier test station model at the reverence cells installed at 40 feet spacing around circumference of 600,000 gallon storage reservoir.

A specification was prepared that included 6 pole-mounted deep anodes and 60 VDC-30ADC ICCP rectifiers with associated ceramic anodes and hardware. The specification was forwarded to ERDC-CERL for review and comment. Each of the six rectifiers were equipped with remote monitoring interrogation/transmission units with system DC voltage, amperage and instant-off potential measurement and all related software for collection of the data for use in an Excel Spreadsheet format.

The specific locations for the six ICCP systems were determined through a review of the historical monitoring data and consultation with the Fort Carson Public Works staff. The selected locations are as follows:

1. Reservoir Road for 600,000 gallon reservoir exterior

   The exterior of the 600,000 gallon reservoir has a ceramic anode grid anode and rectifier for CP. Adequate CP levels cannot be achieved with the grid anode system. The causes for the grid anode deficiency were not investigated, but the current versus tank to soil potential data indicates that the anode grid may be in electrical contact with the tank bottom. The electrical contact creates a low resistance metallic parallel path to the electrolyte current path resulting in insufficient ionic transfer through the electrolyte to polarize the tank's exterior bottom.

A 100 feet deep anode and rectifier unit were designed to supplement the existing CP for the 600,000 gallon reservoir exterior bottom.

2. Titus Blvd and Harr Ave, Fire Protection Main and Steam Lines

   The north loop fire protection main for Evans Hospital had previously been provided with a distributed impressed current anode array with the rectifier located in the electrical room for the hospital. The positive anode feeder cable from the rectifier to the anodes had ceased to function. Replacement of the cable was problematic due to the need to either bore under or go through the exit and entrance driveways to the Emergency Room.

   To reestablish CP to the north fire protection loop, a 100 feet deep anode and rectifier unit was designed to provide the protection to the fire loop. The new installation was originally intended for a grassy area northeast of the Emergency Room entrance, but because of the difficulty in providing AC power to the site, the Titus Blvd and Harr Ave intersection was selected as a viable alternate.

3. Butz Field Bldg 9601, Steam Lines

   The steam heating mains for Butz Airfield have an existing impressed current CP system that has not provided adequate protection to the steam mains. Repairs to the existing anode bed have been required. The existing anode bed is installed to a shallow depth in a rocky area.

   To reestablish CP to the Butz Airfield steam mains, a 100 feet deep anode and a rectifier unit were designed to provide the protection to the steam mains. The new installation is near Building 9611.

4. Wetzel Road, Twin Reservoirs to Prussman Road 16-in. Water Main

   The 16-in. water main from Prussman Road to the Twin Reservoirs has a galvanic anode system that is not providing adequate CP to the water main. Each of 65 test stations has one or more galvanic anodes attached to the 16-in. water main. Because of the monitoring effort caused by the large number of test stations and the inadequate protection levels, a 100 feet deep anode and a rectifier unit were designed to provide the protection to the water main.

5. Brown Road, Twin Reservoirs to Special Forces 16-in. Water Main

   The 16-in. water main from the intersection of Titus Blvd and Brown Road is the primary water supply to the Special Forces Complex. The original magnesium anode CP system is not providing adequate CP levels to the pipeline. A 100-ft deep anode and rectifier unit was designed to provide protection to the water main.

6. Gas Pit 4 to Gas Pit 6 8-in. Gas Main

   The 8-in. natural gas main from Gas Pit 4 at Wickersham Avenue to Barger Avenue has a galvanic anode CP system with approximately 40 monitoring stations. Fort Carson Public Works requested that the burden of monitoring the galvanic anode system be reduced by installation of a new impressed current system. A 100-ft deep anode and rectifier unit was designed to provide protection to the gas main.

All of the new and existing rectifiers at Fort Carson were provided with RDMU units. A summary of the structures provided with either TSDMU or RDMU units is indicated in Table 1.

Table 1. Remote monitoring units implemented.

Structure	Type of Unit	Number of Units
Natural Gas Mains	TSDMU	42
Water and Firewater Mains	TSDMU	47
Water Storage Reservoirs	TSDMU	16
Steam Mains	TSDMU	1
Rectifiers	RDMU	26

The TSDMU and RDMU locations are sorted by structure and listed in Appendix C of this report. Typical installation photographs of TSDMU units are included in Appendix D. Rectifier Manual and specifications are in Appendix E. After installation of the remote monitoring units all were entered into the RMI unit used by the Fort Carson contracted Corrosion Technician. Bushman & Associates, Inc. will be performing a series of monthly interrogations of the TSDMU and RDMU units using one of the RUI units provided to Public Works. The results of the monthly interrogations were reported separately from this project completion report.

Six (6) new rectifiers and deep anode groundbeds were installed at the following locations:

- Reservoir Road for 600,000 Gallon Reservoir Exterior
- Titus Blvd and Harr Ave, Fire Protection Main and Steam Lines
- Butz Field Bldg 9601, Steam Lines
- Wetzel Road, Twin Reservoirs to Prussman Road, 16-in. Water Main
- Brown Road, Twin Reservoirs to Special Forces, 16-in. Water Main
- Gas Pit 4 to Gas Pit 6, 8-in. Gas Main

The initial operating values for each of the six deep anode and rectifier systems installed as part of this contract are provided in Appendix F along with an area map of the installation locations. Additional deep anode bed documentation is presented in Appendix G. Dart coupon reference electrode specifications are in Appendix H. Contractor work plans for this project are presented in Appendix I.

On-site training for Fort Carson maintenance personnel on the systems installed was held on April 5, 2006. Attending the training was Darrell Rowland the Fort Carson Public Works contracted Corrosion Technician.

Three RMI units and software packages were turned over to Fort Carson Public Works. RMI units provided were serial numbers 4626KLV252, 32711K4, and 319098M.

If these technologies had not been implemented, the existing CP systems would not have been properly maintained, thus increasing maintenance cost and the probability that water storage tanks, pipes, and gas systems will corrode, and fail. Water tanks, water well casings and fire suppression pipelines provide mission-critical water for fire fighting, including fire suppression systems in buildings, fire hydrants, and aircraft deluge systems. Continuing deterioration of these systems can lead to frequent shut-downs, and eventually failure. During these shut-down periods, the lack of water could result in catastrophic loss of fire suppression capability, thereby endangering lives and property, and delaying aircraft flights. Also, the military deployment missions can be compromised due to lack of the water for aircraft fire suppression systems and due to the lack of water to fill portable water tanks that are shipped with troops being deployed to arid regions. Gas lines must be cathodically protected by law. Inadequate CP can result in severe corrosion of gas lines and eventual failure, resulting in

fire and explosions that endanger people and mission-critical equipment and structures.

Properly monitored CP systems help to prevent corrosion from occurring, and monitoring these systems using remote monitoring units (RMUs) can help ensure that proper attention is given to any problems with the CP system. For example, the RMUs may alert maintenance personnel to the initial stages of inadequate corrosion protection, so that corrective action may be taken.

4 Metrics

Metrics for this project are based on verification of the corrosivity of the Fort Carson soils and monitoring the performance data of the CP upgrades and the RMUs. In order to assess the corrosivity of the Fort Carson soils, 25 soil samples were obtained and tested according to:

1. ASTM G59: Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements.
2. ASTM G102: Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements.
3. Test soil chemistry according to ASTM G57-95a (2001) Title: Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method as modified using proposed ASTM Standard Test Method for Measurement of Soil Resistivity Using the Two-Electrode Soil Box Method.

A copy of the soil analysis is presented in Appendix J Median as-received soil resistivities were 7,100 ohm-cm. Median saturated soil resistivities were 2,200 ohm-cm. Median pH of the soil was 6.7. Median Chloride content was 22 ppm. Median alkalinity was 110 ppm. Linear polarization data indicated that the Fort Carson median corrosion rates were 3.966 mils per year. The data indicated that the 55% of the Fort Carson soils were considered “highly corrosive,” therefore utilities were in need of corrosion protection.

The remote monitoring system is monitoring 102 CP test stations and current from 26 ICCP system rectifiers. The test station systems measure the structure protection levels on a coupon that is normally connected to the structure and thus receiving the same level of CP as the structure. Once each week, the test station reader automatically decouples the coupon for a time period of 1 second during which it automatically measures and records the instant off IR-drop free potential of the coupon. The potential is measured with respect to an integral permanent copper-copper sulfate reference electrode. If the coupon reading is -850 mV or more negative, the test is complete and the monitoring system becomes dormant for 1 week, at which time it repeats the measurement. A total of up to 12 read-

ings are stored in the unit after which the oldest reading is cleared out and a new reading is stored in the memory, thus the 12 most recent readings are always available for interrogation by the portable "drive-by" data acquisition system.

If the weekly instant off reading is more positive than -850 mV (e.g., -750 mV), then the unit goes into a polarization decay mode, whereby it leaves the coupons decoupled from the structure for the NACE recommended time interval (NACE RP-0169) of 4 hours. At the end of the 4 hours, the unit measures the value of the decayed potential and subtracts this value from the instant off value, in accordance with NACE criteria RP-0169. So long as the decay thus calculated is greater than 100 mV, CP is confirmed on the coupon and the structure on which it is attached. Appendix L presents examples of the potentials for each of the test stations. The rectifier reader unit measures the same values for a coupon installed near the rectifier and, in addition, measures the rectifier output DC voltage and current. The current is measured across the rectifier shunt resistor in mV and is converted to amperes using Ohms Law. IR-Drop Free Potentials measured in this manner on the coupons were found to be within +/- 5 mV of the value similarly measure by a Fluke model 867 precision Volt-ohm-meter (VOM), while the rectifier voltage and current values were tested similarly and were within a tolerance of +/- 2 mV and +/- 200 mA, thus verifying that the CP system and RMUs were operating as designed. A service contract through ERDC-CERL for monitoring and maintaining these systems is in place at Fort Carson until September 2007.

5 Economic Summary

Appendix A presents the assumptions and calculations used in the ROI study.

The estimated unit cost for installation of an ICCP deep anode and groundbed was $50,000 per unit. This cost includes engineering design and ICCP start-up after installation. For the demonstration project, the ICCP portion of the costs was estimated to be $300,000 out of a total of $555,000.

The estimated unit cost for the DMU units was $1,850 per unit. This cost includes the DMU unit, a Stelth® HT “High-Tech” reference electrode, test box head, and installation including permitting. For the demonstration project the DMU portion of the costs was $196,500.

The estimated unit cost for the RMU units was $2,225 per unit. This cost includes the RMU unit, a Stelth® HT “High-Tech” reference electrode, and installation including permitting. For the demonstration project the DMU portion of the costs was $58,500.

The costs presented for ICCP, TSDMU, and RDMU are the direct costs of providing the ICCP, TSDMU, and RDMU. These direct costs would be applicable with regional labor adjustments to the provision of these items at other facilities.

Table 2. Project AR-F-321 cost data.

ICCP		
Rectifier	$ 2,250.00	Each
Drilling	$ 10,000.00	Lot
Anodes	$ 3,000.00	Lot
J-Box & Misc	$ 600.00	Each
Labor	$ 2,500.00	Lot
Unit ICCP Costs	$ 18,350.00	
Total ICCP Costs	$ 110,100.00	
TSDMU		
TS	$ 50.00	Each
Stelth 7	$ 350.00	Each
TSDMU	$ 500.00	Each
Labor	$ 550.00	Lot
Unit TSDMU Costs	$ 1,450.00	
RIU	$ 3,000.00	Each
Total TSDMU Costs	$ 159,700.00	
RDMU		
RDMU	$ 700.00	Each
Stelth 7	$ 350.00	Each
Labor	$ 650.00	Lot
Unit RDMU Costs	$ 1,700.00	
RIU	$ 3,000.00	Each
Total RDMU Costs	$ 47,200.00	
	Total Costs Excluding Engineering	$317,000.00
	Engineering Design & Specifications	$ 80,000.00
	Project Documentation Report	$ 35,000.00
	Project Administration	$ 35,000.00
	Overheads and Profit	$ 88,000.00
	Project Total	$555,000.00

The projected ROI for this project was determined by assessing the project costs and projected cost avoidance due to implementation (in accordance with the recommended procedure based on Appendix B of OMB Circular A94). The ROI was found to be 14.4. Assumptions that support this project ROI and further details are given in Appendix A. Validation of this ROI calculation by N. D. Burke is also shown in Appendix A.

6 Recommendation

1. CP upgrades using deep anode beds should be used for all underground piping which have electrical continuity.
2. Remote monitoring units should be used to monitor CP system performance regularly for underground pipes and water storage tanks.
3. Significant reductions in the time required for manual monitoring could be achieved by extending the remote monitoring program to include additional units.

7 Implementation

This technology is recommended for use at Army and DoD Installations for corrosion protection of utilities. Recommended revisions to existing UFGS 13111A “Cathodic Protection System (Steel Water Tanks)” and UFGS 13112A “Cathodic Protection System (Impressed Current)” are planned. Revisions will include the specifications and instructions for installing the deep bed anode impressed current CP systems. In addition, specifications for the remote monitoring units for utilities will be included.

8 Conclusions

This project demonstrated and implemented 6 deep anode impressed current cathodic protection systems (ICCP), 106 drive-by type remote monitoring units (TSDMU) for existing test stations, and 26 drive-by type remote monitoring units (RDMU) for existing and new rectifiers at Fort Carson. Also, impressed current CP rectifiers and groundbeds were installed on one natural gas main, one steam main, one water storage reservoir, and three separate water supply mains. The six new rectifiers and deep anodes are capable of providing their full rated current output of 30 amperes DC. The rectifier unit outputs were established in December 2005, but follow-up testing and readjustment is standard for ICCP systems and should be considered. The amount of piping under CP has increased significantly as a result of these six new ICCP installations.

The remote monitoring hardware for both test stations and rectifiers has significantly reduced the time required to obtain data from the locations with remote monitoring hardware in place.

Recommended revisions to existing UFGS 13111A “Cathodic Protection System (Steel Water Tanks)” and UFGS 13112A “Cathodic Protection System (Impressed Current)” are planned. Revisions will include the specifications and instructions for installing the advanced impressed current CP systems in conjunction with the “drive-by” remote monitoring units for utilities as demonstrated under this CPC Project.

Appendix A: ROI Calculations and Supporting Assumptions

Alternative 1

Fort Carson has the following systems that are in need of cathodic protection (CP) upgrades and remote monitoring systems in order to insure that the CP systems are properly maintained: underground steel jacketed high temperature steam lines for heating, potable water storage tanks, water distribution lines, fire suppression lines, and gas pipelines. The steam lines will need to be replaced in years 10, 20 and 30 at a cost of $3.3M. The water storage tanks, water distribution lines, fire suppression water lines, and gas lines will need to be replaced in years 15 and 30 at a combined cost of $29.25M.

Average annualized maintenance costs are $50K. All of these costs are shown under *Baseline Cost* in the ROI Spreadsheet and in the Backup Spreadsheet in this appendix. Additional costs will be for excavation to fix and repair leaks to the underground lines, emergency bottled water, fire suppression water trucks standing by in case of fire suppression pipe failure, and high probability of fires and explosions from gas leaks. These costs are initially $100K and they increase to $165K in year 15, when the most of the new systems are installed. Afterward, these additional costs then decrease to $20K, but increase again up to $100K, until new steam lines are installed in year 20. Afterwards, these additional cost decrease to $60K, only to begin increasing again to $265K in year 30.

Alternative 2

Cathodic protection upgrades and remote monitoring of the CP system will be implemented in year 0, for the water storage tanks, water distribution lines, fire suppression water lines, and gas lines at an investment cost of $980K. Average annualized maintenance costs will be $60K to maintain the CP system, as well as the tanks, and pipes, as shown in the ROI Spreadsheet under *New System Costs.* Also, shown under *New System cost* is the cost of rehab of the CP systems in year 15 at $1M. The additional costs described in Alternative 1, will be avoided, and are shown under *New Systems Benefits/Savings.*

Return on Investment Calculation

Investment Required			**980,000**
Return on Investment Ratio	**14.41**	**Percent**	**1441%**
Net Present Value of Costs and Benefits/Savings	**5,390,562**	**19,508,498**	**14,117,936**

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1	50,000		60,000	100,000	56,076	140,190	84,114
2	50,000		60,000	105,000	52,404	135,377	82,973
3	50,000		60,000	110,000	48,978	130,608	81,630
4	50,000		60,000	115,000	45,774	125,879	80,105
5	50,000		60,000	120,000	42,780	121,210	78,430
6	50,000		60,000	125,000	39,978	116,603	76,625
7	50,000		60,000	125,000	37,362	108,973	71,611
8	50,000		60,000	130,000	34,920	104,760	69,840
9	50,000		60,000	130,000	32,634	97,902	65,268
10	3,350,000		60,000	135,000	30,498	1,771,426	1,740,928
11	50,000		60,000	140,000	28,506	90,269	61,763
12	50,000		60,000	150,000	26,640	88,800	62,160
13	50,000		60,000	155,000	24,900	85,075	60,175
14	50,000		60,000	160,000	23,268	81,438	58,170
15	29,300,000		1,060,000	165,000	384,144	10,678,116	10,293,972
16	50,000		60,000	20,000	20,322	23,709	3,387
17	50,000		60,000	40,000	18,996	28,494	9,498
18	50,000		60,000	60,000	17,754	32,549	14,795
19	50,000		60,000	80,000	16,590	35,945	19,355
20	3,350,000		60,000	100,000	15,504	891,480	875,976
21	50,000		60,000	60,000	14,490	26,565	12,075
22	50,000		60,000	75,000	13,542	28,213	14,671
23	50,000		60,000	90,000	12,654	29,526	16,872
24	50,000		60,000	100,000	11,826	29,565	17,739
25	50,000		60,000	110,000	11,052	29,472	18,420
26	50,000		60,000	150,000	10,332	34,440	24,108
27	50,000		60,000	180,000	9,654	37,007	27,353
28	50,000		60,000	210,000	9,024	39,104	30,080
29	50,000		60,000	240,000	8,436	40,774	32,338
30	32,650,000		32,660,000	265,000	4,291,524	4,325,031	33,507

ROI ANALYSIS CATHODIC PROTECTION AND REMOTE MONIORING FOR WATER FACILITIES AND NATURAL GAS MAINS, Ft. CARSON, CO

FY05 OSD Corrosion Project – ROI – AR-F-321

1.0 Executive Summary

1.5 Technology Overview

1.5.1 Cathodic protection (CP) is a technique to control the corrosion of a metal surface by making that surface the cathode of an electrochemical cell. CP is a method commonly used to protect buried and submerges ferrous structures from corrosion. Cathodic protection systems are most commonly used to protect ductile and cast iron water mains, bulk water storage tanks, domestic and commercial hot water hot water tanks, natural gas mains and pipelines, buried steel tanks; steel pier piles, ships, offshore oil platforms, and onshore oil well casings.

The first use of CP was in 1852, when Sir Humphrey Davy, of the British Navy, attached chunks of iron to the external, below water line, hull of a copper clad ship. Iron has a stronger tendency to corrode (rust) than copper and when connected to the hull, the corrosion rate of the copper was dramatically reduced. This original application of CP utilized the iron as sacrificial anodes. Today, galvanic or sacrificial anodes are made in various shapes using alloys of zinc, magnesium and aluminum. The electrochemical potential, current capacity, and consumption rate of these alloys make them excellent materials to use as galvanic anodes for use with ferrous alloys.

Impressed Current CP is used for the larger structures that galvanic anodes cannot be used to economically deliver sufficient current to provide complete protection. Impressed Current Cathodic Protection (ICCP) systems use anodes connected to a DC power source (a cathodic protection rectifier). Anodes for ICCP systems are tubular and solid rod shapes or continuous ribbons of various specialized materials. These include high silicon cast iron, graphite, mixed metal oxide, platinum and niobium coated wire and others. A typical ICCP system for a pipeline would include an AC powered rectifier with a maximum rated DC output of between 5 and 50 amperes and 10 and 60 volts.

Testing and adjustment of both Galvanic CP and ICCP systems is done by measuring the electrochemical potential with standard reference electrodes. Copper-copper(II) sulfate electrodes are typically used for structures in contact with soil or fresh water. Silver chloride electrodes are used for seawater applications. A high impedance voltmeter is connected between the structure of interest and the reference electrode. When obtaining potential data it is important

to eliminate or minimize external voltage errors from the measurement. Measurement related errors can be minimized or eliminated by the use of high impedance voltmeters, calibrated reference electrodes, and proper measurement procedures. Extraneous voltage errors caused by the flow of current through the measurement circuit, IR Drop Errors, are corrected by simultaneous interruption of all cathodic protection sources applicable to the structure or through the use of small buried coupons that are interconnected with the structure but which can be interrupted from the cathodic protection sources for measurement of its potential.

1.5.2 Historically remote monitoring of pipeline cathodic protection levels has undergone several evolutions. In the 1980's a system using ground transmitters and receivers placed in aircraft that routinely flew over the pipeline for inspections was promoted. The fly-by system proved uneconomical and ineffective due to communications frequency issues, low transmitter power, and the cost of the monitoring hardware.

Since the year 2000, advances in remote monitoring technology have focused on the use of limited range and low power transmitters that are battery powered. In some aspects this approach is similar to fly-by system of the 1980's. However, the limited range and low power output eliminates the communications issues of the fly-by system. Advances in electronics miniaturization have enabled the use of batteries to power the transmitters. With a once a month measurement and once a year transmitting schedule the batteries have an estimated life of ten years.

1.6 Demonstration Project Overview

1.6.1 A demonstration project to install six (6) deep anode cathodic protection systems was instituted at Ft. Carson. Ft. Carson is spread over a large area and has many potable water storage tanks that use cathodic protection (CP) systems, which protect the water-side of the tank. The outer surfaces of underground pipes, such as water, or gas distribution systems, also must be protected from corrosion in the soil using similar CP systems. In either case, CP systems need to be monitored in order to make sure that they are providing enough voltage and current to maintain the cathodic protection. Fort Carson has the following systems, which currently have either no cathodic protection or require cathodic protection upgrades to maintain corrosion resistance: 5 potable water storage tanks, 30 miles of potable water distribution lines, 5 miles of high temperature steam lines, 40 miles of natural gas distribution line, 2 miles of fire suppression water lines, and 3 well casings. An Office of the Secretary of Defense (OSD) Corrosion Control and Prevention (CPC) Program project titled "AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson" will help to rectify these corrosion problems and simplify management of corrosion protection systems at Ft. Carson through cathodic protection upgrades and implementation of remote monitoring units. A Contract was been awarded to Bushman Associates, Inc. to accomplish this work.

1.6.2 Remote monitoring hardware was installed for monitoring cathodic protection potential levels for water mains, gas mains, water storage tanks, and steam lines. A companion model remote monitoring unit was installed to record the operating

out puts of both the six new and existing cathodic protection rectifiers installed at Ft. Carson. The DART™ Drive-By Re mote Monitoring Interrogation System remote m onitoring system supplied by Borin Manufacturing was chosen by Bushman and Associates, Inc. T he DART™ Drive-B y Rem ote Monitoring Interrogation System provides remote monitoring of cathodic protection values on buried m etallic pipelines and structures .The system consists of three basic components:

DART™ Remote Monitoring Units (DMU) and the Rectifier Remote Monitoring Units (RMU).

Stelth® HT "High-Tech" reference electrodes.

DART™ Rem ote Monitor ing Inter rogators (RMI) co mprised of PDA/GPS/RADIO. The RMI unit running version 6.00b reads both the DMU and RMU.

1.6.3 Bushman Associates, In c. selected locatio ns for the DMU units f or the f acilities for which the six new deep anode ICCP sy stems installed and for other facilities with existing cathodic protection.

RMU units were insta lled for all ex iting operational rectifiers and for the six new rectifier units.

As reported by Bushman Associates, Inc. 106 DMU units were placed as indicated below:

- Natural Gas Mains 42 DMU units
- Water and Firewater Mains 47 DMU units
- Water Storage Reservoirs 16 DMU units
- Steam Mains 1 DMU unit

As reported by Bushm an Associates, Inc. 26 RMU units were placed at the new and existing rectifiers.

1.6.4 Bushman Associates, Inc. selected six (6) sites for the installation of deep anode cathodic protection system s. These cathod ic protection system s consisted of 6 ceramic anodes installed in a drilled hol e 100 feet deep. The anodes are powered with rec tifier units ra ted at 60 vo lts DC and 30 am peres DC. The six locations selected are:

- 16" cast iron water main along Wetzel Ave. from Prussman Ave. to the Twin Tanks Reservoir,
- 16" ductile iron water main along Brown Road from Titus Ave to 10th Special Forces complex.
- 8" steel natural gas main from Gas Pit 4 to Barger Ave.
- 600,000 gallon water storage tank exterior bottom.
- Steam piping located at Butz Airfield.
- Various water mains and fire control lines in the vicinity of Evans Hospital.

1.7 Demonstration Project Performance

1.7.1 AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson. The six ICCP installations were installed in December 2005. Bushman Associates, Inc. reports the following operational information of the six ICCP systems based on data obtained soon after installation. The rectifier output and groundbed resistance information was obtained by Bushman Associates, Inc.'s subcontractor Cathodic Protection Management, Inc. and witnessed by a representative of ND Burke Associates, Inc. The operational data indicates that all six of the ICCP systems are capable of operating at 100% of rated output if required.

1.7.2 The DMU and RMU units are operating and transmitting data to the hand held Interrogator unit. The data is transferred to a spreadsheet format for review and records maintenance. Two RMU units installed at rectifier units located within Evans Hospital cannot be interrogated external from the hospital due to the number of walls between the rectifier locations and the nearest drive-by access. To gather data from these rectifier units, the operator must walk into the electrical room that houses the rectifiers. That data is gathered into the hand held unit and available for download into the spreadsheet with other rectifier information.

1.7.3 As a subject for a future project would be modifications to the installation procedures for DMU units placed below grade. Among the possible items for consideration would be the use of a "diving bell" type housing to trap air and exclude water, an upgrade model of the DMU with improved water sealing properties, or the use of a sealed housing for the exiting DMU unit.

1.8 Cost and ROI

1.8.1 Cost information obtained from Bushman Associates, Inc. indicates that AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson had a total contract value of $555,000. Upon request Bushman Associates, Inc. provided a breakdown of costs for the installation of the six ICCP systems, the 106 DMU units, and the 26 RMU units. From these costs unit costs could be estimated for each of the work scope items.

1.8.2 The demonstration project contributed significantly to the upgrade of cathodic protection at Ft. Carson. However, additional cathodic protection and remote monitoring upgrades can still be affected at Ft. Carson. For the most part the natural gas system is plastic or steel with cathodic protection. Based on a review of the 2004 Cathodic Protection Survey for the Natural Gas Piping, it is estimated that an additional ICCP installation may be required. The existing ICCP groundbed for one of the three water wells appears to be depleted and requires replacement. A large portion of the water main system is either non-metallic pipe or presently supplied with cathodic protection. There are segments of the metallic water mains with cathodic protection potential levels less than needed for corrosion control. It is estimated that three additional ICC systems may be required for the water mains. The existing ICCP systems on the water storage

tanks appear to be adequate at the present time. A total of five additional ICCP installations may be required to complete the cathodic protection of existing Ft. Carson utility facilities. An estimated $250.000 is required for ICCP of existing utility facilities.

1.8.3 The demonstration project provided 42 DMU units for the Natural Gas Mains, 47 DMU units for the Water and Firewater Mains, 16 DMU units for Water Storage Reservoirs, and 1 DMU unit for Steam Mains. It is estimated that an additional 125 DMU units are required to provide remote monitoring of the existing Ft. Carson utility facilities. Location of these units should be done by a cathodic protection expert after a review of the physical plant records and all monitoring data for the exiting utility systems. An estimated $232,000 is required to provide remote monitoring to the exiting utility facilities at Ft. Carson.

1.8.4 Each of the five additional ICCP systems will require RMU units at and estimated cost of $11,250.

1.8.5 The total estimated cost for additional ICCP and remote monitoring at Ft. Carson is $493,250.

1.8.6 The ROI study prepared prior to the AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson project estimated that the cost of cathodic protection upgrades and remote monitoring for the utility system at Ft. Carson would be $980,000. Combining the $555,000 cost of the AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson and the $493,250 cost estimate to complete the upgrades, produces a total estimate of $1,048,250. The difference in the two estimates is quite close, $68,250 or 7% over the original estimate.

1.8.7 A revised ROI calculation was performed based on the revised cost estimates. No changes were made to the original assumptions pertaining future costs as no information became available to indicate a need to modify the assumptions. It should be noted that the ongoing expansion projects at Ft. Carson will result in expenditures of new utility services, but these new utility facilities are upgrades to the existing core utility systems. It is assumed that any corrosion control related to new facilities will be included in the costs of the new facilities.

1.8.8 Table 1 presents a summary of the ROI values for the original project estimate and for the revised cost estimate. As indicated in Table I, the Net Present Value of Avoided Costs, Net Present Value of New System Costs, and Net Present value of Savings is the same for both ROI estimates because no changes were made to long term cost flow assumptions. The effect of the increase in estimated New System Costs is to slightly lower the return on initial investment ratio from 14.30 to 13.37 and the Internal Rate of Return, IRR, percentage from 23% to 22%. It does not appear that the revised cost estimate significantly impacts the conclusion that based on either ROI analysis, the application of cathodic protection and remote monitoring is justified for the long term corrosion control of the Ft. Carson utility facilities.

Table I

Comparison of ROI Estimates

Financial Data	Original ROI	Revised ROI
New System Cost	$980,000	$1,048,250
Net Present Value of Avoided Costs	$ 19,402,178	$ 19,402,178
Net Present Value of New System Costs	$5,390,741 $5,390,741	
Net Present Value of Savings	$ 14,011,438	$ 14,011,438
ROI Ratio	14.30	13.37
ROI %	1,430%	1,337%
IRR 23%		22%

2.0 Technology Description

2.3 Cathodic Protection

2.3.1 Cathodic protection (CP) is a technique to control the corrosion of a metal surface by making that surface the cathode of an electrochemical cell. CP is a method commonly used to protect buried and submerges ferrous structures from corrosion. Cathodic protection systems are most commonly used to protect ductile and cast iron water mains, bulk water storage tanks, domestic and commercial hot water hot water tanks, natural gas mains and pipelines, buried steel tanks; steel pier piles, ships, offshore oil platforms, and onshore oil well casings.

2.3.2 The first use of CP was in 1852, when Sir Humphrey Davy, of the British Navy, attached chunks of iron to the external, below water line, hull of a copper clad ship. Iron has a stronger tendency to corrode (rust) than copper and when connected to the hull, the corrosion rate of the copper was dramatically reduced. This original application of CP utilized the iron as sacrificial anodes. Today, galvanic or sacrificial anodes are made in various shapes using alloys of zinc, magnesium and aluminum. The electrochemical potential, current capacity, and consumption rate of these alloys make them excellent materials to use as galvanic anodes for use with ferrous alloys.

Galvanic anodes are designed and selected to have a more "active" voltage (technically a more negative electrochemical potential) than the metal of the structure (typically steel). For effective CP, the potential of the steel surface is polarized (pushed) more negative until the surface has a uniform potential. At that stage, the driving force for the corrosion reaction is halted. The galvanic anode continues to corrode, consuming the anode material until eventually it must be replaced. The polarization is caused by the current flow from the anode to the cathode. The driving force for the CP current flow is the difference in electrochemical potential between the anode and the cathode. Galvanic anodes are limited by their electrochemical potential to relatively low cathodic protection current outputs. Galvanic anodes are normally used for small isolated metallic components such as valves or fittings in plastic piping systems or for pipelines and mains with excellent coating systems on the meal surface.

2.3.3 Impressed Current CP is used for the larger structures that galvanic anodes cannot be used to economically deliver sufficient current to provide complete protection. Impressed Current Cathodic Protection (ICCP) systems use anodes connected to a DC power source (a cathodic protection rectifier). Anodes for ICCP systems are tubular and solid rod shapes or continuous ribbons of various specialized materials. These include high silicon cast iron, graphite, mixed metal oxide, platinum and niobium coated wire and others.

A typical ICCP system for a pipeline would include an AC powered rectifier with a maximum rated DC output of between 5 and 50 amperes and 10 and 60 volts. The positive DC output terminal is connected via cables to the array of anodes

buried in the ground (the anode groundbed). For many applications the anodes are installed in a 60 m (200 foot) deep, 25 cm (10-inch) diameter vertical hole and backfilled with conductive coke (a material that improves the performance and life of the anodes). A cable rated for the expected current output connects the negative terminal of the rectifier to the pipeline. The operating output of the rectifier is adjusted to the optimum level by a CP expert after conducting various tests including measurements of electrochemical potential.

2.3.4 Testing and adjustment of both Galvanic CP and ICCP systems is done by measuring the electrochemical potential with standard reference electrodes. Copper-copper(II) sulfate electrodes are typically used for structures in contact with soil or fresh water. Silver chloride electrodes are used for seawater applications. A high impedance voltmeter is connected between the structure of interest and the reference electrode. When obtaining potential data it is important to eliminate or minimize external voltage errors from the measurement. Measurement related errors can be minimized or eliminated by the use of high impedance voltmeters, calibrated reference electrodes, and proper measurement procedures. Extraneous voltage errors caused by the flow of current through the measurement circuit, IR Drop Errors, are corrected by simultaneous interruption of all cathodic protection sources applicable to the structure or through the use of small buried coupons that are interconnected with the structure but which can be interrupted from the cathodic protection sources for measurement of its potential.

The two most commonly used evaluation criteria for cathodic protection are a polarized, IR Drop Error Free, potential of -850 millivolts or more negative or the formation of 100 millivolts of cathodic polarization on the structure related to the potential of the structure prior to the application of cathoidc protection. An alternate form of the 100 millivolt polarization criteria is to disengage all cathodic protection sources and to measure the difference in the IR Drop Error Free potential and the structure potential at a later time period. During the waiting interval the cathodic protection sources must remain disengaged. If the difference is 100 millivolts or more, adequate polarization has occurred for cathodic protection.

Effective cathodic protection levels for various metals have been established and are published in industry standards. In the United States, the standards of NACE International are used to evaluate cathodic protection system operation and design. Among applicable standards for structures located at Ft. Carson, CO are:

NACE RP0169 Control of External Corrosion on Underground or Submerged Metallic Piping Systems,

NACE RP0186 Application of Cathodic Protection for External Surfaces of Steel Well Casings,

NACE RP0193 External Cathodic Protection of on Grade Carbon Steel Storage Tank Bottoms,

NACE RP0285 Corrosion Control of Underground Storage Tank Systems by Cathodic Protection

NACE RPO388 Im pressed Current Cat hodic Protection of Internal Submerged Surfaces of Carbon Steel Water Storage Tanks,

NACE RP0572 Design, Installation, Operation, and Maintenance of Impressed Current Deep Anode Groundbeds,

NACE TM0101 Measurem ent Techniques Re lated the Criteria for Cathodic Protection on underground or Submerged Metallic Tank Systems,

ANSI/NACE RP0104 The Use of C oupons for Cathodic P rotection Monitoring Applications.

In addition to the previously cited i ndustry standards, ca thodic protection of natural gas and hazardo us liquid s pipeline s are covered by federal reg ulations. The Natural Gas Pipeline Safety Act of 1968 as amended (NGPSA) authorizes the Department to regulate pipeline transpor tation of natural (f lammable, toxic, o r corrosive) gas and other gases as well as the transportation and storage of liquefied natural gas (L NG). Similarly, the Hazardous Liquid Pi peline Safety Act of 1979 as am ended (HLPSA) authorizes the Departm ent to regulate pipeline transportation of hazard ous liqu ids (c rude o il, petroleum products, anhydrous ammonia, and carbon dioxide). Both of th ese Acts have been recodified as 49 U.S.C. Chapter 601.

2.3.5 Advantages and limitations

Cathodic protection for corrosion contro l of buried or s ubmerged m etallic facilities has distinct advantages. Among these positive aspects are:

- Cathodic protection can be applied to both new and existing facilities.
- Cathodic protection can be used on both coated and non coated m etallic structures.
- Cathodic protection can prevent corr osion from soil corrosion, bacterial corrosion, and stress corrosion cracking.
- Cathodic protection is applicable over a wide range of e nvironmental conditions.
- The effectiveness of cathodic protection can be measured to ensure proper corrosion control levels are maintained.

Cathodic Protection has some limitations. Among these limitations are:

- Cathodic protection requires expert se rvices for proper design and layout of an integrated corro sion control system . An ove rsight is n eeded to ensure that cathodic protection systems are compatible.
- Cathodic protection cannot restore metal to previously corroded surfaces.
- Cathodic protection is an active pr ocess and requires m onitoring and prompt repair of deficiencies. It ems subject to dam age by third party actions suc h as tes t b oxes and d ielectric ins ulators requ ire con tinual oversight and repairs.

- Changes to the protected structure can negate the cathodic protection system. Elimination of dielectric insulators or improper placement of dielectric insulators can cause all or portions of the structure to lose cathodic protection levels. Placement of plastic pipe can isolate portions of a piping system from the cathodic protection source.

2.4 Remote Monitoring

2.4.1 Historically remote monitoring of pipeline cathodic protection levels has undergone several evolutions. In the 1980's a system using ground transmitters and receivers placed in aircraft that routinely flew over the pipeline for inspections was promoted. The fly-by system proved uneconomical and ineffective due to communications frequency issues, low transmitter power, and the cost of the monitoring hardware.

Also in the 1980's remote monitoring systems using telephone lines and modems began to appear. Although effective, these remote monitoring solutions were limited to locations with access to both AC power and telephone line service. The telephone line modems were replaced with cell phone or satellite phone modems with moderate success. The costs of data transfer became a concern with users with multiple locations and the cellular communications quality varied with weather conditions and locations. Analog type cell phones were used and the shift to digital cell phone systems began to make the cell phone modem systems obsolete.

Since the year 2000, advances in remote monitoring technology have focused on the use of limited range and low power transmitters that are battery powered. In some aspects this approach is similar to fly-by system of the 1980's. However, the limited range and low power output eliminates the communications issues of the fly-by system. Advances in electronics miniaturization have enabled the use of batteries to power the transmitters. With a once a month measurement and once a year transmitting schedule the batteries have an estimated life of ten years.

The size of the data collection and transmission devices is compact enough to fit inside of a standard cathodic protection monitoring station. The reliance on battery power releases the constraints of an AC power supply. Fabrication to military specifications provides serviceability in a wide variety of weather conditions.

Also, advances in computer technology and operating systems have evolved a family of hand held personal computing devices. These hand held devices are used to communicate with the data measurement devices and to retrieve previously recorded data by radio transmission. As programmable devices, the hand held units provide versatility in monitoring functions. One of the features is the inclusion of Global Positioning Coordinates into the data base for the location of test sites.

2.4.2 Advantages and Limitations

Remote monitoring provides distinct advantages over manual collection of data. Among these positive aspects are:

- Reduced man hour requirements to collect data. One hundred (100) or more test points can be monitored in a single working day.
- More man hours available for maintenance of CP systems and corrosion control.
- Reduced errors of transposing field data to Data Report Forms or Data Bases. Measurements are imported directly in electronic format to a spreadsheet application.
- Increased personnel safety as data is collected from a vehicle. Manual collection of data involves traversing rough terrain or stopping at roadside to access a test box installed in the roadway.
- Higher data collect success. Often test points are inaccessible due to parked traffic or snow accumulation. Remote data collection does not require opening of a test box.
- Higher levels of data review and exception reporting are possible with data placed in spreadsheet format.

Remote monitoring has some limitations. Among these limitations are:

- Initial survey set up and selection of critical monitoring points requires expert services that may not be available on site.
- Battery life is dependent on the user determined survey frequency established in initial set up. Replacement of batteries could be prior to 10 years if times between surveys are reduced.
- Although the DMU units can be placed below grade in vaults or flush to grade test boxes, they cannot be used in areas where the units may become submerged.
- Electronic hardware is rapidly evolving and manufacturer support for equipment could be an issue over the projected project life. Adequate spare monitoring units should be obtained. Manufacturers should be tied to long term maintenance agreements.
- The present method of data input into a spreadsheet requires that a person knowledgeable with spreadsheet use and manipulation prepare reports and archive data. The use of a basic database package rather than a spreadsheet may provide better flexibility in data reporting and data archival.

3.0 Demonstration Project

3.3 Cathodic Protection Project

3.3.1 Overview

A demonstration project to install six (6) deep anode cathodic protection system s was instituted at Ft. Carson. Ft. Carson is spread over a large area and has m any potable water storage tanks that use cathodic protection (CP) system s, which protect the water-side o f the tank. The out er surfaces of underground pipes, such as water, or gas distribution systems, also must be protected from corrosion in the soil using similar CP systems. In either case, CP systems need to be monitored in order to make sure that they are providing enough voltage and current to m aintain the cathodic protection. Fort Carson has the following system s, which c urrently have either no cathodic protection or re quire cathodic protec tion upgrades to maintain corrosion resistance: 5 potable water storage tanks, 30 m iles of potable water distribution lines, 5 m iles of hi gh tem perature steam lines, 40 m iles of natural gas distribution line, 2 m iles of fire suppression w ater lines, and 3 well casings. An Office of the Secretary of Defense (OSD) Corrosion Control an d Prevention (CPC) Program project title d "AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protecti on System Upgra des for Tanks and Pipelines at Fort Carso n" will help to rectif y these cor rosion problem s and simplify m anagement of corrosion protec tion system s at Ft. Carson through cathodic protection upgrades and implem entation of re mote m onitoring units. A Contract was been awarded to Bushman Associates, Inc. to accomplish this work.

3.3.2 Demonstration Project

Bushman Associates, Inc. selected six (6) sites for the installation of deep anode cathodic protection systems. These cathodic protection systems consisted of 6 ceramic anodes installed in a drilled hole 100 feet deep. The anodes are powered with rectifier units rated at 60 volts DC and 30 amperes DC. The six locations selected are:

- 16" cast iron water main along Wetzel Ave. from Prussman Ave. to the Twin Tanks Reservoir,
- 16" ductile iron water main along Brown Road from Titus Ave to 10th Special Forces complex.
- 8" steel natural gas main from Gas Pit 4 to Barger Ave.
- 600,000 gallon water storage tank exterior bottom.
- Steam piping located at Butz Airfield.
- Various water mains and fire control lines in the vicinity of Evans Hospital.

3.4 Remote Monitoring

3.4.1 Overview

Remote monitoring hardware was installed for monitoring cathodic protection potential levels for water mains, gas mains, water storage tanks, and steam lines. A companion model remote monitoring unit was installed to record the operating outputs of both the six new and existing cathodic protection rectifiers installed at Ft. Carson. The ***DART***™ Drive-By Remote Monitoring Interrogation System remote monitoring system supplied by Borin Manufacturing was chosen by Bushman and Associates, Inc. The ***DART***™ Drive-By Remote Monitoring Interrogation System provides remote monitoring of cathodic protection values on buried metallic pipelines and structures .The system consists of three basic components:

- ***DART***™ Remote Monitoring Units (DMU) and the Rectifier Remote Monitoring Units (RMU).
- Stelth® HT "High-Tech" reference electrodes.
- DART™ Remote Monitoring Interrogators (RMI) comprised of PDA/GPS/RADIO. The RMI unit running version 6.00b reads both the DMU and RMU.

The ***DART***™ Remote Monitoring Unit (DMU), which is normally placed inside a CP test station, can be used either above or below grade and is connected to one, two, three or structure/ coupon test wires and a **Stelth**® HT reference electrode. The DMU unit measures and stores 12 data sets of corrosion protection potentials.

The ***DART***™ Rectifier Remote Monitoring Unit (RMU), is furnished inside a sealed module and is designed to be installed inside an existing rectifier cabinet. The RMU unit measures and stores 12 data readings of corrosion protection data.

Specifications for the RMU units are:

- Three Analog Voltage Monitoring Inputs capable of negative 0-2.5 volts DC +- 0.005 accuracy with 20 Meg Ohm input impedance, 60 HZ AC rejection of 90db and transient voltage protection of 10,000 volts. Higher voltages can be measured using suitable external voltage divider resistors.
- Designed with state of the art ultra low power Microprocessor and RF Transceiver technology with an internal time of day clock having a 2-second per month accuracy.
- Measure and store twelve sets of voltage readings from three test wire terminals at a field programmable interval of from 10 minutes to 6 months. Other options are factory programmable to customer specifications.

- When interrogated by the wireless RF link with its unit serial number the *DART*™ DMU will send back all of the stored voltage readings and the current internal Lithium battery voltage.
- The wireless RF link uses the North American unlicensed 902-928 MHz ISM band Frequency Hopping Spread Spectrum communications, with a maximum power output of 0.25 watts.
- Wireless communications range in a below grade road box, valve box or regulator vault is 30 - 300 feet depending on installation conditions while the range in a above ground Test Station is greater than 1,000 feet.
- Powered by a Field Replaceable long life A-size lithium–thionyl chloride cell with an expected life in excess of ten years when programmed for a scheduled interrogation of once a year.
- Designed to fit within the standard 3 inch e Cathodic Protection Test Station with Four ¼-20 mounting studs to mount on terminal board in place of the terminal bolts. Dimensions are 4.2" x 2.5" x 0.9" with four 1" long ¼-20 terminals on back side in a 1" center to center square arrangement.

  Epoxy encapsulated electronics will operate in –40 to +85 degrees Centigrade temperatures at 99% humidity. Direct emersion of *DART*™ DMU in water during operation is not allowed under any circumstances.

3.4.2 Demonstration Project

Bushman Associates, Inc. selected locations for the DMU units for the facilities for which the six new deep anode ICCP systems installed and for other facilities with existing cathodic protection. RMU units were installed for all exiting operational rectifiers and for the six new rectifier units.

As reported by Bushman Associates, Inc. 106 DMU units were placed as indicated below:

- Natural Gas Mains 42 DMU units
- Water and Firewater Mains 47 DMU units
- Water Storage Reservoirs 16 DMU units
- Steam Mains 1 DMU unit

As reported by Bushman Associates, Inc. 26 RMU units were placed at the new and existing rectifiers.

4.0 Demonstration Project Performance

4.3 Cathodic Protection Project

4.1.1 AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson. The six ICCP installations were installed in December 2005. Bushman Associates, Inc. reports the following operational information of the six ICCP systems based on data obtained soon after installation. The following rectifier output and groundbed resistance information was obtained by Bushman Associates, Inc.'s subcontractor Cathodic Protection Management, Inc. and witnessed by a representative of ND Burke Associates, Inc.

8" Natural Gas Main
Rectifier Rating 60 DCV - 30 DCA
DC Volts 3.48 V DC Amperes 4.50 A
Groundbed Resistance 0.77 Ohms

Wetzel 16" Water Main
Rectifier Rating 60 DCV - 30 DCA
DC Volts 10.60 V DC Amperes 21.76 A
Groundbed Resistance 0.49 Ohms

600,000 Gallon Water Reservoir
Rectifier Rating 60 DCV - 30 DCA
DC Volts 14.3 V DC Amperes 13.04 A
Groundbed Resistance 1.10 Ohms

Brown Road 16" to 10th Special Forces
Rectifier Rating 60 DCV - 30 DCA
DC Volts 7.66 V DC Amperes 17.12 A
Groundbed Resistance 1.10 Ohms

Butz Airfield Steam Lines
Rectifier Rating 60 DCV - 30 DCA
DC Volts 13.88 V DC Amperes 13.04 A
Groundbed Resistance 1.06 Ohms

The operational data indicates that all six of the ICCP systems are capable of operating at 100% of rated output if required.

In addition to considering the ability of the ICCP systems to provide cathodic protection current, the electrochemical potentials of the protected facilities must be consistent with the criteria for cathodic protection established for the facility. Polarized potentials of -850 millivolts or more negative are required. Establishment of rectifier outputs by a cathodic protection expert is required.

There appear to be technical issues unrelated to the project AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson. At Butz Airfield, the steam lines appear to be

electrically interconnected with the power neutral system and investigations are required to locate the point or points of interconnection and to resolve them with some dielectric isolation materials. At Wetzel Road, the 16" cast iron water main was made electrically continuous at construction with the use of jumper cables connected across mechanical fittings. It appears that one or more of the jumper bonds has disengaged and prevents cathodic protection current flow north towards Prussman Ave. Investigations to locate these defective jumper bonds are required and excavation of the pipe for the placement of new jumper bonds will be required.

Although there are issues unrelated to AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson that must be resolved, the six (6) ICCP systems installed under this project have the capability to operate at full rated output and provide cathodic protection to the facilities to which they are attached.

4.4 Remote Monitoring Project

4.4.1 The DMU and RMU units are operating and transmitting data to the hand held Interrogator unit. The data is transferred to a spreadsheet format for review and records maintenance. Two RMU units installed at rectifier units located within Evans Hospital cannot be interrogated external from the hospital due to the number of walls between the rectifier locations and the nearest drive-by access. To gather data from these rectifier units, the operator must walk into the electrical room that houses the rectifiers. That data is gathered into the hand held unit and available for download into the spreadsheet with other rectifier information.

4.4.2 During the course of the AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson project, four DMU units placed in flush test stations were damaged by water that intruded into the flush to grade test stations after installation. Prior to installation there was no indication of water accumulation in the test boxes. These four DMU units were replaced and relocated to above grade test box sites. The four DMU units that were damaged were in locations near freight loading and unloading docks. Having these units in place would have been beneficial in reducing the time to manually obtain data and in eliminating access problems due to parked trucks. The manufacturer's literature does indicate that the DMU units should not be placed in areas where they may become submerged.

As a subject for a future project would be modifications to the installation procedures for DMU units placed below grade. Among the possible items for consideration would be the use of a "diving bell" type housing to trap air and exclude water, an upgrade model of the DMU with improved water sealing properties, or the use of a sealed housing for the exiting DMU unit.

5.0 Costs and ROI

5.4 Demonstration Project Costs

5.4.1 Cost information obtained from Bushman Associates, Inc. indicates that AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson had a total contract value of $555,000. Upon request Bushman Associates, Inc. provided a breakdown of costs for the installation of the six ICCP systems, the 106 DMU units, and the 26 RMU units. From these costs unit costs could be estimated for each of the work scope items.

5.4.2 The estimated unit cost for installation of an ICCP deep anode and groundbed was $50,000 per unit. This cost includes engineering design and ICCP start-up after installation. For the demonstration project, the ICCP portion of the costs was $300,000.

5.4.3 The estimated unit cost for the DMU units was $1,850 per unit. This cost includes the DMU unit, a Stelth® HT "High-Tech" reference electrode, test box head, and installation including permitting. For the demonstration project the DMU portion of the costs was $196,500.

5.4.4 The estimated unit cost for the RMU units was $2,225 per unit. This cost includes the RMU unit, a Stelth® HT "High-Tech" reference electrode, and installation including permitting. For the demonstration project the DMU portion of the costs was $58,500.

5.5 Estimated Future Cathodic Protection and Remote Monitoring Costs

5.5.1 The demonstration project contributed significantly to the upgrade of cathodic protection at Ft. Carson. However, additional cathodic protection and remote monitoring upgrades can still be affected at Ft. Carson. For the most part the natural gas system is plastic or steel with cathodic protection. Based on a review of the 2004 Cathodic Protection Survey for the Natural Gas Piping, it is estimated that an additional ICCP installation may be required. The existing ICCP groundbed for one of the three water wells appears to be depleted and requires replacement. A large portion of the water main system is either non-metallic pipe or presently supplied with cathodic protection. There are segments of the metallic water mains with cathodic protection potential levels less than needed for corrosion control. It is estimated that three additional ICC systems may be required for the water mains. The existing ICCP systems on the water storage tanks appear to be adequate at the present time.

5.5.2 A total of five additional ICCP installations may be required to complete the cathodic protection of existing Ft. Carson utility facilities. An estimated $250.000 is required for ICCP of existing utility facilities.

5.5.3 The demonstration project provided 42 DMU units for the Natural Gas Mains, 47 DMU units for the Water and Firewater Mains, 16 DMU units for Water Storage Reservoirs, and 1 DMU unit for Steam Mains. It is estimated that an additional 125 DMU units are required to provide remote monitoring of the existing Ft.

Carson utility facilities. Location of these units should be done by a cathodic protection expert after a review of the physical plant records and all monitoring data for the exiting utility systems.

5.5.4 An estimated $232,000 is required to provide remote monitoring to the exiting utility facilities at Ft. Carson.

5.5.5 Each of the five additional ICCP systems will require RMU units at and estimated cost of $11,250.

5.5.6 The total estimated cost for additional ICCP and remote monitoring at Ft. Carson is $493,250.

5.6 ROI Study Prepared for AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson

5.6.1 The ROI study prepared prior to the AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson project estimated that the cost of cathodic protection upgrades and remote monitoring for the utility system at Ft. Carson would be $980,000. Combining the $555,00 costs of the AR-F-321- "Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson and the $493,250 cost estimate to complete the upgrades, produces a total estimate of $1,048,250. The difference in the two estimates is quite close, $68,250 or 7% over the original estimate.

5.6.2 A revised ROI calculation was performed based on the revised cost estimates. No changes were made to the original assumptions pertaining future costs as no information became available to indicate a need to modify the assumptions. It should be noted that the ongoing expansion projects at Ft. Carson will result in expenditures of new utility services, but these new utility facilities are upgrades to the existing core utility systems. It is assumed that any corrosion control related to new facilities will be included in the costs of the new facilities.

5.6.3 Table 1 presents a summary of the ROI values for the original project estimate and for the revised cost estimate. As indicated in Table 1, the Net Present Value of Avoided Costs, Net Present Value of New System Costs, and Net Present value of Savings is the same for both ROI estimates because no changes were made to long term cost flow assumptions. The effect of the increase in estimated New System Costs is to slightly lower the return on initial investment ratio from 14.30 to 13.37 and the Internal Rate of Return, IRR, percentage from 23% to 22%. It does not appear that the revised cost estimate significantly impacts the conclusion that based on either ROI analysis, the application of cathodic protection and remote monitoring is justified for the long term corrosion control of the Ft. Carson utility facilities.

Table 1

Comparison of ROI Estimates

Financial Data	Original ROI	Revised ROI
New System Cost	$980,000	$1,048,250
Net Present Value of Avoided Costs	$ 19,402,178	$ 19,402,178
Net Present Value of New System Costs	$5,390,741 $5,390,741	
Net Present Value of Savings	$ 14,011,438	$ 14,011,438
ROI Ratio	14.30	13.37
ROI %	1,430%	1,337%
IRR 23%		22%

5.6.4 The original ROI study is presented in Table 2 and Table 2A. The information within these tables and the calculations are as presented in the FY05 OSD Corrosion Project – ROI – AR-F-321. There are slight differences in numerical values that are attributed to the numerical precision of the calculations and equations.

5.6.5 The revised cost ROI study is presented in Table 3 and Table 3A.

Table 2

ORIGINAL ROI ANALYSIS FT. CARSON CATHODIC PROTECTION AND REMOTE MONITORING

Cost of Capital 7.00% Initial Investment $ 980,000

ROI Ratio 14.30 ROI % 1430%

IRR 2 3%

	Net Present Value of Avoided Costs	Net Present Value of New System Costs	Net Present Value of Savings
	$ 19,402,178	$ 5,390,741	$ 14,011,438

Year	Total Baseline and Avoided Costs	Present value of Avoided Costs	Present Value of New System	Total Present Value
0			$ 980,000	$ (980,000)
1	$ 150,000	$ 140,188	$ 56,075	$ 84,113
2	$ 155,000	$ 135,385	$ 52,407	$ 82,978
3	$ 160,000	$ 130,611	$ 48,979	$ 81,632
4	$ 165,000	$ 125,882	$ 45,775	$ 80,107
5	$ 170,000	$ 121,213	$ 42,781	$ 78,432
6	$ 175,000	$ 116,616	$ 39,983	$ 76,633
7	$ 175,000	$ 108,988	$ 37,367	$ 71,620
8	$ 180,000	$ 104,769	$ 34,923	$ 69,846
9	$ 180,000	$ 97,915	$ 32,638	$ 65,277
10	$ 185,000	$ 94,052	$ 30,504	$ 63,549
11	$ 3,490,000	$ 1,658,226	$ 28,508	$ 1,629,718
12	$ 200,000	$ 88,811	$ 26,643	$ 62,168
13	$ 205,000	$ 85,077	$ 24,901	$ 60,176
14	$ 210,000	$ 81,451	$ 23,272	$ 58,179
15	$ 29,465,000	$ 10,680,808	$ 384,241	$ 10,296,568
16	$ 70,000	$ 23,715	$ 20,327	$ 3,388
17	$ 90,000	$ 28,496	$ 18,997	$ 9,499
18	$ 110,000	$ 32,550	$ 17,755	$ 14,795
19	$ 130,000	$ 35,952	$ 16,593	$ 19,359
20	$ 3,450,000	$ 891,694	$ 15,508	$ 876,187
21	$ 110,000	$ 26,571	$ 14,493	$ 12,078
22	$ 125,000	$ 28,219	$ 13,545	$ 14,674
23	$ 140,000	$ 29,538	$ 12,659	$ 16,879
24	$ 150,000	$ 29,578	$ 11,831	$ 17,747
25	$ 160,000	$ 29,486	$ 11,057	$ 18,429
26	$ 200,000	$ 34,447	$ 10,334	$ 24,113
27	$ 230,000	$ 37,022	$ 9,658	$ 27,364
28	$ 260,000	$ 39,114	$ 9,026	$ 30,087
29	$ 290,000	$ 40,773	$ 8,436	$ 32,337
30	$ 32,915,000	$ 4,325,031	$ 4,291,524	$ 33,507

Table 3
REVISED ROI ANALYSIS
FT. CARSON CATHODIC PROTECTION AND REMOTE MONITORING

Cost of Capital	7.00%		Initial Investment	$ 1,098,550	
ROI Ratio	12.75		ROI %	1275%	
IRR	22%		Net Present Value of Avoided Costs	Net Present Value of New System Costs	Net Present Value of Savings
			$ 19,402,178	$ 5,390,741	$ 14,011,438
Year	Total Baseline and Avoided Costs		Present value of Avoided Costs	Present Value of New System	Total Present Value
0				$ 1,048,250	$ (1,048,250)
1	$	150,000	$ 140,188	$ 56,075	$ 84,113
2	$	155,000	$ 135,385	$ 52,407	$ 82,978
3	$	160,000	$ 130,611	$ 48,979	$ 81,632
4	$	165,000	$ 125,882	$ 45,775	$ 80,107
5	$	170,000	$ 121,213	$ 42,781	$ 78,432
6	$	175,000	$ 116,616	$ 39,983	$ 76,633
7	$	175,000	$ 108,988	$ 37,367	$ 71,620
8	$	180,000	$ 104,769	$ 34,923	$ 69,846
9	$	180,000	$ 97,915	$ 32,638	$ 65,277
10	$	185,000	$ 94,052	$ 30,504	$ 63,549
11	$	3,490,000	$ 1,658,226	$ 28,508	$ 1,629,718
12	$	200,000	$ 88,811	$ 26,643	$ 62,168
13	$	205,000	$ 85,077	$ 24,901	$ 60,176
14	$	210,000	$ 81,451	$ 23,272	$ 58,179
15	$	29,465,000	$ 10,680,808	$ 384,241	$ 10,296,568
16	$	70,000	$ 23,715	$ 20,327	$ 3,388
17	$	90,000	$ 28,496	$ 18,997	$ 9,499
18	$	110,000	$ 32,550	$ 17,755	$ 14,795
19	$	130,000	$ 35,952	$ 16,593	$ 19,359
20	$	3,450,000	$ 891,694	$ 15,508	$ 876,187
21	$	110,000	$ 26,571	$ 14,493	$ 12,078
22	$	125,000	$ 28,219	$ 13,545	$ 14,674
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26	$	200,000	$ 34,447	$ 10,334	$ 24,113
27	$	230,000	$ 37,022	$ 9,658	$ 27,364
28	$	260,000	$ 39,114	$ 9,026	$ 30,087
29	$	290,000	$ 40,773	$ 8,436	$ 32,337
30	$	32,915,000	$ 4,325,031	$ 4,291,524	$ 33,507

Table 2A

ORIGINAL ROI ANALYSIS FT. CARSON CATHODIC PROTECTION AND REMOTE MONITORING BACK-UP SPREADSHEET

Year	Maintenance Cost	Base Capital Expenditures	Avoided Costs	CP System & Remote Monitoring Costs	New System Capital Costs	Total New System Costs
0					$980,000.00	$980,000.00
1	$50,000.00		$100,000.00	$60,000.00		$60,000.00
2	$50,000.00		$105,000.00	$60,000.00		$60,000.00
3	$50,000.00		$110,000.00	$60,000.00		$60,000.00
4	$50,000.00		$115,000.00	$60,000.00		$60,000.00
5	$50,000.00		$120,000.00	$60,000.00		$60,000.00
6	$50,000.00		$125,000.00	$60,000.00		$60,000.00
7	$50,000.00		$125,000.00	$60,000.00		$60,000.00
8	$50,000.00		$130,000.00	$60,000.00		$60,000.00
9	$50,000.00		$130,000.00	$60,000.00		$60,000.00
10	$50,000.00		$135,000.00	$60,000.00		$60,000.00
11	$ 50,000.00	$3,300,000.00	$140,000.00	$60,000.00		$60,000.00
12	$50,000.00		$150,000.00	$60,000.00		$60,000.00
13	$50,000.00		$155,000.00	$60,000.00		$60,000.00
14	$50,000.00		$160,000.00	$60,000.00		$60,000.00
15	$ 50,000.00	$29,250,000.00	$165,000.00	$60,000.00	$ 1,000,000.00	$1,060,000.00
16	$50,000.00		$20,000.00	$60,000.00		$60,000.00
17	$50,000.00		$40,000.00	$60,000.00		$60,000.00
18	$50,000.00		$60,000.00	$60,000.00		$60,000.00
19	$50,000.00		$80,000.00	$60,000.00		$60,000.00
20	$ 50,000.00	$3,300,000.00	$100,000.00	$60,000.00		$60,000.00
21	$50,000.00		$60,000.00	$60,000.00		$60,000.00
22	$50,000.00		$75,000.00	$60,000.00		$60,000.00
23	$50,000.00		$90,000.00	$60,000.00		$60,000.00
24	$50,000.00		$100,000.00	$60,000.00		$60,000.00
25	$50,000.00		$110,000.00	$60,000.00		$60,000.00
26	$50,000.00		$150,000.00	$60,000.00		$60,000.00
27	$50,000.00		$180,000.00	$60,000.00		$60,000.00
28	$50,000.00		$210,000.00	$60,000.00		$60,000.00
29	$50,000.00		$240,000.00	$60,000.00		$60,000.00
30	$ 50,000.00	$32,600,000.00	$265,000.00	$60,000.00	$ 32,600,000.00	$32,660,000.00

Table 3A

REVISED ROI ANALYSIS FT. CARSON CATHODIC PROTECTION AND REMOTE MONITORING BACK-UP SPREADSHEET

Year	Maintenance Cost	Base Capital Expenditures	Avoided Costs	CP System & Remote Monitoring Costs	New System Capital Costs	Total New System Costs
0					$1,048,250.00	$1,048,250.00
1	$ 50,000.00		$100,000.00	$60,000.00		$60,000.00
2	$ 50,000.00		$105,000.00	$60,000.00		$60,000.00
3	$ 50,000.00		$110,000.00	$60,000.00		$60,000.00
4	$ 50,000.00		$115,000.00	$60,000.00		$60,000.00
5	$ 50,000.00		$120,000.00	$60,000.00		$60,000.00
6	$ 50,000.00		$125,000.00	$60,000.00		$60,000.00
7	$ 50,000.00		$125,000.00	$60,000.00		$60,000.00
8	$ 50,000.00		$130,000.00	$60,000.00		$60,000.00
9	$ 50,000.00		$130,000.00	$60,000.00		$60,000.00
10	$ 50,000.00		$135,000.00	$60,000.00		$60,000.00
11	$ 50,000.00	$3,300,000.00	$140,000.00	$60,000.00		$60,000.00
12	$ 50,000.00		$150,000.00	$60,000.00		$60,000.00
13	$ 50,000.00		$155,000.00	$60,000.00		$60,000.00
14	$ 50,000.00		$160,000.00	$60,000.00		$60,000.00
15	$ 50,000.00	$29,250,000.00	$165,000.00	$60,000.00	$ 1,000,000.00	$1,060,000.00
16	$ 50,000.00		$20,000.00	$60,000.00		$60,000.00
17	$ 50,000.00		$40,000.00	$60,000.00		$60,000.00
18	$ 50,000.00		$60,000.00	$60,000.00		$60,000.00
19	$ 50,000.00		$80,000.00	$60,000.00		$60,000.00
20	$ 50,000.00	$3,300,000.00	$100,000.00	$60,000.00		$60,000.00
21	$ 50,000.00		$60,000.00	$60,000.00		$60,000.00
22	$ 50,000.00		$75,000.00	$60,000.00		$60,000.00
23	$ 50,000.00		$90,000.00	$60,000.00		$60,000.00
24	$ 50,000.00		$100,000.00	$60,000.00		$60,000.00
25	$ 50,000.00		$110,000.00	$60,000.00		$60,000.00
26	$ 50,000.00		$150,000.00	$60,000.00		$60,000.00
27	$ 50,000.00		$180,000.00	$60,000.00		$60,000.00
28	$ 50,000.00		$210,000.00	$60,000.00		$60,000.00
29	$ 50,000.00		$240,000.00	$60,000.00		$60,000.00
30	$ 50,000.00	$32,600,000.00	$265,000.00	$60,000.00	$ 32,600,000.00	$32,660,000.00

Appendix B: Structure-to-Electrolyte Potential Study

BUSHMAN & Associates, Inc.
CORROSION CONSULTANTS
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STRUCTURE POTENTIAL SURVEY
FT. CARSON

Bushman & Associates, Inc. performed a general electrical potential survey for various public works facilities at Ft. Carson, CO. The survey is included among the tasks in AR-F-321- Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson. The survey was conducted during the months of September, October, and November of 2005.

The collected data is included in a series of appendices organized into groups representative of the faculties tested. Table 1 is a list of the faculties and the Annex that contains the data for the facility. For many of the test locations, photographs were obtained of the test station to indicate the general condition of the test stations and to provide a visual reference. Photographs are numbered to correspond to the test station number used in the data tables. Thumbnail size photographs are presented at the end of the appropriate Annex. Digital photograph files are included in the attached digital media.

Table 1

Annex	Facilities
Annex A	16" WATER MAIN PARALLEL TO WETZEL RD FROM PRUSSMAN AVE TO TWIN RESERVOIRS
Annex B	16" WATER MAIN PARALLEL TO BROWN AVE FROM TITUS BLVD TO 10TH SPECIAL FORCES COMPLEX
Annex C	MISCELLANEOUS WATER MAINS AND FIRE MAINS LOCATED AT FT. CARSON
Annex D	VARIOUS NATURAL GAS MAINS
Annex E	SEWER MAINS
Annex F	600,000 GALLON AND 1,0000 GALLON WATER RESERVOIRS
Annex G	OPERATIONAL RECTIFIER LIST

ANNEX A

16” WATER MAIN PARALLEL TO WETZEL RD FROM PRUSSMAN AVE TO TWIN RESERVOIRS

16" cast iron waterline going up to the Twin Water Reservoirs from Prussman Boulevard.

WTS #	LOCATION	10/05 P/S (Neg mV's)	PIPE TYPE	MAP #	PICTURES	GPS E	GPS N	COMMENTS
1	Corner Prussman & Wetzel (NE Crn New Fire Sta)	-560	16" DI	405	1 & 1A	13518407	4287406	Grey Big Fink T/S Proposed RMU site
2	S. of above	-484	"		2 & 2A	13518415	4287384	Grey Big Fink T/S
3	"	-596	"		3 & 3A	13518431	4287373	Grey Big Fink T/S
4	" - 2 x Red TL's	-431	"		4 & 4A	13518449	4287337	Big Fink T/S (cvr missing - leads disconnected)
	1 x Blk TL	-1441						
5	" Red TL	-452	"		5 & 5A	13518470	4287323	Big Fink T/S (head missing - leads disconnected)
	Blk TL	-1441						
6	Iron Horse Park	-631	"		6 & 6A	13518567	4287303	Glen 4 FMTS (Busted Cvr) Proposed RMU site
7	~100' S. of above T/S	-432	"		7 & 7A	13518533	4287282	Glen 4 FMTS
8	"	N/A	"		8 & 8A	13518585	4287254	Skipped - Glen 4 FMTS
9	"	-618	"		9 & 9A	13518603	4287244	Glen 4 Flush T/S
10	"	N/A	"		No Pictures	13518667	4287213	Skipped - Glen 4 FMTS
11	Off Wetzel/Iron Horse Park	-452	"		11 & 11A	13518698	4287173	Glen 4 Flush T/S Proposed RMU site
12	S.Driveway–off Wetzel	N/A	"		12	13518707	4287159	Skipped - Grey Big Fink T/S
13	S. of above T/S	-431	"		13 & 13A	13518728	4287143	Grey Big Fink T/S
14	S. of above	0	"		14 & 14A	13518742	4287124	Skipped - Grey Big Fink T/S
15	" & NW of FH	-431	"		15 & 15A	13518760	4287108	Blue Big Fink T/S
16	"	N/A	"		16 & 16A	13518870	4287091	Skipped - Blue Big Fink T/S
17	N/W ditch by track	-650	"		17 & 17A	13518787	4287074	Blue Big Fink T/S Proposed RMU site
18	" – between ditches	N/A	"		18 & 18A	13518798	4287056	Skipped - Blue Big Fink T/S
19	S. of above T/S	-461	"		19 & 19A	13518817	4287046	Blue Big Fink T/S
20	"	N/A	"		20 & 20A	13518828	4287025	Skipped - Grey Big Fink T/S
21	Hillside	-423	"		21 & 21A	13518446	4287009	Grey Big Fink T/S
22	Next to 3 water valves	N/A	"		22 & 22A	13518857	4286987	Skipped - Grey Big Fink T/S
23	By water pit	-440	"		23 & 23A	13518873	4286972	Grey Big Fink T/S with Broke Base Proposed RMU site
24	S. of above T/S	N/A	"		24 & 24A	13518882	4286952	Skipped - Blue Big Fink T/S
25	"	-451	"		25 & 25A	13518890	4286930	Grey Big Fink T/S
26	"	0	"		26 & 26A	13518884	4286909	Skipped - Grey Big Fink T/S
27	"	-425	"		27 & 27A	13518885	4286886	Grey Big Fink T/S - Next to yellow poles

Annex A continued								
WTS #	**LOCATION**	**10/05 P/S (Neg mV's)**	**PIPE TYPE**	**MAP #**	**PICTURES**	**GPS E**	**GPS N**	**COMMENTS**
28	"	N/A	"		28 & 28A	13518880	4286867	Skipped - Grey Big Fink T/S - SW of yellow poles
29	"	-478	"		29 & 29A	13518884	4286845	Grey Big Fink T/S
30	"	N/A	"		30 & 30A	13518889	4286825	Skipped - Grey Big Fink T/S
31	"	-531	"		31 & 31A	13518888	4286820	Blue Big Fink T/S Proposed RMU site
32	"	-468	"		32 & 32A	13518889	4286819	Blue Big Fink T/S
33	Building 2200 / N. side drive	-487	"		33 & 33A	13518893	4286799	Bldg 2200 Demolished???Busted Glen 4 FM T/S - Leads Disconnected
34	Building 2200/Parking lot	N/A	"		34 & 34A	13518895	4286777	Skipped - Busted Glen 4 FMTS - Leads Disconnected
35	Building 2200 / S. side drive	-582	"		35 & 35A	13518902	4286751	Grey Big Fink T/S Proposed RMU site
36	S. of above T/S	N/A	"		36 & 36A	13518903	4286730	Skipped - Grey Big Fink T/S
37	"	-431	"		37 & 37A	13518911	4286708	Blue Big Fink T/S
38	"	N/A	"		38 & 38A	13518910	4286685	Skipped - Blue Big Fink T/S
39	"	-431	"		39 & 39A	13518922	4286666	Blue Big Fink T/S
40	S. side running track	N/A	"		40 & 40A	13518921	4286640	1st B/F T/S S. side track - Skipped - Blue Big Fink T/S
41	S. of above T/S	-456	"		41 & 41A	13518929	4286596	Grey Big Fink T/S
42	"	N/A	"		42 & 42A	13518938	4286575	Skipped - Blue Big Fink T/S
43	"	-450	"		43 & 43A	13518945	4286555	Blue Big Fink T/S
44	W. of gas pit 11	N/A	"		44 & 44A	13518961	4286541	Skipped - Grey Big Fink T/S
45	Across from gas pit 11 - 2 X Red TL's	-405	"		45 & 45A	13518963	4286537	Grey Big Fink T/S Proposed RMU site
	2 x Wht TL's	-711						
46	W. side dirt road	N/A	"		46 & 46A	13518970	4286520	Skipped - Blue Big Fink T/S
47	E. side dirt road	-468	"		47 & 47A	13518985	4286501	Grey Big Fink T/S
48	S/E of above T/S	0	"		48 & 48A	13518995	4286479	Skipped - Grey Big Fink T/S
49	"	-454	"		49 & 49A	13519011	4286463	Grey Big Fink T/S
50	"	N/A	"		50 & 50A	13519023	4286442	Skipped - Grey Big Fink T/S
51	"	-466	"		51 & 51A	13519037	4286428	Grey Big Fink T/S
52	"	N/A	"		52 & 52A	13519068	4286404	Skipped - Grey Big Fink T/S
53	"	-438	"		53 & 53A	13519083	4286389	Grey Big Fink T/S
54	Bottom hill Twin Reservoirs	-399	"		54 & 54A	13519101	4286377	Blue Big Fink T/S

Annex A continued								
WTS #	**LOCATION**	**10/05 P/S (Neg mV's)**	**PIPE TYPE**	**MAP #**	**PICTURES**	**GPS E**	**GPS N**	**COMMENTS**
55	Bottom hill Twin Reservoirs- 2 X Blk TL's	-465	"		55 & 55A	13519101	4286376	Grey Big Fink T/S Proposed RMU site
	2 X Blk TL's	-399						
56	Bottom Hill Twin Reservoirs	N/A	"		56 & 56A	13519104	4286372	Big fink side by side - Skipped - Grey Big Fink T/S
57	Bottom Hill Twin Reservoirs	-527	"		57 & 57A	13519105	4286371	Grey Big Fink T/S
58	Midway Up Hill	-595	"		58 & 58A	13519096	4286358	Grey Big Fink T/S Midway Up Hill
59	Top of Hill	-520	"		59 & 59A	13519084	4286331	Last Grey Big Fink T/S Before Fink at Top of Hill

Annex A
Thumbnail Pictures


WTS - 21A


WTS - 22


WTS - 22A


WTS - 23


WTS - 23A


WTS - 24


WTS - 24A


WTS - 25


WTS - 25A


WTS - 26


WTS - 26A


WTS - 27


WTS - 27A


WTS - 28


WTS - 28A


WTS - 29


WTS - 29A


WTS - 30


WTS - 30A


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WTS - 31A


WTS - 32


WTS - 32A


WTS - 33


WTS - 33A


WTS - 34


WTS - 34A


WTS - 35


WTS - 35A


WTS - 36


WTS - 36A


WTS - 37


WTS - 37A


WTS - 38


WTS - 38A


WTS - 39
WTS - 39A
WTS - 40
WTS - 40A
WTS - 41
WTS - 41A
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WTS - 54
WTS - 54A
WTS - 55
WTS - 55A
WTS - 56
WTS - 56A
WTS - 57

WTS - 57A

WTS - 58

WTS - 58A

WTS - 59

ANNEX B

16” WATER MAIN PARALLEL TO BROWN RD FROM TITUS BLVD TO 10TH SPECIAL FORCES COMPLEX

New 16" ductile iron water on east loop for 10th Special Forces Group.

BTS #	LOCATION	10/05 P/S (Neg mV's)	PIPE TYPE	MAP #	PICTURES	GPS E	GPS N	COMMENTS
1	N. side Titus Blvd. - BLK #12 + RED #12	-903	16" DI		1 - 1A	13519075	4286011	Grey Big Fink PMTS - N/W Brown Rd. – substation Proposed RMU site
	RED #12 + WHT #12	-795						Glen 4 FMTS
2	S. side Titus Blvd.	-589			2 - 2A	13519059	4285918	Glen 4 FMTS - W. of Brown Rd.
3	S. of above T/S	-698			3 - 3A	13519097	4285838	**Glen 4 FMTS- Proposed RMU site**
4	"	-619			4 - 4A	13519137	4285756	Glen 4 FMTS
5	"	-658			5 - 5A	13519189	4285681	Glen 4 FMTS
6	N Side of Creek	-619			6 - 6A	13519263	4285417	**Glen 4 FMTS- Proposed RMU site**
	FH # 9200 in Field S of Creek	-464						
7	S. Edge Bad Toelz Rd. - YEL #12 + WHT #12	-764						**Glen 4 FMTS- Proposed RMU site**
	2 X BLK #12	-730						
	WHT #12	-740						
8	S Side of Bad N of Tank Trails	-921			8 + 9 - 8A + 9A	13519317	4285243	Glen 4 FMTS
9	S Side of Bad N of Tank Trails	-921			8 + 9 - 8A + 9A	13519317	4285243	Glen 4 FMTS

Annex B
Thumbnail Pictures


BRN VLV VAULT 1


BRN VLV VAULT 4


BRN VLV VAULT 5


BRN VLV VAULT 6


BRN VLV VAULT 7


BTS - 1


BTS - 1A


BTS - 2


BTS - 2A


BTS - 3


BTS - 3A


BTS - 4


BTS - 4A


BTS - 5


BTS - 5A


BTS - 6


BTS - 6A


BTS - 8 + 9


BTS - 8A + 9A

ANNEX C

MISCELLANEOUS WATER MAINS

MISCELLANEOUS WATER MAINS

MTS #	LOCATION	10/05 P/S (Neg mV's)	PIPE TYPE	MAP #	PICTURES	GPS E	GPS N	COMMENTS
1	In Field Between Titus & Hospital	-1072	12" DI	307	1 & 1A	13517825	4285656	Blue Big Fink T/S PROPOSED RMU SITE
2	So Bldg 3703 in Field	-673			2 & 2A	13521908	4286444	Orange Big Fink T/S PROPOSED RMU SITE
3	SW Bldg 3703	-353			3 & 3A	13522046	4286535	Orange Big Fink T/S PROPOSED RMU SITE
4	E Side of Specker - ~10' E of FH 520C	-1292			4 & 4A	13517376	4289443	Glen 4 Flush T/S PROPOSED RMU SITE
5	N/E Fire Hyd #00501C N of Motor Pool Bldg	-1302			5 & 5A	13517381	4289564	Glen 4 Flush T/S PROPOSED RMU SITE
6	W of Fink W of Motor Pool Bldg	-1037			6 & 6A	13517381	4289442	Glen 4 Flush T/S PROPOSED RMU SITE
7	S of Bldg 520 X FH 520A	-1272			7 & 7A	13517630	4289421	Glen 4 Flush T/S PROPOSED RMU SITE
8	NW RR BLDG 238 X FH	-963			8 & 8A	13517550	4290215	Glen 4 Flush T/S PROPOSED RMU SITE
9	SE Crn Shed NW of Motor Pool	-1270			9 & 9A	13517339	4289547	Glen 4 Flush T/S PROPOSED RMU SITE
10	Across Intersection at Nelson & Specker x Backflow Preventers	-972			10 & 10A	13518178	4288135	Mini Glen 4 Flush T/S PROPOSED RMU SITE
11	W of Bad Tolez Rd W of Bldg 7404	-1380			11 & 11A	13518178	4285673	Glen 4 Flush T/S PROPOSED RMU SITE
12	SW Crn Bldg 7404	-700			12 & 12A	13518633	4285428	Glen 4 FMTS (Busted Cvr) PROPOSED RMU SITE
13	W Side of Ent to SeaBees Bldg 9271	-546			13 & 13A	13519504	4283603	Busted Ground Level Blue Big Fink T/S PROPOSED RMU SITE
14	SE Crn Shoppette at Butts Airfield	-627			14 & 14A	13520499	4280994	Glen 4 Flush T/S PROPOSED RMU SITE

Annex C continued

MTS #	LOCATION	10/05 P/S (Neg mV's)	PIPE TYPE	MAP #	PICTURES	GPS E	GPS N	COMMENTS
15	On Airfield Rd SE of Bldg 9638 at Butts Airfield	-942			15 & 15A	13520439	4281041	Glen 4 Flush T/S PROPOSED RMU SITE
16	E Side of Bldg 7400 x FH7400	-1327			16 & 16A	13518679	4285648	Glen 4 Flush T/S PROPOSED RMU SITE
17	IN Front of Golf Clubhouse x FH -Yl TL	-477				13516677	4285195	Glen 4 Flush T/S - Anode Not Connected?
	Blk TL	-1545						
18	Titus & St Lo	-940				13518869	4286009	Grey BFPMTS
19	Along McGrath across from Bldg 1662 - Blk	-1493			19 & 19A	13518992	4288356	Glen 4 Flush T/S
	2 x Bl TL's	-593						
20	Along McGrath across from Bldg 1662 - Blk	-1471			20 & 20A	13518991	4288358	Glen 4 Flush T/S
	2 x Bl TL's	-596						
21	Along McGrath across from Bldg 1661 - Blk	-1593			21 & 21A	13518930	4288445	Glen 4 Flush T/S
	2 x Blk TL's	-863						
22	Crn McGrath & Nelson across from Bldg 1660 - Blk	-1601			22 & 22A	13518885	4288520	Glen 4 Flush T/S
	2 x Blk TL's	-842						
23	Crn McGrath & Nelson across from Bldg 1660 - Blk	-1606			23 & 23A	13518862	4288555	Glen 4 Flush T/S
	2 x Blk TL's	-851						
24	Along McGrath across from Bldg 1369 - Blk	-1619			24 & 24A	13518861	4288556	Glen 4 Flush T/S
	2 x Blk TL's	-826						

Annex C continued

MTS #	LOCATION	10/05 P/S (Neg mV's)	PIPE TYPE	MAP #	PICTURES	GPS E	GPS N	COMMENTS
25	Along McGrath across from Bldg 1369 - Blk	-1598			25 & 25A	13518819	4288623	Glen 4 Flush T/S
	2 x Bl TL's	-851						
26	Along McGrath across from Bldg 1369 - Blk	-1593			26 & 26A	13518818	4288622	Glen 4 Flush T/S
	2 x Blk TL's	-853						
27	Along McGrath across from Bldg 1368 - Blk	-1508			27 & 27A	13518800	4288651	Glen 4 Flush T/S
	2 x Bl TL's	-863						
28	Along McGrath across from Bldg 1368 - Blk	-1515			28 & 28A	13518809	4288657	Glen 4 Flush T/S
	2 x Blk TL's	-893						
29	Along McGrath - Blk	-1601			29 & 29A	13518756	4288732	Glen 4 Flush T/S
	2 x Blk TL's	-890						
30	Along McGrath x Gate - Blk	-1599			30 & 30A	13518729	4288768	Glen 4 Flush T/S
	2 x Blk TL's	-884						
31	Along McGrath x Gate - Blk	-1602			31 & 31A	13518728	4288772	Glen 4 Flush T/S
	2 x Blk TL's	-890						
32	Along McGrath across from Bldg 1362 - Blk	-1611			32 & 32A	13518696	4288831	Glen 4 Flush T/S
	2 x Blk TL's	-861						
33	Along McGrath across from Bldg 1362 - Blk	-1621			33 & 33A	13518703	4288833	Glen 4 Flush T/S
	2 x Blk TL's	-869						
34	Along McGrath across from Bldg 1360 - Blk	-1600			34 & 34A	13518639	4288915	Glen 4 Flush T/S
	2 x Bl TL's	-872						

Annex C continued

MTS #	LOCATION	10/05 P/S (Neg mV's)	PIPE TYPE	MAP #	PICTURES	GPS E	GPS N	COMMENTS
35	Along McGrath across from Bldg 1360 - Blk	-1603			35 & 35A	13518643	4288920	Glen 4 Flush T/S
	2 x Bl TL's	-891						
36	Along Titus	-846			36 & 36A	13518274	4285958	Grey BFPMTS
37	Along Titus	-912			37 & 37A	13518370	4286174	Grey BFPMTS
38	Along Titus	-870			38 & 38A	13518476	4286280	Grey BFPMTS
39	Along Titus	-876			39 & 39A	13518582	4286386	Grey BFPMTS
40	Along Titus	-904			40 & 40A	13518688	4286492	Grey BFPMTS
41	Along Titus	-901			41 & 41A	13518794	4286598	Grey BFPMTS

Annex C
Thumbnail Pictures


MTS - 26A
MTS - 27
MTS - 27A
MTS - 28
MTS - 29
MTS - 29A
MTS - 30
MTS - 30A
MTS - 31
MTS - 31A
MTS - 32
MTS - 32A
MTS - 33
MTS - 33A
MTS - 34
MTS - 34A
MTS - 35
MTS - 35A
MTS - 36
MTS - 36A
MTS - 37
MTS - 37A
MTS - 38
MTS - 38A
MTS - 39
MTS - 39A
MTS - 40
MTS - 40A
MTS - 41
MTS - 41A

ANNEX D

VARIOUS NATURAL GAS MAINS

VARIOUS NATURAL GAS MAINS

GTS #	LOCATION	10/05 P/S (Neg mV's)	PIPE TYPE	MAP #	PICTURES	GPS E	GPS N	COMMENTS
1	95' W. Old Gas Pits 1 & 2	-947	10" Steel	0301	1 - 1A	13517904	4290509	O.L.F. T/S . PROPOSED RMU SITE
2	Gas Pit 3	-910	"	"	2 - 2A	13517905	4290504	O.L.F. T/S . PROPOSED RMU SITE
3	N/E Gas Pit 29	-1085	8" Steel	0505	3 - 3A	13519399	4286958	Inside fenced track– O.L.F. PROPOSED RMU SITE
4	Gas Pit 29	-854	"	0506	4 - 4A	13519371	4286878	27' West Gas Pit 29 O.L.F. T/S PROPOSED RMU SITE
5	East Gas Pit 10	-873	"	"	5 - 5A	13519265	4286763	O.L.F. T/S . PROPOSED RMU SITE
6	2' west of Gas Pit 11 – 10A	-885	"	"	6 - 6A	13518981	4286535	O.L.F. T/S . PROPOSED RMU SITE
7	2' West Gas Pit 12	-858	6" Steel	"	7 - 7A	13518754	4286478	O.L.F. T/S . PROPOSED RMU SITE
8	5' East Gas Pit 24	-865	"	"	8 - 8A	13518186	4286489	O.L.F. T/S . PROPOSED RMU SITE
9	Between Gas Pit 11 & 12	-994	"	"	9 - 9A	13518890	4286496	Gas Main going to B.A.A.F. PROPOSED RMU SITE
10	Crow's Foot	-908	4" Steel	508	10 - 10A	13519256	4285355	O.L.F. T/S . PROPOSED RMU SITE
11	N/E crn Seabees Bldg. 9271	-953	"	FIND MAP#	11 - 11A	13519515	4283674	O.L.F. T/S . PROPOSED RMU SITE
12	B.A.A.F. Entrance	-954	"	"	12 - 12A	13519351	4284930	O.L.F. T/S . PROPOSED RMU SITE
13	PDO Sal vage Ya rd (Specker & Wickersham)	-1420	"	"	13 - 13A	13517478	4290164	O.L.F. T/S . PROPOSED RMU SITE
14	West Side Gas Pit 14	-892	6" Steel	"	14 - 14A	13517475	4289764	F/M T/S West Side Gas Pit PROPOSED RMU SITE
15	2nd OLF T/S South of Gas Pit 14	-942			15 - 15A	13517514	4289554	W Specker E Motorpool 501 .O.L.F. T/S . PROPOSED RMU SITE
16	68' North Gas Pit 16	-954	"	"	16 - 16A	13517248	4289047	O.L.F. T/S . PROPOSED RMU SITE
17	3' East Gas Pit 18	-877	8" Steel	"	17 - 17A	13517379	4288562	O.L.F. T/S . PROPOSED RMU SITE

Annex D continued

GTS #	LOCATION	10/05 P/S (Neg mV's)	PIPE TYPE	MAP #	PICTURES	GPS E	GPS N	COMMENTS
18	Ellis & Ch iles (SW corner & west of Gully)	-943	"	0304	18 - 18A	13517471	4288370	O.L.F. T/S South Side Ellis St. . PROPOSED RMU SITE
19	Gas Pit 21	-1216	6" Steel	0306	19 - 19A	13518178	4286877	O.L.F. T/S . PROPOSED RMU SITE
20	1st TS N of Gas Pit 23	-1366	"	"	20 - 20A	13518178	4286518	O.L.F. T/S . PROPOSED RMU SITE
21	5' S Side of Pit 24	-656	"	"	21 - 21A	13518188	4286496	O.L.F. T/S . PROPOSED RMU SITE
22	5' N of Gas Pit 26	-1100	"	307	22 - 22A	13518183	4286066	O.L.F. T/S . PROPOSED RMU SITE
23	W Side Sheridan W of Tree Line in Pa rk Across from Gas Pit 21	-1293	"	305	23 - 23A	13518143	4286881	O.L.F. T/S . PROPOSED RMU SITE
24	51' N/ W Gas Pi t 33 (NE of Tenn is Crt in Park)	-1307	"	"	24 - 24A	13518274	4287014	O.L.F. T/S . PROPOSED RMU SITE
25	N Edge Old Helo Pad	-1231	"	"	25 - 25A	13517731	4287186	O.L.F. T/S . PROPOSED RMU SITE
26	Across Rd from Range 63	-1082			26 - 26A	13519355	4284124	O.L.F. T/S **.**
27	Across From Range Control Complex	-1093			27 - 27A	13519498	4281865	1 of 2 O.L.F. T/S **.**
28	Across From Range Control Complex	-1062			28 - 28A	13519499	4281867	2 of 2 O.L.F. T/S **.**
29	By Bldg K Across Rd from Range 55	-1106			29- 29A	13519529	4283306	O.L.F. T/S **.**
30	By Trees Across Rd from Range 55	-1003			30 - 30A	13519538	4283128	O.L.F. T/S **.**
31	Crn of Sheridan & Titus - 2 x Red TL's	-1110			31 - 31A	13518177	4285953	O.L.F. T/S **.**
	2 x Red TL's	-945						

Annex D continued

GTS #	LOCATION	10/05 P/S (Neg mV's)	PIPE TYPE	MAP #	PICTURES	GPS E	GPS N	COMMENTS
32	Along Sheridan - 2 x Red TL's	-1191			32 - 32A	13518167	4286122	O.L.F. T/S .
	2 x Red TL's	-912						
33	Along Sheridan - Red TL	-1161			33 - 33A	13518157	4286291	O.L.F. T/S .
	Grn TL	-908						
34	Along Sheridan - Yl-Grn TL	-1365			34 - 34A	13518136	4286460	O.L.F. T/S .
	Blue TL	-911						
35	Along Sheridan - Blk TL	-891			35 - 35A	13518133	4286529	O.L.F. T/S .
	Bk-Grn TL	-1393						
36	Along Sheridan - Blk TL	-890			36 - 36A	1351822	4286688	O.L.F. T/S .
	Bk-Grn TL	-1298						
37	Along Sheridan Befor St Lo - Blk TL	-1288			37 - 37A	1351812	4286824	O.L.F. T/S .
	Red TL	-853						
38	Along Sheridan - Red TL	-984			38 - 38A	1351798	4286955	O.L.F. T/S .
	Grn TL	-1293						
39	Along Sheridan - Bl TL	-903			39 - 39A	1351781	4286993	O.L.F. T/S .
	Yl TL	-903						
40	Along Sheridan - Blk TL	-1368			40 - 40A	1351761	428712	O.L.F. T/S .
	Bl-Grn TL	-980						

Annex D continued								
GTS #	**LOCATION**	**10/05 P/S (Neg mV's)**	**PIPE TYPE**	**MAP #**	**PICTURES**	**GPS E**	**GPS N**	**COMMENTS**
41	Along Sheridan - Yl TL	-1380			41 - 41A	1351742	428729	O.L.F. T/S .
	Bl-Grn TL	-901						
42	Along Sheridan - Bl TL	-1406			42 - 42A	1351731	428743	O.L.F. T/S .
	Bl-Grn TL	-871						
43	Along Sheridan - Bl TL	-1401			43 - 43A	1351712	428756	O.L.F. T/S .
	Yl-Grn TL	-863						
44	Along Sheridan Just Before Pit 21- Yl TL	NA			44 - 44A	1351690	428769	O.L.F. T/S .

Annex D
Thumbnail Pictures


GTS - 18A


GTS - 19


GTS - 19A


GTS - 20


GTS - 20A


GTS - 21


GTS - 21A


GTS - 22


GTS - 22A


GTS - 23


GTS - 23A


GTS - 24


GTS - 24A


GTS - 25


GTS - 25A


GTS - 26


GTS - 26A


GTS - 27


GTS - 27A


GTS - 28


GTS - 28A


GTS - 29


GTS - 29A


GTS - 30


GTS - 30A


GTS - 31


GTS - 31A


GTS - 32


GTS - 32A


GTS - 33


GTS - 33A


GTS - 34


GTS - 34A


GTS - 35


GTS - 35A

GTS - 36

GTS - 36A

GTS - 37

GTS - 37A

GTS - 38

GTS - 38A

GTS - 39

GTS - 39A

GTS - 40

GTS - 40A

GTS - 41

GTS - 41A

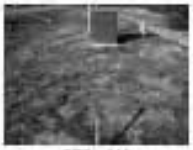
GTS - 42

GTS - 42A

GTS - 43

GTS - 43A

GTS - 44



GTS - 44A

ANNEX E
SEWER MAIN

SEWER MAIN

STS #	LOCATION	10/05 P/S (Neg mV's)	PIPE TYPE	MAP #	PICTURES	GPS E	GPS N	COMMENTS
1	Across Rt 5 from Range 57	-1123	Sewer Rd Csng		1 - 1A	13519529	4283550	Handley Flush T/S PROPOSED RMU SITE
2	Edge of road by Bldg E	-898	Sewer Rd Csng		2 - 2A	13519554	4283369	Handley Flush T/S PROPOSED RMU SITE
3	By Hazardous Waster Ent Across Rt 5 from Range 51	-611	Sewer Rd Csng		3 - 3A	13519553	4282754	Handley Flush T/S PROPOSED RMU SITE

Annex E
Thumbnail Pictures


STS 1


STS 1A


STS 2


STS 2A


STS 3


STS 3A

ANNEX F

600,000 GALLON AND 1,000,000 GALLON WATER RESERVOIRS

WATER RESERVOIRS

RES #	LOCATION	09/27 P/S (Neg mV's)		MAP #	PICTURES
		ON	OFF		
RES 1	600,000 GALLON AT RECTIFIERS	-768	-630		R01
RES 2	40' CC FROM RES 1	-800	-700		
RES 3	40' CC FROM RES 2	-750	-652		
RES 4	40' CC FROM RES 3	-789	-676		
RES 5	40' CC FROM RES 4	-759	-642		
RES 6	1,000,000 GALLON AT RECTIFIERS	-2749	-1004		R02
RES 7	62' CC FROM RES 6	-2678	-984		
RES 8	62' CC FROM RES 7	-2321	-872		
RES 9	62' CC FROM RES 8	-2366	-868		
RES 10	62' CC FROM RES 9	-2317	-860		

ANNEX G

OPERATIONAL RECTIFIERS AT FT. CARSON

OPERATIONAL RECTIFER LIST

RECT #	LOCATION		M/N	S/N	OUTPUT E	SHUNT I	PICTURES	GPS E	GPS N
	600,000 GALLON RESEVOIR-INTERNAL	INTERNAL OF 600,000 GALLON WATER TANK	CORRPRO		2	0.01	R01		
	600,000 GALLON RESEVOIR-EXTERNAL	EXTERNAL OF 600,000 GALLON WATER TANK	CORRPRO		2.2	1.93	R01		
	TANK 7900 1,000,000 GALLON RESEVOIR-INTERNAL	INTERNAL OF 1,000,000 GALLON WATER TANK	CORRPRO		2.28	0	R02		
	TANK 7900 1,000,000 GALLON RESEVOIR-EXTERNAL	EXTERNAL OF 1,000,000 GALLON WATER TANK	CORRPRO		8.4	8.34	R02		
	Tank 2401 TWIN RESERVOIR-INTERNAL	INTERNAL OF 1,000,000 GALLON WATER TANK	CORRPRO	C-0501211					
	TANK 2401 TWIN RESERVOIRS-EXTERNAL	EXTERNAL OF 1,000,000 GALLON WATER TANK	CORRPRO	C-020724					
	TANK 2402 TWIN RESERVOIR-INTERNAL	INTERNAL OF 1,000,000 GALLON WATER TANK	CORRPRO	C-050120					
	TANK 2402 TWIN RESERVOIR-EXTERNAL	EXTERNAL OF 1,000,000 GALLON WATER TANK	CORRPRO	C-033218					
	SOUTH OF TANK 7900 ON RESERVOIR ROAD	WATER MAINS	CORRPRO				R03		
	HARR ROAD GOLF COURSE	WATER MAINS	CORRPRO				RO5		
	TITUS AND SHERIDAN	WATER AND GAS MAINS	CORRPRO				R06		
	TITUS AT SR. OFFICERS HOUSING	WATER MAINS	CORRPRO				RO7		
R-5	7500 EVANS HOSPITAL	FIRE MAINS (INOPERATIVE)	PEM				R05		
R-6	7500 EVANS HOSPITAL	STEAM, GAS, AND WATER MAINS	PEM				R05		
R-7	7500 EVANS HOSPITAL	FIRE MAINS	PEM				R05		

Annex G Continured									
RECT #	**LOCATION**		**M/N**	**S/N**	**OUTPUT E**	**SHUNT I**	**PICTURES**	**GPS E**	**GPS N**
	MOTOR POOL 800O SOUTH	FIRE MAINS	UNIVERSAL				R08		
	MOTOR POOL 800O EAST	FIRE MAINS	UNIVERSAL				R09		
	HEATING PLANT 9609 BUTZ AIRFIELD	STEAMLINES	CORRPRO						
16	RANGE 131/ 135	WATER WELL CASING	GOODALL	82J1317	9.86	0.04	R16 - R16C	13515857	4274122
17	SOUTH RED DEVIL RD	WATER WELL CASING	GOODALL	82J1316	9.7	1.56	R17 - R17C	13507744	4261064
18	ROAD 14A	WATER WELL CASING	GOODALL	82J1314	5.42	1.3	18 - 18A	13519553	4282754

Annex G
Thumbnail Pictures

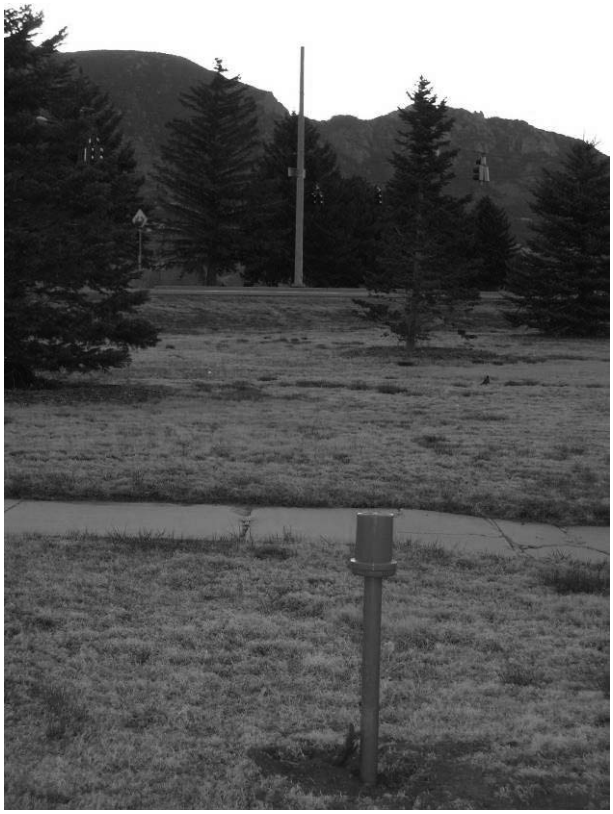
Appendix C: TSDMU and RDMU Locations

Confidential To:
Jim Bushman
BUSHMAN ASC

FT CARSON ARMY BASE
DART INSPECTION
MANUAL RECTIFIER LOG

GPS-N	GPS-W	LOCATIONS	RECTIFIER	DCV	DCA	Mv	SHUNT RATING	PDA	COMMENTS
38.43875	104.7779333	RECTIFIER DOWN RANGE 14A	GOODALL - S/N 82J1314			50 mV = 10 Amp			
38.49976667	104.9116333	RECTIFIER DOWN RANGE RED DEVIL	GOODALL - S/N 82J1316			50 mV = 10 Amp			
38.61726667	104.8184167	RECTIFIER DOWN RANGE 131	GOODALL - S/N 82J1317			50 mV = 10 Amp			
38.67896667	104.7634167	RECTIFIER BUTZ HEATING PLANT BLDG 96	RTS - S/N: C-982737			50 mV = 50 Amp			
38.68063333	104.7653	RECTIFIER DEEP ANODE BAAF BLDG 9611	IRT - S/N: O5R-1057						Rectifier Not Operating
38.70436667	104.7994667	RECTIFIER DEEP ANODE TITUS AND HARR	IRT - S/N: O5R-1059			50 mV = 40 Amp			
38.71808333	104.7963333	RECTIFIER HOSPITAL # R6 (Inside Bldg)	PEM - S/N: 83B109			50 mV = 5 Amp			
38.71808333	104.7963333	RECTIFIER HOSPITAL # R7 (Inside Bldg)	PEM - S/N: 83D109			50 mV = 5 Amp			Anodes Not Connected
38.7216	104.7799167	RECTIFIER DEEP ANODE BROWN AND TIT	IRT - S/N: O5R-1060			50 mV = 40 Amp			
38.72446667	104.7913833	RECTIFIER SHERIDAN NORTH OF TITUS	GOODALL - S/N 82C2324			50 mV = 30 Amp			
38.7247	104.80265	RECTIFIER GOLF COURSE	GOODALL - S/N 82C2323			50 mV = 60 Amp			3011 replaced 3012 by Borin
38.72703333	104.7807	TANK 2401 INTERNAL	GOODALL - S/N TASCA 30-8 CJ				LED Digital		
38.72703333	104.7807	TWIN MILLION WATER TANK 2401	WESTERN - S/N: O5H-109			50 mV = 50 Amp			
38.7271	104.7811667	TWIN MILLION WATER TANK 2402	WESTERN - S/N: O5H-108			50 mV = 50 Amp			
38.7271	104.7811667	TANK 2402 INTERIOR	CORRP0WER - S/N: C033218				LED Digital		
38.72721667	104.8146167	RECTIFIER DEEP ANODE 600,000 (Waterlin	IRT - S/N: O5R-1058			50 mV = 40 Amp			
38.72721667	104.8146167	RECTIFIER TANK 600,000 BOTTOM	CORRP0WER - S/N: C011996			LED 10mV = 1 Amp			Rectifer Turned OFF 6-19-06
38.72721667	104.8146167	TANK 600 K INTERIOR	CORRP0WER - S/N: C011946				LED Digital		
38.72833333	104.8099667	RECTIFIER 1MM TANK BOTTOM #7901	UNIVERSAL - S/N 011253			50 mV = 15 Amp			
38.72833333	104.8099667	TANK 7901 INTERIOR	UNIVERSAL - S/N 010436				LED Digital		
38.72881667	104.80715	RECTIFIER WATERLINE TO WATER TANK 7	GOODALL - S/N 80W2515			50 mV = 25 Amp			
38.73176667	104.78345	RECTIFIER DEEP ANODE WETZEL & MISTE	Did Not Access						Rectifier Not Operating
38.75591667	104.7826333	MOTOR POOL 8000 BLDG SOUTH RECT	UNIVERSAL - S/N 96105A			50 mV = 10 Amp			
38.75695	104.7818333	MOTOR POOL 8000 BLDG EAST RECT	UNIVERSAL - S/N 96105B			50 mV = 10 Amp			
38.75828333	104.7933333	RECTIFIER DEEP ANODE GAS PIT 5	IRT - S/N: O5R-1058			50 mV = 40 Amp			
38.89091667	104.7847	SRO HOUSING RECTIFIER	CORRP0WER - S/N: C000675			50 mV = 20 Amp			

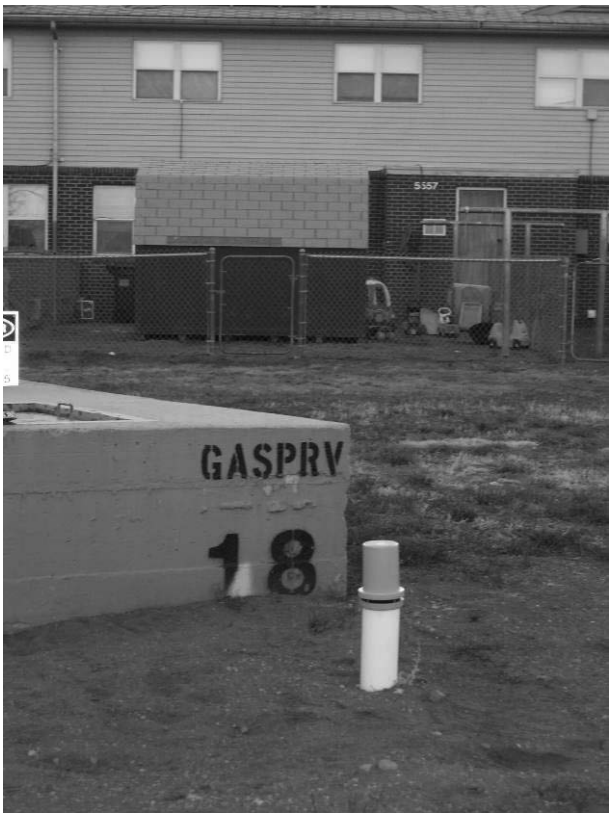
Appendix D: Representative Photographs of Installed TSDMUs



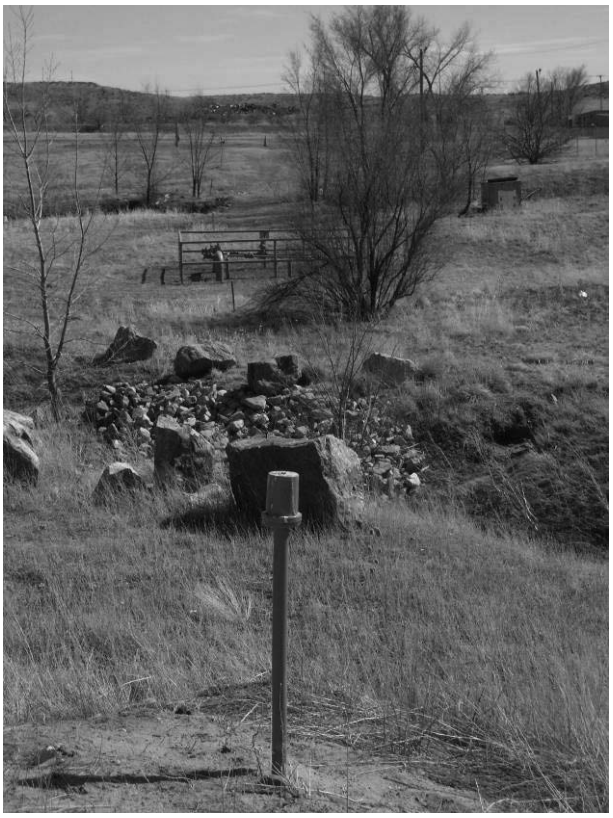

GAS
PIT
4

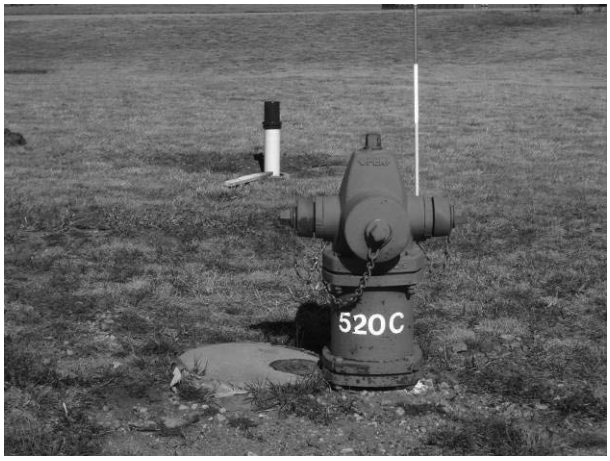

GAS PRV 24


DANGER

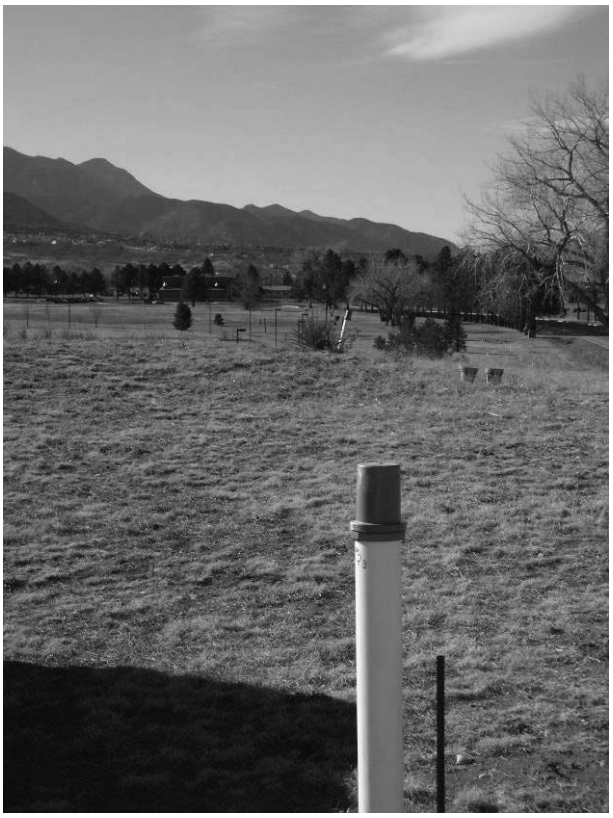

5557
GASPRV
18

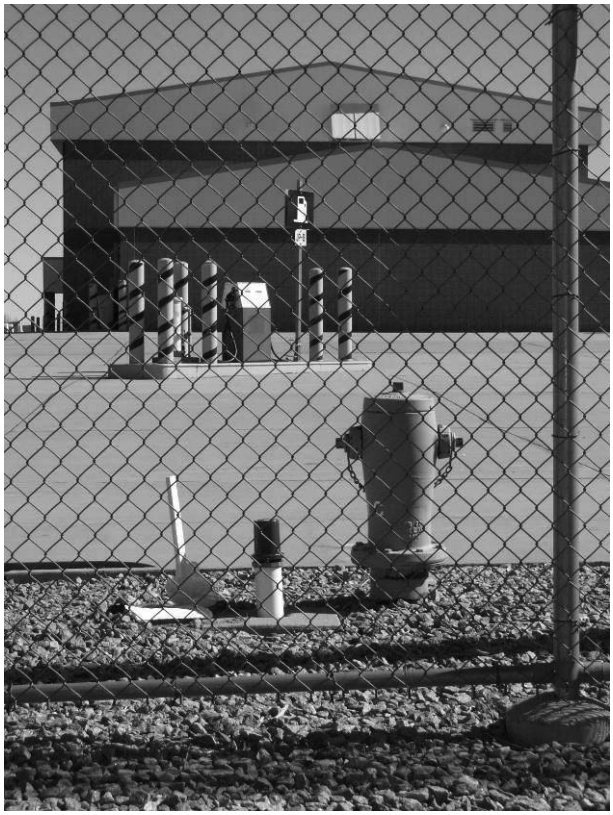

520A




520C


DANGER
HIGH PRESSURE
- GAS LINE -






DANGER
DANGER


Housing/Temp L
Elkhorn Conferen
Legal Ofc/Courtroor
Tax Center 628 4

Appendix E: Rectifier Manual and Specifications

CONSTANT VOLTAGE MANUAL TYPE CATHODIC PROTECTION RECTIFIER

INSTALLATION, OPERATION, & MAINTENANCE MANUAL

INTEGRATED RECTIFIER TECHNOLOGIES, INC.
15360 – 116 Avenue, Edmonton, Alberta, Canada T5M 3Z6
Phone: (780) 447-1114 Fax: (780) 454-0004 Email: sales@irtrectifier.com

INDEX

INTRODUCTION

Corrosion of underground structures (pipelines, well casings, etc.) is a process that occurs every minute of every day. As such, continuous protection is required to effectively prevent damage that could cost a company significantly in lost revenues, manpower, and equipment. The proper selection, installation, and operation of a suitable corrosion prevention system can be crucial to ensure that this costly damage does not occur. For well-coated structures, structures with small surface areas, or where minimal Cathodic Protection is required, a “sacrificial” type corrosion prevention system may be used. For poorly coated structures, structures with large surface areas, or where a larger amount of Cathodic Protection is required, an “impressed current” type corrosion prevention system is required. One key component of an impressed current corrosion protection system is a Cathodic Protection rectifier. A rectifier is a device that is used to convert “alternating current” (AC), as provided by the power utility, to “direct current” (DC), as is required for Cathodic Protection. The rectifier should be selected based on the type of control required for the specific application, the amount of Cathodic Protection required to provide effective protection, and the reliability of operation in the subject environment. IRT Integrated Rectifier Technologies, Inc. manufactures Cathodic Protection rectifiers that exceed industry standards for superior corrosion prevention and, as such, an IRT rectifier unit is a smart investment for any company.

IRT Integrated Rectifier Technologies, Inc. Cathodic Protection rectifiers and associated products are designed by a knowledgeable engineering team with years of experience in the corrosion field and manufactured by skilled technicians with a dedication to quality. The IRT units are designed with superior components to provide a high quality, reliable rectifier with an economic cost for your application. IRT maintains a large volume of in-stock components and sub-assemblies to ensure that orders can be shipped to you in the shortest time frame possible.

IRT products are sold and serviced by leading corrosion prevention engineering companies throughout North America and Internationally. These companies have superior expertise in the corrosion industry and have the personnel to meet all of your corrosion prevention system requirements including design, installation, and maintenance. IRT products are also available through leading material supply companies throughout North America.

Rectifiers manufactured by Integrated Rectifier Technologies, Inc. are guaranteed against defects in design, workmanship, or material for a period of one year from the time of shipment from our facility. Please refer to our warranty statement for further details.

DELIVERY INSPECTION

Although the rectifier unit may not be scheduled for immediate installation, we recommend that it be thoroughly inspected, both externally and internally, upon receipt to ensure that no damage has occurred during shipment. Please remember that although the outside of the rectifier packaging may not show any signs of damage, there may be internal damage that will not be apparent until the outer packaging is removed. Any damage, whether internal or external, must be reported to the freight carrier immediately. If any damage has occurred during shipment; an indication of this should made on the freight paperwork, the shipment

should then be accepted, and a claim filed with the freight carrier. Please ensure to retain the original packaging that may indicate how the damage occurred.

If damage has occurred during shipment and repairs or a return to the factory is required, please contact us, or your local IRT distributor, with the Serial Number and the Model Number of the rectifier. This information is crucial for us to determine the rectifier unit in question and to be able to provide suitable assistance. An RMA number must be obtained from the factory prior to return of any damaged rectifier units.

PRE-INSTALLATION STORAGE

If the rectifier unit is to be stored prior to installation, it is recommended that it be stored in a dry area, preferably indoors. If the unit is to be stored outdoors for an extended period of time, it is recommended that it be placed on a raised surface (pallet or platform) and covered with a protective sheet or tarp to ensure the packaging does not deteriorate due to rain or snow. Whether stored indoors or outdoors, the unit should be placed in an area where it is protected from accidental damage from moving vehicles or equipment. Ensure that the rectifier unit is transferred to and from the storage facility using proper handling techniques.

SAFETY PRACTICES

As Cathodic Protection rectifiers are connected to the AC utility power, electrical shock hazards are present within the rectifier units. It is recommended that only qualified electronic or electrical personnel operate and maintain these units and that those personnel familiarize themselves with the areas of possible hazard within the unit. Following these practices can enhance the safety of personnel.

1.) Prior to site maintenance or inspection, familiarize yourself with the rectifier and conditions at the site.

2.) Prior to doing any maintenance or troubleshooting on a rectifier unit, familiarize yourself with any possible hazard points within the unit by reviewing the electrical schematic and the physical layout of the rectifier.

3.) Whenever possible, set the AC disconnect from the power utility to the “OFF” position prior to starting any work on the rectifier unit. Even with the rectifier AC input circuit breaker in the “OFF” position, hazardous voltages are still present at any terminals connected to the rectifier AC input terminals. Always tag and lock out the disconnect to ensure others do not energize it while you are completing the rectifier work.

4.) Prior to opening the rectifier enclosure door, lightly touch the back of your hand to the enclosure latch. If you feel an electrical tingle, set the fused AC disconnect to the “OFF” position and contact an electrician for assistance.

5.) When taking readings across the rectifier terminals, it is recommended to use only one hand, if possible.

GENERAL INSTALLATION TIPS

To ensure reliable, long-term operation of the Cathodic Protection rectifier, proper installation of the unit is required. Though most installation sites differ, there are several key guidelines that should be followed.

a) Prior to installation, check the connections (especially the electrical connections) on the rectifier unit to ensure that nothing has become loose during shipment. It is also recommended that if any scratches occur to the enclosure during installation, that these points be touched-up to prevent corrosion on the enclosure.

b) Selecting the site of installation is a very important factor. The rectifier should be installed in a location that is easily accessible by company personnel for regular adjustment and maintenance. However, it should not be located in areas where unauthorized personnel have easy access to the unit and may damage or vandalize it (i.e. residential areas, playgrounds, farm yards, etc.). The convenient access to AC power and the cathodic protection DC connections must also be considered when choosing the rectifier location.

c) Proper ventilation and cooling of the rectifier unit must be considered when choosing a suitable location. Air-cooled rectifiers are cooled by the natural convection of cool air drawn into the bottom of the rectifier enclosure, passing over the internal components, and the resultant warm air expelled from the top or sides of the enclosure. Oil-cooled rectifiers are cooled by the natural circulation of oil from the bottom to the top of the rectifier tank, over the internal components, and the resultant heat is radiated from the upper walls of the rectifier tank. As such, when choosing the installation site for the rectifier, adequate spacing should be allowed for around the sides of the rectifier unit. The rectifier should not be located near sources of heat such as exhaust vents, power generators, etc. If possible, place the rectifier unit in an area where it will be shaded during the hottest part of the day. If the rectifier is to be installed in an area with a high ambient temperature and minimal natural shading, a protective sunshade is recommended.

d) The rectifier unit should be mounted on a secure surface. Ensure that the wall, pole, frame, or mounting pad is designed to hold the full weight of the rectifier unit.

e) If the rectifier is to be installed in an area subject to frequent lightning activity, upgraded, high-energy type surge arrestors are recommended.

f) Do not install other equipment on or inside the rectifier enclosure without prior consent from the factory. Unauthorized equipment installation will invalidate the rectifier guarantee as IRT has no control of the equipment added or the resultant detrimental affect to proper rectifier cooling / operation.

AC & DC CONNECTION

After the rectifier has been installed in a suitable location, have a qualified electrician connect the rectifier unit to the AC supply following local and national codes. Please note that most electrical codes require a disconnect device between the AC power supply and the rectifier. Ensure that for dual input rectifiers (115 / 230 or 230 / 460 VAC), that the AC input terminal jumpers are properly configured for the actual AC input voltage being supplied and that the AC input wires are connected to the correct AC input terminals.

A grounding rod or rods should be installed as close as possible to the rectifier location but not too close to the AC input or DC output cables. The grounding rod(s) should be connected to the ground lug terminal adjacent to the AC input terminals within the rectifier.

Next, connect the cable(s) from the anode bed to the rectifier positive output lug terminal(s) and the structure cable(s) to the rectifier's negative output lug terminal(s). Ensure that these cables are suitably sized for the expected current and the length of the cable run. Also, it is absolutely imperative that the polarity of DC connections is correct. A reversal of the DC cables can actually cause accelerated corrosion and eventually, severe damage to the structure to be protected.

GENERAL COMPONENT DESCRIPTION

When operating any instrument, it is a good practice to become familiar with the key components and the general operation of that instrument. As such, the key components of a rectifier shall now be reviewed.

The **AC Input Surge Arrestor** is a device that protects the rectifier components from voltage surges that may occur across the AC input of the rectifier. It does this by providing a bypass circuit for the resultant current from these high voltage surges after a specific voltage threshold has been reached. Most surge arrestors are designed to handle a certain number or energy value of surges prior to failing.

The rectifier **AC Input Circuit Breaker** (CB1) is a fully magnetic type that serves three key functions. It is used as an "OFF-ON" switch for the rectifier, it provides "short circuit" protection, and, to a lesser degree, provides input overload protection.

The rectifier **Main Transformer** (T1) provides full electrical isolation between the utility AC power and the Cathodic Protection DC circuit. It also steps the voltage up or down as required for the DC circuit and, for tap type units, provides a means of output adjustment.

The rectifier **AC Secondary Fuse** is a semiconductor or fast-blow type that provides protection from not only short-circuits or overloads in the DC output circuit but also in the diode bridge circuit.

The rectifier **Diode Bridge Assembly** is made up of silicon diodes configured into a full-wave bridge configuration. The diodes are supplied with suitably sized heatsinks to ensure that the diodes do not exceed 100°C at full rated output. The diode bridge is the device that converts the AC secondary voltage of the transformer into DC voltage that can be used for Cathodic Protection.

A **Varistor** is supplied across the AC input to the diode bridge to provide additional protection from any voltage surges that may pass the main AC surge arrestor or be developed by the main transformer. A second varistor may also be supplied across the DC output of the diode bridge at special request.

The **Current Monitoring Shunt** is a block style calibrated resistor with an accuracy of 0.25%. The DC current and voltage rating are stamped into the body of the shunt.

The rectifier **Metering** utilizes an analog, taut-band type movement that provides ±2% accuracy. The DC output amperage of the rectifier is monitored by a meter connection across the calibrated test screws of the above shunt. The DC output voltage of the rectifier is monitored by a meter connection across the DC output terminals of the rectifier.

The **DC Output Surge Arrestor** is a device that protects the rectifier components from voltage surges that may occur across the DC output of the rectifier. It's operation and characteristics are similar to the AC input surge arrestor.

As many optional features / components are available for our customers, it is not practical for this manual to describe all of the possible options in detail. As such, it is recommended that the rectifier data sheet and the electrical schematic be reviewed in detail to become familiar with any features not detailed in this manual.

INITIAL ENERGIZATION

After the rectifier has been properly connected to the AC supply and the DC output cables, it is ready to be energized. However, never take anything for granted. Before energizing, double-check both the AC and DC connections to ensure they are properly connected. Ensure that for dual input rectifiers (115 / 230 or 230 / 460 VAC), that the AC input terminal jumpers are properly configured for the actual AC input voltage being supplied and that the AC input wires are connected to the proper terminals. Also, make sure that the rectifier is at its lowest control setting. For tap-adjust type units, set the tap connections to "Coarse-A" & "Fine-1" and for variable transformer control type units, set the control knob to 0%. For three-phase input type units, ensure that all secondary tap connections are adjusted to the same setting.

At this point, set the AC fused disconnect switch to the "ON" position and measure across the rectifier AC input terminals to ensure the voltage present is as expected. Then set the rectifier AC input circuit breaker also to the "ON" position and verify that there is some deflection on the panel meters (this deflection may be quite minimal). For units with a metering switch, ensure to set the switch to the "ON" position. Next, set the rectifier AC input circuit breaker to

the “OFF” position and adjust the rectifier to a slightly higher output setting. For tap-adjust type units, moving the tap links bars or the AC wire on the adjustment terminal block to setting “Coarse-B” & “Fine-1” will suffice. For variable transformer control type units, setting the control knob to a 20-25% setting on the dial is adequate. Set the circuit breaker to the “ON” position and verify the metering has deflected to a suitable value. If either meter deflects fully to the right, immediately set the rectifier circuit breaker to the “OFF” position and adjust the rectifier to a lower output setting. Also, verify that the DC voltage and current shown on the metering is as expected for the subject output circuit (i.e. structure-to-anode bed resistance). If no problems are evident, the rectifier can be adjusted to the “target” current required to provide a sufficient cathodic protection potential on the output structure. Always set the rectifier circuit breaker to the “OFF” position before adjusting the rectifier.

After the “target” current has been achieved, verify the rectifier metering is showing accurate readings by comparing them to readings taken with an external Digital Volt Meter (DVM). The rectifier on-board voltmeter can be verified by simply measuring the DC voltage across the rectifier DC output lug terminals with the DVM. The rectifier on-board ammeter can be verified by measuring the voltage (in millivolts) across the calibrated test screws of the rectifier shunt (not across the connection bolts). To determine the current through the shunt from the millivolt reading taken, the following formula can be used:

$$\text{DC Current (I)} = \frac{\text{Measured Shunt Voltage (millivolts) X Rated Shunt Current}}{\text{Rated Shunt Voltage (50 millivolts typical)}}$$

Note: Rated shunt current and voltage values are stamped onto the body of the shunt and are also shown on the rectifier data page.

The ammeter can also be verified with an external DC clamp-on type meter, if available.

It is also useful to check the conversion efficiency percentage of the rectifier, which is defined as:

$$\text{Conversion Efficiency (\%)} = \frac{\text{DC Output Voltage X DC Output Amperage X 100\%}}{\text{AC Input Wattage}}$$

The AC input wattage can be obtained by connecting an AC Wattmeter to the AC input of the rectifier. The expected conversion efficiency for a single-phase rectifier with a full-wave silicon diode bridge is approximately 70-75%. For a three-phase rectifier, the expected efficiency would be approximately 90-95%. If the efficiency of the rectifier is significantly lower than these values, this may be an indication of a damaged diode bridge (refer to the “Troubleshooting” section).

It is recommended that all initial energization readings be recorded for future reference. Useful readings to record are structure potential levels prior to energization, AC input voltage & current, DC output voltage and current, tap or adjustment dial setting, conversion efficiency, structure potential levels after energization, as well as any observed problems or possible future concerns with the installation, in general.

After the structure potential readings have been taken and prior to leaving the site, it is recommended that the DC output connections to the rectifier be rechecked to ensure a secure connection. It is also beneficial to recheck the rectifier to ensure that all air inlet and outlet venting on the enclosure is not obstructed in any manner. The rectifier O&M manual should be securely set in it's holder (for small rectifiers without a manual holder, it is recommended that the manual be kept with the main operator or in the control room of the closest station). Also verify that all holes within the enclosure (other than the venting screens) are suitably plugged (such as unused conduit knockouts). For rectifier units with "OFF-ON" meter switches, ensure that the switch is in the "OFF" position prior to leaving the site.

REGULAR MAINTAINANCE & ADJUSTMENT

One of the fundamental formulas to remember when dealing with Cathodic Protection rectifiers is the "Ohm's Law" formula **"Current (I) = Voltage (V) / Resistance (R)"**. As you can see from the formula, if voltage stays constant and resistance varies (up or down), current will also vary (up or down). Now, as the description suggests, the output voltage of a "constant voltage" type rectifier is "constant" (this is true so long as the AC input to the rectifier is constant). As such, with changes in the output circuit (structure-to-anode bed) resistance, the DC output current of the rectifier will also vary. As the resistance between the structure and the anode bed typically varies during the year due to environmental conditions (rain, drought, frost, snow, etc.), if the rectifier DC voltage output is not periodically adjusted to compensate for this phenomenon, the DC output current will not remain at the desired "target" level. Therefore, dependant on the environmental conditions in your area, it is recommended that the rectifier be checked and adjusted as required at least twice per year. Some local regulatory bodies require a monthly or semi-monthly check to ensure proper protection levels are being maintained. These checks also allow you to ensure that the rectifier has not been damaged. When completing this maintenance and adjustment check, it is recommended that all readings and observations be recorded in the site file. With regular maintenance checks and by maintaining good records, future troubleshooting and repair costs can be reduced.

Prior to arriving at the site for the rectifier maintenance check, it is recommended that the technician review the existing rectifier site file to gain familiarization with the subject rectifier and site conditions. Upon arriving at the rectifier site, a visual check should be completed to determine if any changes have occurred. Things to look for are signs of new underground construction, buildings, pipeline tie-ins, bonds, etc. Prior to adjustment of the rectifier, it is recommended that structure potential readings be taken, to determine the adjustment level required. Even if the potential levels are within the required range, the rectifier should still be checked for proper operation.

When approaching the rectifier, ensure that no items have been placed near the rectifier enclosure in such a manner as to block the venting, either on the bottom or sides. As the vent openings on the rectifier enclosure are screened, there should be no refuse inside from birds or larger insects. However, after opening the door of the enclosure, ensure that there has been no significant accumulation of dirt, snow, or other small debris at the bottom of the enclosure, which may adversely affect proper venting.

Prior to any adjustment of the rectifier, measure and record the “As Found” readings of the rectifier (DC voltage, DC amperage, etc.). Next, set the rectifier circuit breaker and the utility disconnect to the “OFF” position to allow for a detailed rectifier inspection.

CAUTION: Please ensure that the utility disconnect is in the “OFF” position prior to any internal rectifier maintenance as hazardous voltages are still present within the rectifier even with the rectifier circuit breaker in the “OFF” position.

At least once a year the rectifier should be inspected for loose electrical connections that could eventually cause damage to the electrical panel, wiring, or rectifier components. If an electrical connection becomes loose, the resistance of the connection increases and causes it to heat up. This additional heat will cause the connection to oxidize and become even higher resistant until a failure occurs. The best way to check for a heated connection is with a temperature probe, however, as these are not typically standard issue for Cathodic field maintenance, the visual inspection method will suffice. First, visually inspect all of the main electrical connections within the rectifier for signs of discoloration on the connection terminal, the electrical panel, or the wire attached to the terminal. Key points to check are the DC output lug terminal connections and the fuse holder connections. If you see a suspect connection, use a wrench or other suitable tools to see if the connection is indeed loose. (Note: Be careful when touching these types of connections with your hand as the temperature of loose high current connections can cause a significant burn.) If you do find a loose connection, it should be secured with suitable tools (ensure to secure both the front and rear of panel connections). If a loose connection has already caused damage to the electrical panel, the panel should be repaired or replaced, as re-tightening a connection on a degraded panel will most likely still lead to a future failure.

Certain main components within the rectifier should also be inspected for signs of over-heating or other damage.

The main isolation transformer (T1) within the rectifier is designed to operate at a fairly high temperature and thus is usually somewhat discoloured. However, it should not be extremely dark or black. If it is, this could indicate insufficient / blocked venting or a problem within the transformer itself.

The AC primary, AC secondary, and the DC output surge arrestors should be checked to ensure that a significant voltage surge has not damaged them. Signs of damage to an arrestor device are usually visually noticeable by a blackened or cracked housing. Please note however that sometimes the operational status of an arrestor is not discernable visually and requires further checking (see Troubleshooting section).

The rectifier fusing should also be checked for overheating. If the fusing is a bolt-on type (for larger rectifier units), ensure that the fastening studs or bolts are secure on both the front and rear. Many smaller rectifier units utilize the “clip-type” fuse connectors that are very convenient for fuse replacement but are also infamous for becoming loose and oxidizing over time. However, with regular checks and maintenance, problems can be avoided. For this type of connection, if oxidation is apparent, the fuse should be removed and both the fuse and the

fuse contact surface of the clips cleaned up with some very fine sand paper or emery cloth (only the oxidation layer should be removed, not the protective coating on the copper). If the fuse clips have lost tension, they should be replaced. If replacements are not immediately available, the clips can be “squeezed” together and should then provide a suitable short-term connection to the fuse. A notation should be made however, in the site inspection form for replacement on the next maintenance check. The connection hardware on each fuse clip should also be checked and re-tightened if necessary.

If, after completing the inspection on the rectifier unit, a problem is found other than just a loose connection, refer to the “Troubleshooting” section of this manual. If no problems have been found, the rectifier can be adjusted to a new DC output setting (if deemed required based on the “as-found” structure potential levels). As per the adjustment procedure indicated in the “Initial Energization” section, adjust the DC output of the rectifier to the level required to provide suitable protection to the structure. If the rectifier is adjusted to or near it’s maximum rated output, future replacement of the rectifier with a larger unit or the addition of anodes may need to be considered. If the required “target” DC output current from the rectifier varies significantly over the year due to soil resistance changes, maintenance checks should be done frequently. As an alternate to this, the rectifier could be replaced with an “automatic, constant current” type rectifier. This type of rectifier would automatically (electronically) adjust the DC output voltage to maintain a constant DC output current in accordance with DC circuit resistance changes.

TROUBLESHOOTING

If a problem is found with the rectifier during the maintenance inspection or reported by the local operator, the following troubleshooting procedure can be followed to determine the cause.

The only way to effectively determine the cause of a failure in any piece of equipment is to conduct a systematic analysis of the function and operation of the key components. For this troubleshooting procedure, we shall review the possible faults that may occur starting from the DC output and working back to the AC input. Please refer to the attached electrical schematic for component descriptions and test points.

CAUTION: Please be advised that hazardous voltages are present within the rectifier unit even with the rectifier AC input circuit breaker in the “OFF” position. Extreme care should be observed when taking measurements on the front of the instrument panel or the side AC input panel. Internal troubleshooting of the rectifier should only be attempted by qualified electronic or electrical technicians. The fused AC disconnect should be set to the “OFF” position prior to any internal rectifier maintenance or repair.

1.) If there is no reading on the rectifier ammeter, ensure to check that there is not a metering switch that must be activated to get a reading on the meter. If there isn’t a metering switch or if the metering switch is activated and there still is no current showing on the meter, the operational status of the ammeter should be verified. This can be done

by measuring the DC voltage across the calibrated test screws of the rectifier shunt or by using an external DC clamp-on type meter, if available. If the shunt measurement or clamp-on indicates that there is no current, continue to the next step. If the measurement indicates that there is current, there is either a problem with the ammeter, the ammeter connection or, if supplied, the ammeter switch. With power to the rectifier “OFF”, trace the ammeter wires from the shunt to the meter itself. Use a Digital Volt Meter (DVM) on the resistance or diode check setting to determine if the wires are continuous from the shunt terminals to the meter terminals. If the DVM reads a high resistance, the subject wire or the crimp connection has gone high resistant and should either be repaired or replaced. If there is an ammeter switch, ensure to activate it during this test. If the DVM still shows a high resistance even after the ammeter switch is activated, the switch has most likely failed and should be replaced. If the wire connections and the ammeter switch are continuous, the ammeter has most likely failed and should be replaced.

2.) If there is no DC output current from the rectifier, as verified in the above step, but there is DC output voltage, verify that the DC output connections are secure and that the DC output cabling is continuous. A common misconception is that if there is DC voltage at the rectifier output terminals but no DC current, that there is a problem with the rectifier. This is incorrect. If there is DC voltage at the rectifier output terminals but no DC current, it is almost guaranteed that the DC output cabling to either the structure or the anode bed is discontinuous. As per Ohm’s Law, if the circuit resistance is infinitely high, the current will be infinitely low. To verify this, a temporary load resistor could be connected across the DC output terminals of the rectifier. If there is now DC output current, there is a problem with the DC output circuit or cabling.

3.) If there is no reading on the rectifier voltmeter, ensure to check that there is not a metering switch that must be activated to get a reading on the meter. If there isn’t a metering switch or if the metering switch is activated and there still is no voltage showing on the meter, the operational status of the voltmeter should be verified by measuring the DC voltage across the DC output terminals of the rectifier. If the measurement indicates that there is no voltage, continue to the next step. If the measurement indicates that there is a DC voltage, there is either a problem with the voltmeter, the voltmeter connection or, if supplied, the voltmeter switch. Follow the steps outlined in Step 1 above to determine where the fault lies.

4.) If it is found that there is no output voltage or current from the rectifier, there are five key items to check:

   a. Check the continuity of the AC secondary fusing (or DC output fusing, if supplied) by setting the DVM to the resistance or diode check mode and measure across the fuse(s). If a high resistance is measured, the fuse has opened and should be replaced (prior to replacement see Step 5). If a very low resistance is measured, the fuse is operational and other components should be checked.

b. Verify that the correct level of AC input voltage is present at the AC input terminals of the rectifier unit. Please note that this should be done with the rectifier AC input circuit breaker in the “ON” position to eliminate the possibility of a “static” voltage reading (as may occur if one AC line becomes discontinuous). If the correct AC input is not available, contact the local power utility company for assistance.

c. With the AC power and the rectifier input circuit breaker “ON”, check the proper operation of the rectifier circuit breaker (CB1) by measuring the AC voltage at the input (top) terminal(s) and also at the output (bottom) terminal(s) of the breaker. The AC voltage at the output terminals of the circuit breaker should match the voltage at the input terminals. If the voltage doesn’t match, the rectifier AC input circuit breaker has probably developed bad contacts and should be replaced.

d. Another possible cause could be a discontinuous wire connection in the rectifier. Do a visual check of all the electrical connections within the rectifier for a heated or burnt wire connection. Check all connections for tightness and do a slight pull test on all wire connectors. If a poor or discontinuous connection is found, it should be repaired or replaced. If replacement is required, ensure to use the same type of wire and/or connector.

e. With the rectifier input circuit breaker “ON”, verify that there is an AC voltage out of the main transformer (T1) secondary by measuring across the tap link bars or terminals (for tap type units) or across the AC input to the diode bridge assembly (for variable transformer types). For this check, ensure that the rectifier is adjusted to at least 25% of rated output. If no AC voltage is measured at the secondary terminals, the main transformer has probably failed and should be replaced.

5.) If the rectifier fusing is found to have become discontinuous or high resistant, there are several possible causes for this that should be explored prior to fuse replacement. If the fuse is replaced before these possible causes are checked, the new fuse may fail immediately after replacement.

a. The AC secondary fuse may fail if the DC output circuit becomes low resistant or shorted. This is possible during very wet periods, if the rectifier has been adjusted to or over maximum rated output, or when the DC output cables are damaged during construction. To determine if this is the problem, the DC output cables can be checked with a soil resistance meter (a typical DVM will not work) to determine if they are shorted. As an alternate to this, the DC output cables could be disconnected from the rectifier and a temporary test load used. If the DC output cables are found to be shorted, they must be repaired prior to further operation of the rectifier. If a very low DC circuit resistance is suspected, after replacing the fuse, energize the rectifier at a very low setting to ensure an over-current situation doesn’t occur.

b. The AC secondary fuse may fail during a DC output voltage surge situation when the DC surge arrestor acts as a bypass for the surge current. Though the DC surge arrestor protects the rectifier circuitry from the surge current, it also acts as

a zero resistance bypass circuit for the rectifier current and thus the fuse will fail. As long as the DC surge arrestor doesn't fail in a shorted condition (zero resistance), the fuse can simply be replaced and the rectifier should operate properly. However, if the DC surge arrestor does fail in a shorted condition, any replacement fuses installed will fail immediately. To determine if the DC output arrestor has shorted, disconnect the DC output cables from the rectifier and measure across the rectifier DC output terminals with a Digital Volt Meter (DVM) on the resistance or diode check setting. If a very low resistance is measured, the arrestor has probably failed. Remove the arrestor from the circuit, re-check it, and replace as necessary.

c. The AC secondary fuse may also fail if one or more of the diodes in the diode bridge assembly have shorted. To determine if this is the cause, the following diode bridge verification procedure should be followed.

    i. With the AC power "OFF", disconnect one of the two wires from the AC input of the diode bridge (BAC1). This can be easily done on tap type units by removing a tap link bar or tap wire. For three-phase input rectifiers, two of the three AC input wires to the diode bridge (BAC1 & BAC2) should be removed. The output cables should also be disconnected from the rectifier DC output lug terminals.

    ii. With the DVM set on the diode check range, place the positive (Red) meter lead on the bridge negative terminal (BDC-) and touch the negative (Black) meter lead to each of the bridge AC input terminals. An operational diode should measure approximately 0.4 to 0.6 volts on the diode check setting and the DVM may emit a single beep. An open or short circuit reading will indicate a faulty diode that requires replacement.

    iii. Next, place the negative meter lead on the bridge positive terminal (BDC+) and touch the positive (Red) meter lead to each of the bridge A.C. terminals.

    iv. When replacing the damaged diodes, ensure to replace them the same type and polarity (consult the rectifier data sheet or the factory for details). When installing the diodes, do not over-tighten them as the mounting studs may be easily damaged.

    v. A final check to complete on the diode bridge assembly is to determine if any of the components are shorted to a grounding point. With the DVM again set on the diode check range, attach the negative (Black) meter lead to the rectifier ground terminal or frame and touch each of the diodes and heatsinks with the positive (Red) meter lead. There should an infinite resistance reading on the meter. If the meter reads a low resistance or short, somewhere one of the diode bridge components or wires is contacting a grounding point and must be repaired.

6.) If the rectifier AC input circuit breaker continually trips to the “OFF” position when the rectifier is energized, there are several factors that may cause this.

   a. Visually inspect the rectifier AC input surge arrestor for damage (usually located adjacent to the AC input terminals). If the housing of the arrestor is cracked or blackened, the arrestor has failed and should be replaced. Always replace the arrestor with one of the same type. If an immediate replacement cannot be obtained, the rectifier can operate without this arrestor for a limited period, however, please remember that the rectifier then has no protection against surges. In certain circumstances, the arrestor may also fail without any external signs of damage. As such, to ensure that the AC arrestor is not the problem and with the AC power “OFF”, disconnect the wires of the arrestor from the circuit breaker terminals. If the rectifier circuit breaker now remains in the “ON” position when energized, the arrestor has failed and should be replaced.

   b. If the breaker still trips to the “OFF” position, disconnect the wires between output (bottom) terminals of the rectifier circuit breaker (CB1) and the AC primary of the main transformer (T1). If the rectifier circuit breaker now remains in the “ON” position when energized, the main transformer has most likely failed and should be replaced (consult the factory for a replacement).

   c. Another possibility is that the AC configuration terminals of the main transformer (T1) (for dual input types only) are incorrectly set for the actual AC input voltage applied to the rectifier. Please confirm that these terminals are configured properly (refer to the electrical schematic) for the AC voltage being applied.

   d. If the breaker is still tripping to the “OFF” position after checking the above steps, it is most likely that the rectifier AC input circuit breaker itself has failed and will require replacement.

7.) If the DC output of the rectifier is intermittent, this could be caused by a loose or a high resistant connection. Refer to Step 4d above.

8.) If the efficiency of the rectifier is not as expected, one or more of the diodes in the bridge assembly may not be functioning. Follow the steps outlined in Step 5.c above to determine if this is the problem.

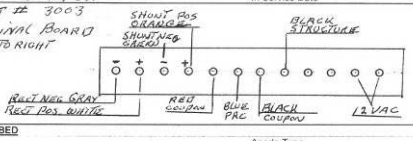
9.) If, by following the above troubleshooting steps, the rectifier problem cannot be solved, please feel free to contact the factory or your local supplier for technical assistance.

Appendix F: Operating Values for Deep Anode and Rectifier Systems

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER
Owner
Location HOSPITAL R-6
Unit No.
Manufacturer PIEM
Model No. PATSA 18-14
AC Input 120
Shunt Size 50MV / 5A
Type
Serial No. 83B109
DC Output 18V / 17A
In Service Date

DART # 3003
TERMINAL BOARD
LEFT TO RIGHT



GROUNDBED
Type
Anode Qty
Location
Anode Type
Anode Size

GPS: N 38 43.085
W 104 47.780

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F3	8.0 / 8.0	8.15 / 14.86	4/3/06	WC	

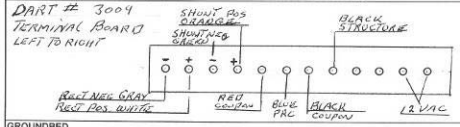
CATHODIC
PROTECTION
MANAGEMENT, Inc.

Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER
Owner
Location TITUS & HARR DEEP ANODE
Unit No.
Manufacturer FIRT
Model No. MMA31FS 60-34 MYZ
AC Input 230
Shunt Size 50MV / 90A
Type
Serial No. 05R 1059
DC Output 60V / 34A
In Service Date

DART # 3004
TERMINAL BOARD
LEFT TO RIGHT



GROUNDBED
Type DEEP
Anode Qty 6
Location
Anode Type MMO
Anode Size

GPS: N 38 42.262
W 104 47.968

1: 2.29A 2: 2.18A 3: 1.84A 4: 1.77A 5: 2.29A 6: 3.65A

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F3	7 / 14	7.26 / 14.16	4/1/06	WC	

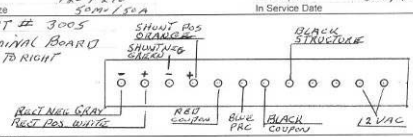
CATHODIC
PROTECTION
MANAGEMENT, Inc.

Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER
Owner
Location 2402 11MM TWIN
Unit No.
Manufacturer WESTURN
Model No. WSTSE 30-40
AC Input 120 / 240
Shunt Size 50MV / 50A
Type
Serial No. 05H 108
DC Output 30V / 40A
In Service Date

DART # 3005
TERMINAL BOARD
LEFT TO RIGHT



GROUNDBED
Type
Anode Qty
Location
Anode Type
Anode Size

GPS: N 38 43.626
W 104 46.870

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
C13 / F5	17 / 28	16.99 / 27.4	4/4/06	WC	

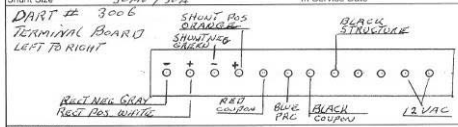
CATHODIC
PROTECTION
MANAGEMENT, Inc.

Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER
Owner
Location ON SHERIDAN NORTH OF TITUS
Unit No.
Manufacturer GOODALL
Model No. CSAY3A 18-72 EWPZ
AC Input 115
Shunt Size 50MV / 50A
Type
Serial No. B2C2324
DC Output 18V / 12A
In Service Date

DART # 3006
TERMINAL BOARD
LEFT TO RIGHT



GROUNDBED
Type
Anode Qty
Location
Anode Type
Anode Size

GPS: N 38 43.468
W 104 47.483

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
C13 / F1	6.5 / 2.0	7.03 / 4.0	4/4/06	WC	

CATHODIC
PROTECTION
MANAGEMENT, Inc.

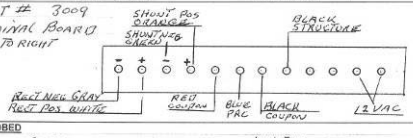
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner
Location 600,000 TANK
Unit No.
Manufacturer IRT
Model No. ADASFS 60-34MYZ
AC Input 230
Shunt Size 50MV / 90A
Type
Serial No. 05R: 1058
DC Output 60V / 34A
In Service Date

DART # 3009
TERMINAL BOARD
LEFT TO RIGHT



GROUNDBED

Type DEEP
Anode Qty 6
Location
Anode Type MMO
Anode Size

GPS: N 38 43.693
W 104 48.877

1: 1.57A 2: 1.73A 3: 1.55A 4: 1.75A 5: 1.01A 6: 1.77A

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F4	10.0 / 9.0	10.38 / 8.88	4/1/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

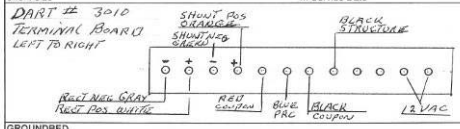
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner
Location ROAD TO WATER TANK 7900
Unit No.
Manufacturer GOULD ALL
Model No. GSASE 24-22W
AC Input 120/230
Shunt Size
Type
Serial No. BWW3515
DC Output 24V / 22A
In Service Date

DART # 3010
TERMINAL BOARD
LEFT TO RIGHT



GROUNDBED

Type
Anode Qty
Location
Anode Type
Anode Size

GPS: N 38 43.729
W 104 48.432

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F4	5.5 / 5.0	5.6 / 5.5	4/3/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

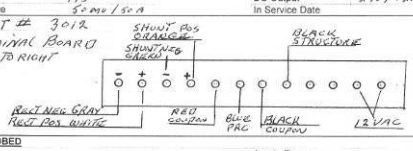
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner
Location GOLF COURSE
Unit No.
Manufacturer GOULD ALL
Model No. CSAYSA 24-42.ENBZ
AC Input 115
Shunt Size 50MV / 50A
Type
Serial No. B2C2323
DC Output 24V / 42A
In Service Date

DART # 3012
TERMINAL BOARD
LEFT TO RIGHT



GROUNDBED

Type
Anode Qty
Location
Anode Type
Anode Size

GPS: N 38 43.482
W 104 48.159

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F4	4.0 / 8.5	5.06 / 7.5	4/4/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

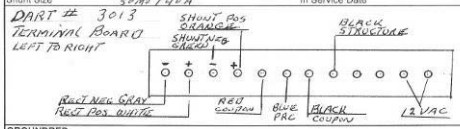
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner
Location GAS PIT #5
Unit No.
Manufacturer IRT
Model No. ADASFS 60-34MYZ
AC Input 115
Shunt Size 50MV / 40A
Type
Serial No. 05R 1056
DC Output 60V / 34A
In Service Date

DART # 3013
TERMINAL BOARD
LEFT TO RIGHT



GROUNDBED

Type DEEP
Anode Qty 6
Location
Anode Type MMO
Anode Size

GPS: N 38 45.497
W 104 47.660

1: 1.17A 2: 1.00A 3: 0.83A 4: 1.03A 5: 0.65A 6: 1.05A

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F2	4.0 / 5.0	4.51 / 5.84	4/3/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

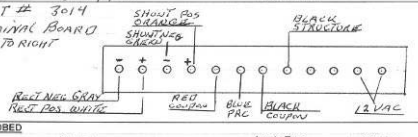
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	WETZEL & MINTER		
Unit No.			
Manufacturer	IRT	Type	
Model No.	ADASFS 60-74 MYC	Serial No.	05R 1055
AC Input	230	DC Output	60V/34A
Shunt Size	50MV/40A	In Service Date	

DART # 3014 TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type	DEEP	Anode Type	MMO
Anode Qty	6	Anode Size	
Location			

GPS N. 38 43.906
W. 104 47.007

1: 2.35A 2: 1.98A 3: 1.89A 4: 2.31A 5: 2.37A 6: 8.95

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA

DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F2	7.6 / 15.0	7.39 / 14.8	4/1/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

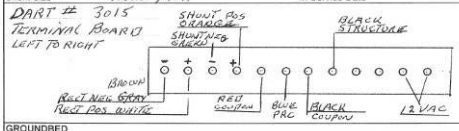
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	2402 TANK INTERIOR		
Unit No.			
Manufacturer	CORPOWER	Type	
Model No.	TASCA CONTROL	Serial No.	C-073218
AC Input	115	DC Output	30V/8A
Shunt Size	100MV/10A	In Service Date	

DART # 3015 TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA

DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F2	1.8 / 0.01	1.8 / 0.01	5/7/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

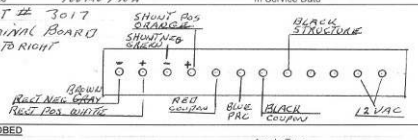
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	2401 TANK INTERIOR		
Unit No.			
Manufacturer	CORPOWER	Type	
Model No.	TASCA CONTROL	Serial No.	C-020729
AC Input	115	DC Output	30V/8A
Shunt Size	100MV/10A	In Service Date	

DART # 3017 TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA

DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F2	1.8 / 0.01	1.78 / 0.01	5/7/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

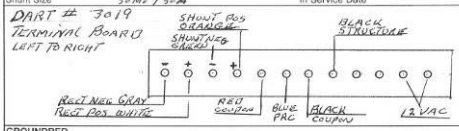
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	2401 TWIN MM		
Unit No.			
Manufacturer	WESTERN	Type	
Model No.	WST35E 30-40C	Serial No.	0514109
AC Input	120/240	DC Output	30V/40A
Shunt Size	50MV/50A	In Service Date	

DART # 3019 TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

GPS: N 38 43.622
W 104 46.842

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA

DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F5	8.0 / 24.0	8.59 / 24.2	4/6/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

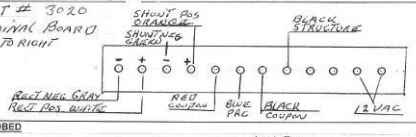
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	DOWN RANGE 14A		
Unit No.			
Manufacturer	GOODALL	Type	
Model No.	T3AW30 16-6 ENS	Serial No.	82T1314
AC Input	480	DC Output	28V/6A
Shunt Size	50MV/10A	In Service Date	

DART # 3020 TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

GPS: N38 26.325
W104 46.676

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA

DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F3	4.0 / 1.2	5.18 / 1.12	4/3/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

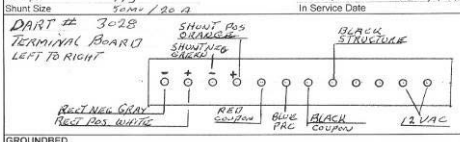
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	S.R.O. HOUSING		
Unit No.			
Manufacturer	RTS	Type	
Model No.	CSAY5A 18-16	Serial No.	000675
AC Input	115	DC Output	18V/16A
Shunt Size	50MV/20A	In Service Date	

DART # 3028 TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

GPS: N 38 43.455
W 104 47.082

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA

DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CC / F1	9.5 / 5.0	9.93 / 5.24	4/2/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

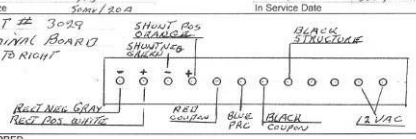
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	600,000 TANK INTERIOR NORTH RECT		
Unit No.			
Manufacturer	CORROSHIELD	Type	
Model No.	CSAY5 30-16 ARTV2-13	Serial No.	C-011996
AC Input	115	DC Output	30C/16A
Shunt Size	50MV/20A	In Service Date	

DART # 3029 TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

GPS: N 38 43.483
W 104 48.877

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA

DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F2	2.3 / 1.41	2.41 / 3.52	4/1/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

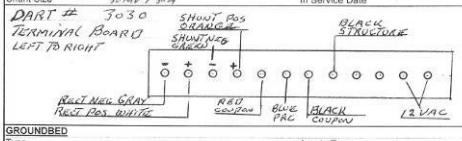
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	DOWN RANGE 13A		
Unit No.			
Manufacturer	GOODALL	Type	
Model No.	T3BW30E 28-6	Serial No.	82T1317
AC Input	480	DC Output	28V/6A
Shunt Size	50MV/5A	In Service Date	

DART # 3030 TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

GPS: N 38 37.036
W 104 49.105

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA

DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F5	9.5 / 0.0	9.69 / 0.2	4/3/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

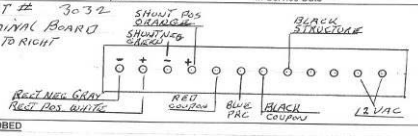
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner
Location: 8000 BLDG Motor Pool South Rect
Unit No.
Manufacturer: UNIVERSAL
Model No.: AUP
AC Input: 115/230
Shunt Size: 50MV/10A
Type
Serial No.
DC Output
In Service Date

DART # 3032
TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type
Anode Qty
Location
Anode Type
Anode Size

GPS: N 38 45.355
W 104 46.958

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F1	2.5 / 0.5A	2.6 / 0.4B	4/3/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

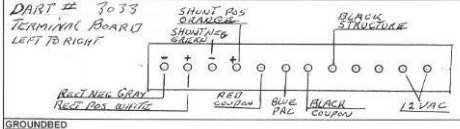
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner
Location: TITUS & BROWN
Unit No.
Manufacturer: IRT
Model No.: ADAS 60-34 MVZ
AC Input: 230
Shunt Size: 50MV/40A
Type
Serial No.: 05R 1060
DC Output: 60V/34A
In Service Date

DART # 3033
TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type: DEEP
Anode Qty: 6
Location
Anode Type: MMO
Anode Size

GPS: N 38 43.296
W 104 46.795

1: 1.81A 2: 1.81A 3: 1.62 4: 1.58A 5: 1.37A 6: 1.78A

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F2	4 / 10	4.29 / 10.24	4/1/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

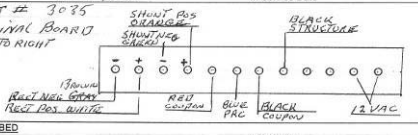
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner
Location: 600,000 TANK INTERIOR South Rect.
Unit No.
Manufacturer: CORROSWICH
Model No.: TASCA
AC Input: 115
Shunt Size: 100MV/10A
Type
Serial No.: C010946
DC Output: 20V/5A
In Service Date

DART # 3035
TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type
Anode Qty
Location
Anode Type
Anode Size

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F3	2.0 / 0.01	1.99 / 0.01	5/7/06	WC	

CATHODIC PROTECTION MANAGEMENT, Inc.

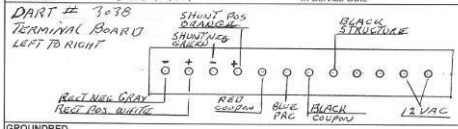
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner
Location: BAAF BLDG 9611
Unit No.
Manufacturer: IRT
Model No.: ADASES 60-34 MVZ
AC Input: 230
Shunt Size: 50MV / 40A
Type
Serial No.: 05R 1057
DC Output: 60V / 34A
In Service Date

DART # 3038
TERMINAL BOARD LEFT TO RIGHT



GROUNDBED

Type: DEEP
Anode Qty: 6
Location
Anode Type: MMO
Anode Size

GPS: N 38 40.838
W 104 45.918
LEFT OFF

1: 1.7A 2: 0.98A 3: 0.98A 4: 0.93A 5: 0.87A 6: 1.21A

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
CA / F3	6 / 6	6.28 / 6.12	4/1/06	WC	

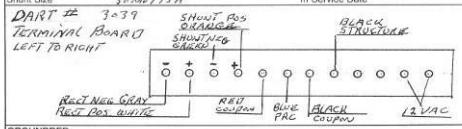
CATHODIC PROTECTION MANAGEMENT, Inc.

Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	7901 TANK BOTTOM WEST RECT		
Unit No.			
Manufacturer	UNIVERSAL	Type	
Model No.	ASAI	Serial No.	012253
AC Input	115/230	DC Output	48V/13A
Shunt Size	50mv/15A	In Service Date	



GROUNDBED

Type	ASTARTA	Anode Type	
Anode Qty		Anode Size	
Location			

GPS: N 38 49.700
W 104 48.598

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
C1 / T4	11.0 / 6.8	11.91 / 7.3	4/1/06	WC	

CATHODIC
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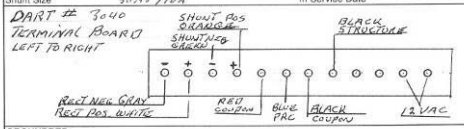
MANAGEMENT, Inc.

Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	DOWN RANGE RED DEVIL		
Unit No.			
Manufacturer	GLEDALL	Type	
Model No.	JSAWSP 28-6 EWS	Serial No.	82J1316
AC Input	480	DC Output	28V/6A
Shunt Size	50mv/10A	In Service Date	



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

GPS: N 38 29.986
W 104 54.698

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
C13 / F1	9.0 / 1.0	9.67 / 1.38	4/3/06	WC	

CATHODIC
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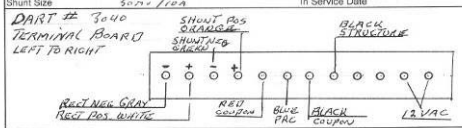
MANAGEMENT, Inc.

Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	DOWN RANGE RED DEVIL		
Unit No.			
Manufacturer	GLEDALL	Type	
Model No.	JSAWSP 28-6 EWS	Serial No.	82J1316
AC Input	480	DC Output	28V/6A
Shunt Size	50mv/10A	In Service Date	



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

GPS: N 38 29.986
W 104 54.698

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
C13 / F1	9.0 / 1.0	9.67 / 1.38	4/3/06	WC	

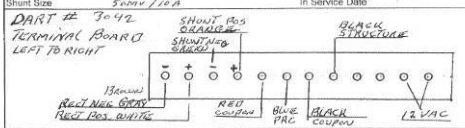
CATHODIC
PROTECTION
MANAGEMENT, Inc.

Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	7901 TANK INTERIOR EAST RECT		
Unit No.			
Manufacturer	UNIVERSAL	Type	
Model No.	ASAI	Serial No.	010436
AC Input	115/230	DC Output	28V/6A
Shunt Size	50mv/10A	In Service Date	



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA
DC Output (Volts/Amps)

SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
C1 / F2	2.5 / 0.1	2.35 / 0.1	5/11/06	WC	

CATHODIC
PROTECTION
MANAGEMENT, Inc.

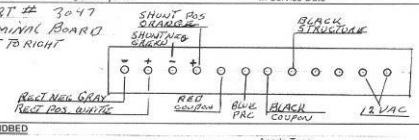
Sheet 1

RECTIFIER / GROUNDBED INFORMATION

RECTIFIER

Owner			
Location	BLDG 8000 MOTOR POOL EAST RECT		
Unit No.			
Manufacturer	UNIVERSAL	Type	
Model No.	AUP	Serial No.	960153
AC Input	115	DC Output	28V/6A
Shunt Size	50MV/10A	In Service Date	

DART # 3047
TERMINAL BOARD
LEFT TO RIGHT



GROUNDBED

Type		Anode Type	
Anode Qty		Anode Size	
Location			

GPS: N 38 45.417
W 104 46.910

ANODE CIRCUIT OUTPUT:

RECTIFIER OUTPUT DATA

	DC Output (Volts/Amps)				
SETTING	PANEL METER	PORTABLE METER	DATE	BY	NOTES
C1 / I=3	4.5/0.6	4.24/0.42	4/16/06	WC	

CATHODIC
PROTECTION
MANAGEMENT, Inc.

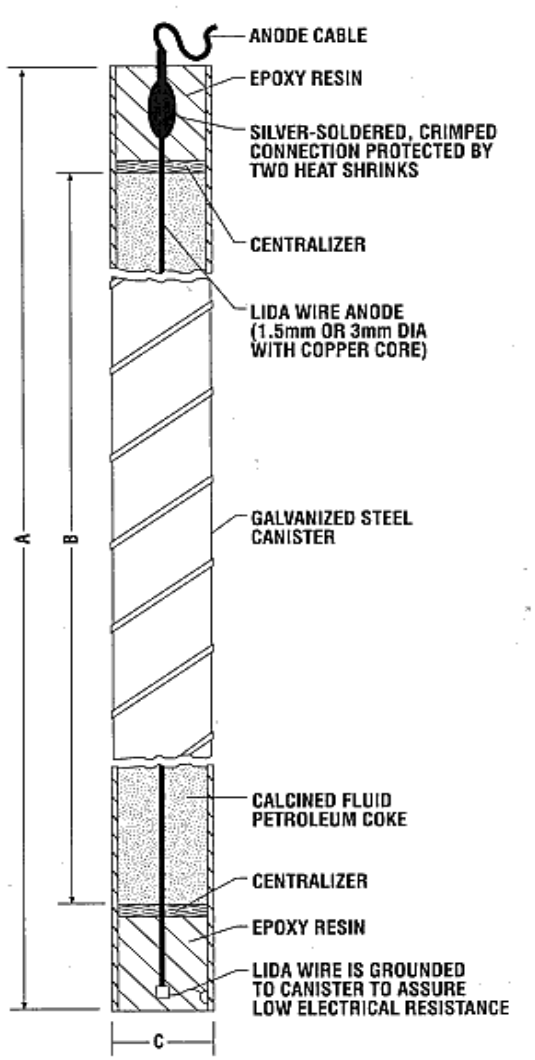
Sheet 1

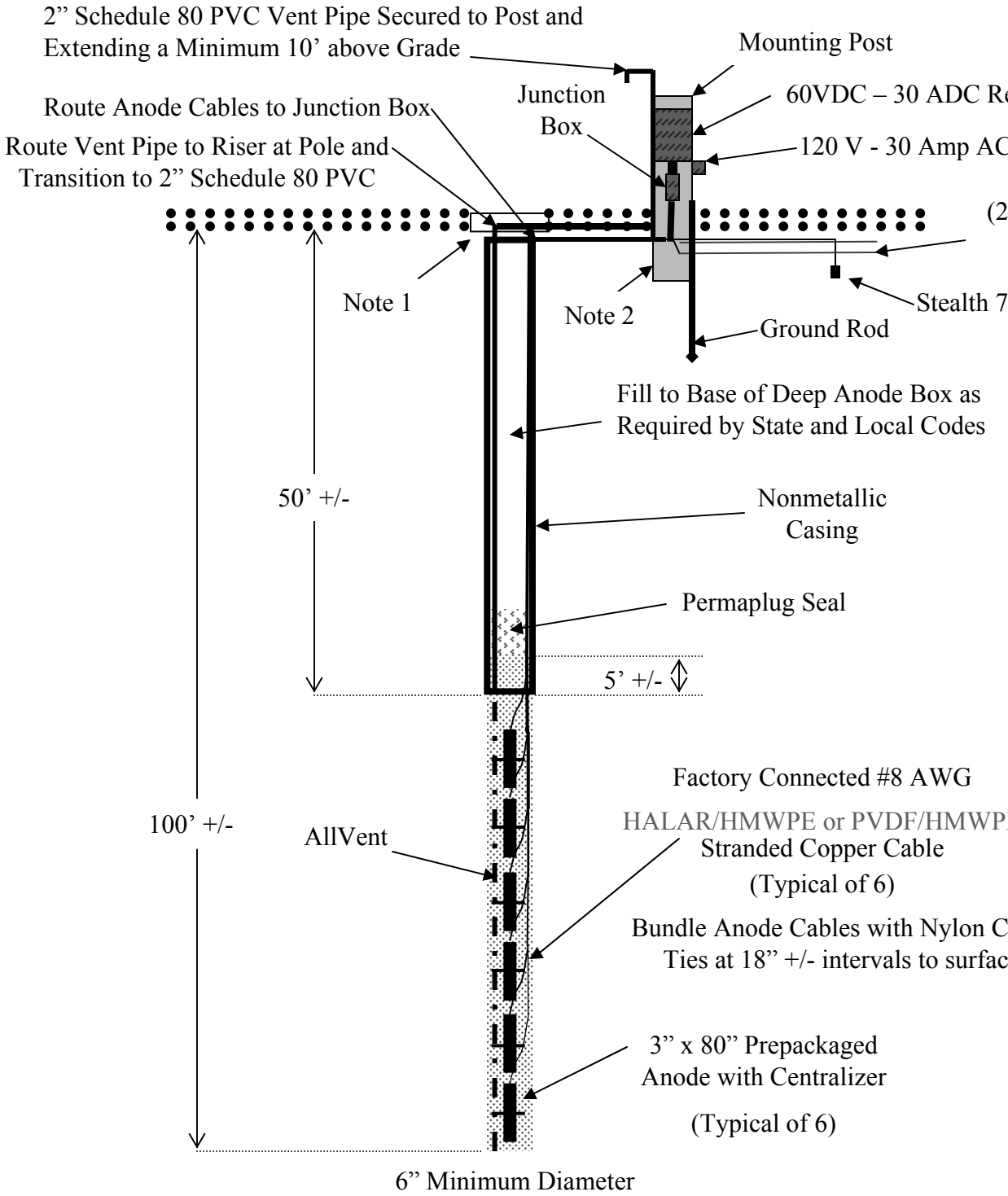
Appendix G: Deep Anode Bed Documentation

Ft. Carson ICCP Bill of Materials - Ver. 3.0 Alternate - 9-27-05

Item	Quantity	Units	Description
1	6	each	Integrated Rectifier Technologies C.P. Sentinel Series Air cooled, pole mounted rectifier with constant current control. AC input single Phase, 120/240 VAC, 60 HZ; DC output 60 VDC and 30 DCA; Provide DC Current Min/Max up time hours and tenths of hours meter with accumulated capacity minimum of 99,999 hours; provide safety guards for all exposed AC & DC voltage terminations in excess of 40 volts.
2	6	each	Treated wooden pole or post minimum 8" diameter and 10 feet in length.
3	6	each	AC safety switch with 30 ACA fuse
4	6	each	copper clad ground rods; 5/8-inch diameter by 8 feet in length
5	60	feet	#6 solid copper ground cable
6	90	feet	1-1/4 inch diameter GRS conduit and fittings
7	2	pound	Duct seal compound
8	4,400	lbs	Loresco type SC-3 calcined petroleum coke breeze
9	300	ft	Loresco AllVent with a nominal inside diameter of 1 inch
10	300	ft	I-inch diameter PVC conduit compatible with AllVent
11	300	lbs	Loresco PERMAPLUG ENVIRONMENTAL EARTH SEAL
12	300	ft	6-inch Diameter Thermoplastic Water Well Casing
13	36	ea	1/4-inch diameter by 4-feet MMO anodes with 150 feet of No. 8 AWG stranded copper conductors with HALAR/HMWPE or PVDF/HMWPE insulation factory attached using silver soldered crimps and sealed with a minimum two heat shrink sleeves suitable for deep anode applications. Extend heat shrink along cable a minimum of 6-inches outside of canister. Package anodes in 3" Diameter by 80 " long metallic canisters. Center anodes in canister, provide electrical contact from bottom of anode to canister, fill canister without voids with compacted Loresco SWK calcined petroleum coke breeze. Packaging per Figure 1 or approved equal.
14	36	each	Anode centralizer devices
15	6	each	Anode well head assemblies
16	6	each	Anode Junction box with six circuits and Holloway Type RS shunts for each anode
17	400	feet	AWG #4 HMWPE stranded copper cable
18	20	each	Thermite braze charges for AWG #4 connection to ductile iron pipe
19	1	each	Thermite weld mold for 12" and larger pipe
20	1	each	Thermite weld mold for 10" and smaller pipe
21	20	each	Royston Handi-Caps with primer

Figure 1
Typical Anode Package





Notes:

1. Provide Strngwell Quazite PG2436BB18 Box with PG2436CA00 lID (Source Contact 800-346-3062)
2. Install rectifier post a minimum 48" deep. Provide support and achorage as required to secure post with rectifier attached.
3. Conduct resistance measuremtns between a 3" diameter 5' long (minimum) test electrode and the protected strucutre at 10 feet intervals in active anode zone
4. Inspect anodes and cables for damage prior to placement in the hole. Route cable via centralizers or vent pipe to prevent damage by canister edges to wire insulation during installation.
5. Pump coke breeze into the bottom of the hole and fill from the bottom up.
6. Measure depth of cole breeze after a minimum 12 hour period and add additional coke breeze as required
7. Install Permaplug and any additional fill after cole breeeze level reaches 5' into nonmettalic casing

SPECIFICATIONS/DATA

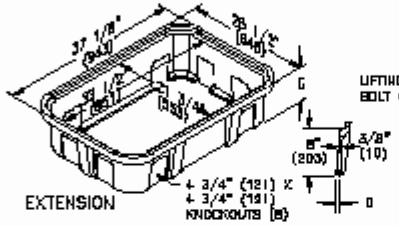
24" x 36" PG Style (Stackable) Assembly

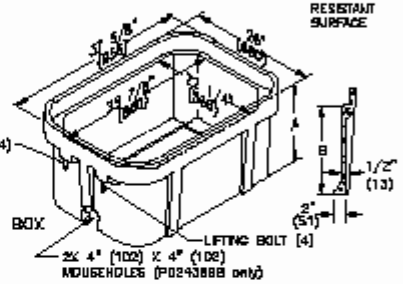
Covers (Blank unless logo is specified)

	DESCRIPTION	PART NO.	WEIGHT #	DESIGN/TEST LOAD #	ANSI TIER
(J)	W/2 Bolts	PG2436CA00	100 (45.4 kg)	8,000 / 12,000	8
(K)	Gasketed w/2 Bolts	PG2436CG00	100 (45.4 kg)	8,000 / 12,000	8
(L)	No Bolts	PG2436WA00	100 (45.4 kg)	8,000 / 12,000	8
(A)	Heavy Duty w/2 Bolts	PG2436HA00	115 (52.2 kg)	15,000 / 22,500	15
(A)	Gasketed Heavy Duty w/2 Bolts	PG2436HG00	115 (52.2 kg)	15,000 / 22,500	15
	Extra Heavy Duty w/2 Bolts	PG2436HH00	122 (55.2 kg)	22,500 / 33,750	15*

- Covers with meter lids available upon request.
- Gasketed covers and bolt grommets must be used with a gasketed box. Gaskets reduce the inflow of fluids but do not make the enclosure water tight.

* Loadings for HH covers comply with all test provisions of ANSI/SCTE 77 except that the vertical design load is 22,500 lbs. with a test load of 33,750 lbs. over a 10" x 20" plate.





Boxes (Stackable with self-aligning, replaceable EZ-Nut) *24", 30" & 42" deep boxes must be used as bottom of any stack

	DESCRIPTION	PART NO.	WEIGHT #	DIMENSION A	DIMENSION B	DESIGN/TEST LOAD #	ANSI TIER
(J)	Open Bottom	PG2436BA18	141 (64.0 kg)	18" (457 mm)	15" (381 mm)	22,500 / 33,750	15**
	*	PG2436BA24	180 (81.6 kg)	24" (610 mm)	21" (533 mm)	22,500 / 33,750	15**
	*	PG2436BA30	196 (88.9 kg)	30" (762 mm)	27" (686 mm)	22,500 / 33,750	15**
	*	PG2436BA42	265 (120.0 kg)	42" (1067 mm)	39" (991 mm)	22,500 / 33,750	15**
(K)	Open Bottom w/ Gasket	PG2436BG18	141 (64.0 kg)	18" (457 mm)	15" (381 mm)	22,500 / 33,750	15**
	*	PG2436BG24	180 (81.6 kg)	24" (610 mm)	21" (533 mm)	22,500 / 33,750	15**
	*	PG2436BG30	196 (88.9 kg)	30" (762 mm)	27" (686 mm)	22,500 / 33,750	15**
	*	PG2436BG42	265 (120.0 kg)	42" (1067 mm)	39" (991 mm)	22,500 / 33,750	15**
(L)	Open Bottom w/ 2 Mouseholes	PG2436BB18	139 (63.1 kg)	18" (457 mm)	15" (381 mm)	22,500 / 33,750	15**
	*	PG2436BB24	178 (80.7 kg)	24" (610 mm)	21" (533 mm)	22,500 / 33,750	15**
	*	PG2436BB30	194 (88.0 kg)	30" (762 mm)	27" (686 mm)	22,500 / 33,750	15**
	*	PG2436BB42*	263 (119.3 kg)	42" (1067 mm)	39" (991 mm)	22,500 / 33,750	15**
(D)	Solid Bottom	PG2436DA18	181 (82.1 kg)	18 1/2" (470 mm)	15" (381 mm)	22,500 / 33,750	15**
	*	PG2436DA24	228 (103.4 kg)	24 1/2" (622 mm)	21" (533 mm)	22,500 / 33,750	15**
	*	PG2436DA30	238 (107.0 kg)	30 1/2" (775 mm)	27" (686 mm)	22,500 / 33,750	15**
	*	PG2436DA42	293 (133.0 kg)	42 1/2" (1080 mm)	39" (991 mm)	22,500 / 33,750	15**
(D)	Solid Bottom w/ Gasket	PG2436DG18	181 (82.1 kg)	18 1/2" (470 mm)	15" (381 mm)	22,500 / 33,750	15**
	*	PG2436DG24	228 (103.4 kg)	24 1/2" (622 mm)	21" (533 mm)	22,500 / 33,750	15**
	*	PG2436DG30	238 (107.0 kg)	30 1/2" (775 mm)	27" (686 mm)	22,500 / 33,750	15**
	*	PG2436DG42	293 (133.0 kg)	42 1/2" (1080 mm)	39" (991 mm)	22,500 / 33,750	15**

* PG 2436BB42 is not UL Listed.

** Loadings comply with ANSI/SCTE 77. These boxes meet and exceed ANSI Tier 15 test provisions.

Extensions (For use under 18" deep boxes only, one per box. For grade adjustable extension see page 44.)

DESCRIPTION	PART NO.	WEIGHT #	DIMENSION C	DIMENSION D	DESIGN/TEST LOAD #	ANSI TIER
Open Bottom	PG2436EA08	57 (25.9 kg)	8 3/4" (222 mm)	1" (25 mm)	22,500 / 33,750	15*
Solid Bottom	PG2436RA08	95 (43.1 kg)	9 1/4" (235 mm)	N/A	22,500 / 33,750	15*

* Loadings comply with ANSI/SCTE 77. These extensions meet and exceed ANSI Tier 15 test provisions.

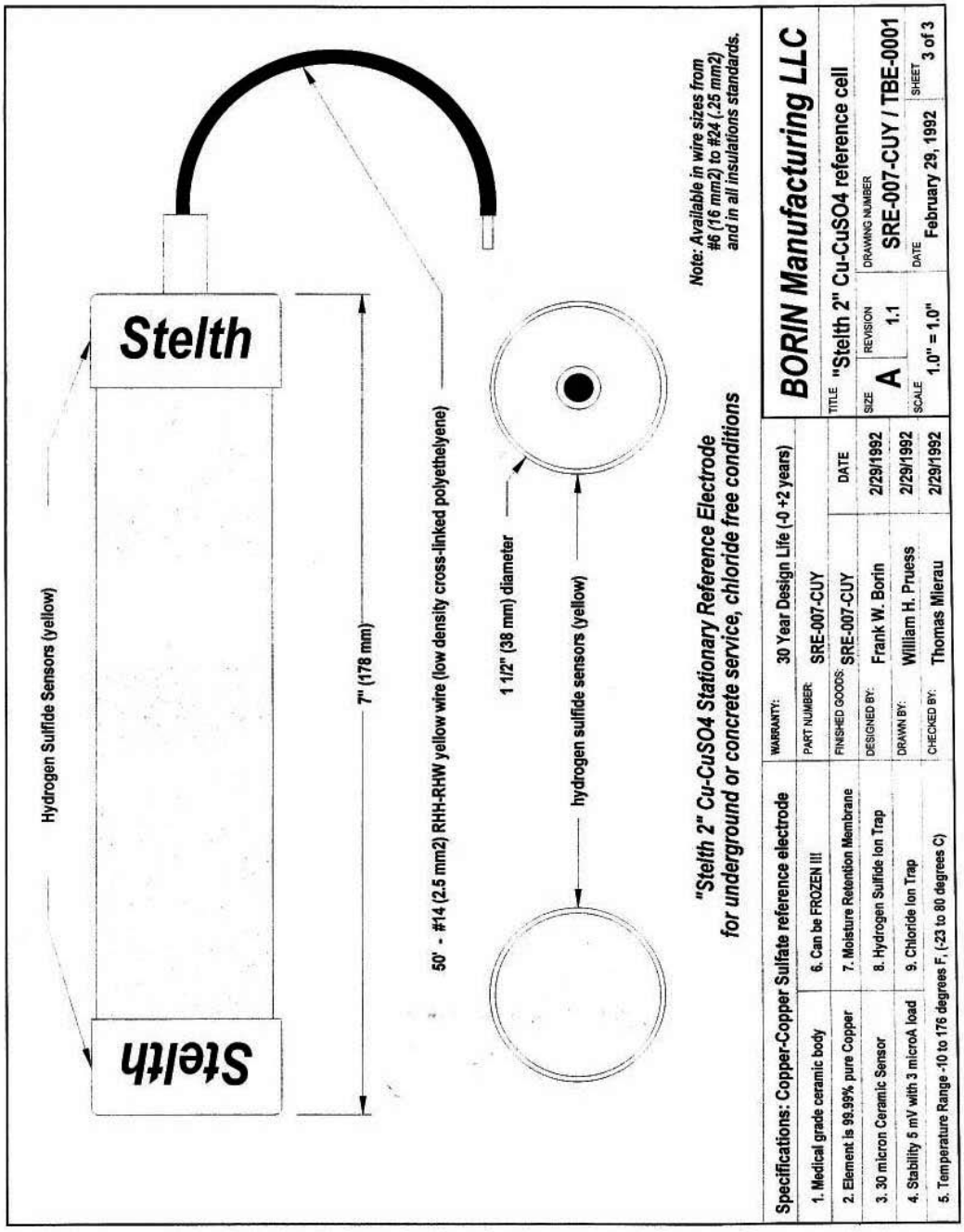
Dimensions & weights in parentheses are metric equivalent.

Deep Anode Bed Details for B&A Fort Carson Project – Ver. 3.0 – Page 2 of 3

Rectifier Mounting Detail

(Typical of 6)

Appendix H: Reference Electrode Specifications



Appendix I: Contractor Work Plans and Submittals

BUSHMAN & Associates, Inc.

CORROSION CONSULTANTS

P.O. Box 425, Medina, OH 44258 • Phone 330/769-3694, Fax 330/769-2197

B&A Work Plan for AR-F-321 (Ver. 4.0)

Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson

1.0 Background

Ft. Carson is spread over a large area and has many potable water storage tanks that use cathodic protection (CP) systems, which protect the waterside of the tank. The outer surfaces of underground pipes, such as water, or gas distribution systems, also must be protected from corrosion in the soil using similar CP systems. In either case, CP systems need to be monitored in order to make sure that they are providing enough voltage and current to maintain the cathodic protection. The objective of AR-F-321 is to provide remote monitoring hardware and software to expedite the collection and analysis of dc potentials and currents used to evaluate the effectiveness of cathodic protection systems. Remote monitoring to ascertain the operational status of impressed current cathodic protection dc power supplies is to be provided to selected impressed current dc power supply units.

Fort Carson has metallic utility facilities which currently are not provided with cathodic protection or have cathodic protection systems that require upgrades to maintain adequate corrosion protection. Included in the utility facilities are:

1. 5 potable water storage tanks,
2. 30 miles of potable water distribution lines,
3. 5 miles of high temperature steam lines,
4. 40 miles of natural gas distribution lines,
5. 2 miles of fire suppression water lines,
6. 3 well casings.

2.0 Compliance with Contract Requirement

In accordance with the Memorandum of Record of the 28 June 2005 meeting at Fort Carson, CO, B&A will comply with the following during the performance of this contract:

1. Drill Rig Mast Height may require special marking based on Flight Restrictions. B&A will coordinate the locations of potential drill sites and will comply with all special marking and restrictions with respect to air traffic.
2. B&A does not contemplate procuring any equipment manufactured outside the United States but notes that there is no requirement in their contract to buy all components from US manufacturers.
3. B&A will comply with access policies for workers entering Fort Carson. These policies are to be provided to B&A in writing (in detail) by the COE Resident Office.
4. B&A understands the Hot Work Permits will be required for welding work and will obtain same from the Fort Carson Fire Department (Prime Contact – Mr. Dave Bacharach)
5. Contract Technical Authority POC is Mr. L. D. Stephenson.
6. B&A understands and will cooperate with the Resident Office of the COE who is providing site QA and safety inspection support for CERL, and is the primary coordinator between the contractor, DPW, and CERL. While FCNRO and RMAO have no contractual authority, it is also understood that they CERL's local "eyes and ears" for the project. The Fort Carson Resident Office (FCNRO) will be the contractor's initial POC for all matters relating to this project.
7. B&A understands that the Rocky Mountain Area Office (RMAO) will provide first line technical support for this project. FCNRO and B&A will utilize RMAO for first line review of technical matters. RMAO will provide technical support and coordinate with the DPW as necessary on minor day to day technical matters. RMAO will coordinate with and/or forward larger technical issues to CERL for resolution.

8. B&A understands that CERL will provide technical support for larger and more critical technical matters and will provide review/approval of final design package developed by the B&A.
9. B&A understands that CERL will maintain the final technical authority with respect to this contract. All contractual are exclusively between B&A and S&K Technologies, Inc. (SKT) and all payment responsibilities remain with SKT. The contractor will provide monthly billing requests directly to SKT with copies to CERL and FCNRO. It is further understood that either approve or explain differences of opinion by either CERL or FCNRO as to the validity of each invoice within 7 days to B&A. Invoices will be sent via FAX or email to all parties for approval and payment.
10. B&A understands that no contractual changes shall be made with the express written approval of SKT.
11. B&A and/or it subcontractors will meet with FCRNO to discuss the scope of work and phase safety aspects of each phase of work.
12. B&A will disturb less than one acre of land during the entire project and therefore and NOI will not be required for this project.
13. The primary point of contact for the FCRNO is Mr. Robert T. Giles, Resident Engineer, Fort Carson Resident Office. The primary point of contacts for the DPW with respect to Cathodic Protection at Fort Carson is Mr. Dan Golden and Mr. Darrell W Rowland, Corrosion Technician with LB&B, Fort Carson

3.0 Principal Contact List for Project

Name	Title	Address	Office Phone	Cell Phone
Jim Bushman	President - Bushman & Associates, Inc. (B&A)	PO Box 425, Medina, OH 44255 6395 Kennard Road, Medina, OH 44256	330-769-3694	330-310-9099
Matt Ellis	Rocky Mountain Area Office, Chief of Contract Administration CENWO-CD-RM, COE	Fort Carson Resident Office, 1051 South Academy Blvd, Suite 100, Colorado Springs, CO 80910	719-570-7797	719-440-4221
Robert T. Giles	Resident Engineer CENWO-CD-RM-C, COE	Fort Carson Resident Office, 1051 South Academy Blvd, Suite 100, Colorado Springs, CO 80910	719-526-5448	719-338-8921
Pete Sturdivent	Project Engineer, COE	5030 Tevis Street, Bldg 304	719-526-5448	

Steve Klimm	Electrical Engineer, COE	1050 South Academy Blvd, Suite 100, Colorado Springs, 80910	719-570-7797	
Don Fuhrman	Chief BOD, DPL	5050 Travis Street, Fort Carson, CO	719-516-2215	714-491-8595
Ashok Kumer	Project Manger CERL	ERD/CERL P. O. Box 9005	217-373-7235	
L D Stephenson	Asst. Proj. Mgr. CERL	ERD/CERL P. O. Box 9005	217-373-6758	
Dan Golden	DPW Fort Carson, Mgr. of Utility Programs including Cathodic Protection Systems	5050 Tevis St, Fort Carson, CO	719-526-9274	
Dave Bacharach	Chief - Fire Prevention	Bldg 526 Ft Carson, CO 80913	719-526-9355	719-338-9541
Darrell W Rowland	Corrosion Tech for Fort Carson	P. O. Box 13700 Ft Carson, CO 80913	719-526-6551	714-491-8473
Bill Carlson	President - CPM - Subcontractor to B&A	Cathodic Protection Management, Inc., Box 95665, Hoffman Estates, IL 0160195	847-885-7777	224-588-6760

4.0 Conduct a potential survey of cathodic protection of tanks and pipelines for utilities systems at Ft. Carson.

The general cathodic protection levels of the utilities listed in Part 1.0 are to determined by review of historical records available at Ft. Carson and field surveys for each existing cathodic protection installation. A substantial amount of buried piping at Ft. Carson presently has cathodic protection installed. To best locate the six rectifier-groundbed combinations included in this contract and to determine the optimum for the remote monitoring equipment, an analysis of the existing conditions is required.

During the potential survey, verification of electrical isolation and continuity of the water mains will be undertaken. In the event that deficiencies in electrical isolation or continuity are found, Ft. Carson Staff will be notified.

The information obtained from the analysis will be utilized in the determination of the placement of remote monitoring equipment at all ICCP Rectifier Sites, at representative Test Station Location and for Six Deep Anode Impressed Current installations. Emphasis on monitor locations will be on identifying locations of minimum, typical and/or maximum protective levels, locations of critical bonds and potential interference locations. A list of

proposed remote monitoring locations will be provided to Ft. Carson staff. Coordination with Ft. Carson facilities staff concerning the proposed locations with respect to constructability and preconstruction utility locations are included in the work.

Candidate locations for deep anode installations will be identified and coordinated with Ft. Carson staff. Coordination with Ft. Carson facilities staff concerning the proposed locations with respect to constructability, availability of AC power, and preconstruction utility locations are included in the work plan.

Specifications and details sufficient for the installation of remote monitoring equipment and cathodic protection deep anode installations will be developed. Prior to procurement of hardware and equipment, Ft. Carson staff and CERL will be presented copies of the specifications and details drawings along with applicable catalog cuts for review and comment.

5.0 Equipment to be installed include:

1. 6 Deep Anode ICCP Systems on DI Water Distribution System
2. Remote monitoring systems on Water Storage Tanks with Interior and Exterior ICCP Systems
   a. Two (2) each remote monitor interrogation/transmission units with system DC voltage, amperage and instant-off potential measurement; (Note: Instant-off potentials on Tank Interior ICCP Systems will be measured using the existing reading already being measured by the automatic control system. No other method is possible with these systems as interruption of the system output would interfere with the units normal automatic regulation.)
   b. Four (4) each remote monitor interrogation/transmission units with coupon "on" and "instant-off" potential measurement capability;
   c. Four (4) each system effectiveness evaluation coupons with integrated permanent Cu-CuSO4 reference electrode including junction box;
3. Water and Gas Distribution Systems
   a. six (6) each remote monitor interrogation/transmission units with system DC voltage, amperage and instant-off potential measurement. One each to be installed at each ICCP Rectifier Power Supply associated with the Deep Anode Ground Beds;
   b. fifty-four (54) each remote monitor interrogation/transmission units with coupon "on" and "instant-off" potential measurement capability;

c. sixty (60) each system effectiveness evaluation coupon with integrated permanent Cu-CuSO4 reference electrode including junction box;

6.0- Provision for Installation of Remote Monitoring Equipment and Impressed Current Systems.

Obtain any required excavation permits and contact appropriate agencies for utility locating. Inspect all hardware and equipment received on site of transportation related damage and verification that it matches with the items procured.

Install, and provide final cathodic protection systems testing for the following systems for fifteen (15) miles of ductile iron pipe water main and fifteen (15) miles of service and lateral off water main:

1. Impressed current Systems
   a. Six (6) each pole mounted deep anode ICCP rectifiers
   b. Six (6) each 100 ft. deep x 6 inch diameter anode bore, with top 50 ft' cased in non-conductive casing
   c. Thirty-Six (36) each ceramic anodes with minimum 20 years design life based on rectifier rated ampacity.
   d. Thirty-Six (36) each 3 inch dia. x 8 inch long anode canisters containing the above ceramic anodes factory assembled with individual anode lead wires of sufficient length to reach the anode junction box without splice. The annulus between the canister and the anode to be filled completely with low resistance calcined fluid petroleum coke.
   e. Six (6) each anode well heads complete with vent and anode junction box fitted with individual current measuring shunt resistors for each anode lead terminated in the junction box
   f. As required, low resistance calcined fluid petroleum coke backfill designed for use in deep anode beds pumped into place in each anode bore to encapsulated each anode canister
   g. Systems final test and commissioning to ensure that applicable National Association of Corrosion engineers (NACE) Standards are met.
2. Remote Monitoring Hardware
   a. Remote monitoring hardware as identified in Part 2.0
   b. Provide and set up the remote monitoring hardware and software to include programming including map routing, data formatting and Microsoft EXCEL downloading/tabulation and pass/fail analysis software;

c. System final test and commissioning to ensure that, within the limits of the installed system capacity, that the applicable National Association of Corrosion engineers (NACE) Standards are met.

7.0 Training

Upon completion of hardware and equipment provide on-site training for Ft. Carson maintenance personnel on the remote monitoring systems and cathodic protection systems installed in Part 3.0. Training will include the adjustment and set up of remote monitoring units and the use of software programs.

8.0 Project Documentation

Provide project documentation it include:

1. Perform final inspection of all project work,
2. Analyze and summarize results of all equipment installations,
3. Photo documentation of all project major components,
4. Document and analyze all individual component costs for detailed project compliance cost and performance report,

Provide cost/benefits information in format similar to that given at the website http://www.estcp.org/documents/guidance/CP_CP.pdf.

BUSHMAN & Associates, Inc.

CORROSION CONSULTANTS

P.O. Box 425, Medina, OH 44258 • Phone 330/769-3694, Fax 330/769-2197

B&A Environmental Impact Statement

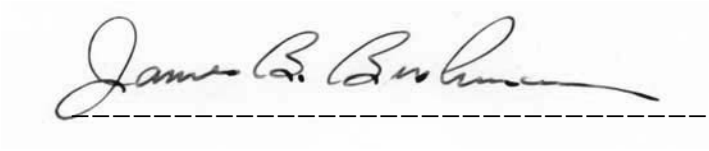
— Ver. 3.0

AR-F-321- Remote Monitoring of Cathodic Protection & Cathodic Protection System Upgrades for Tanks and Pipelines at Fort Carson

B&A hereby certifies that this project will involve disturbing significantly less than 1 acre of land and thus no Environmental Impact Statement or Plan is required for this project.

Signed:

Bushman & Associates, Inc.



James B. Bushman, P.E., C.P.S., S.C.T.

President

B&A HEALTH & SAFETY MANUAL

Ver. 4.0

BUSHMAN & Associates, Inc.
CORROSION CONSULTANTS
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Website: www.bushman.cc

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GENERAL INFORMATION

OVERVIEW

Industrial injury accidents create a no-win situation for everyone involved. Employees experience pain, suffering and incapacitation while the company suffers from the loss of the injured person's contributions. This document provides information and guidance for the establishment and maintenance of an accident-free work environment.

PROCEDURES

The appendixes to this directive contain guidance for safety procedures to be followed, and forms to be used. Supervisors are expected to integrate the procedures into the appropriate work activity and employees are expected to apply them on the job. The sample forms are to be used if they apply to the job concerned.

A copy of this statement will be issued to all supervisory and management personnel. A copy of the policy statement will give to each employee.

REGULATIONS

A copy of the following documents will be maintained on each job site:

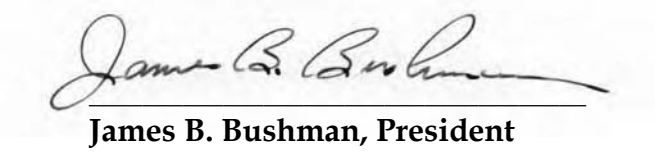
- Bushman & Associates Safety Manual
- OSHA Safety and Health Standards (29 CFR 1926 - Construction and 29 CFR 1910 – General Industry)

SAFETY AND HEALTH POLICY

The purpose of this policy is to develop a high standard of safety throughout all operations of Bushman & Associates and to provide guidelines so employees are not required to work under conditions that are hazardous or unsanitary.

Employees have the right to derive personal satisfaction from their jobs. The prevention of occupational injury or illness is central to this belief that it will be given top priority at all times.

It is Bushman & Associates's goal to initiate and maintain complete accident prevention and safety training programs. Each individual is responsible for the safety and health of those persons in their charge and co-workers around them. By accepting mutual responsibility to operate safely, we will all contribute to the well being of personnel.



James B. Bushman, President

SAFETY AND HEALTH RESPONSIBILITIES

Responsibility for safety and health include the establishment and maintenance of an effective communication system between workers, supervisors and management. To this end, all personnel are responsible to make sure that their messages are received and understood by the intended receiver. Specific safety and health responsibilities for personnel are as follows:

MANAGEMENT OFFICIALS:

Active participation in and support of safety and health programs is essential. Managers will display interest in safety and health matters. At least one manager (as designated) will participate in project safety and health meetings, accident investigations and job site inspections. Each manager will establish realistic goals for accident reduction in his/her area of responsibility and will establish the necessary implementing instructions for meeting the goals. Goals and implementing instructions shall be within the framework established by this document.

SUPERVISORS:

The safety and health of the employees they supervise is a primary responsibility of supervisors. To accomplish this obligation, supervisors will:

- Conduct pre-job safety orientations with all workers to outline safety and health rules, regulations and policies. Review rules as the job or conditions change or as required.
- Require the proper care and use of all required protective equipment.
- Identify and eliminate job hazards through job safety analysis procedures.
- Inform and train all employees on the hazardous chemicals they MAY encounter under normal working conditions or during an emergency situation.
- Conduct crew/leader meetings the first five minutes of each work shift to discuss safety matters and work plans for the work day.
- Receive and take initial action on employee suggestions, awards or disciplinary measures.
- Train all employees in the safe and efficient methods of accomplishing each job or task.
- Review accident trends and establish prevention measures.

- Attend safety meetings and actively participate in the proceedings.
- Participate in investigations and inspections on safety and health related matters.
- Promote employee participation in the safety and health program.
- Actively follow the progress of injured workers and display an interest in their rapid recovery and return to work. The Department of Labor & Industries can assist you in developing a program to effectively follow and manage injury claims.

EMPLOYEES:

Observe the items of responsibility established in this document as well as job safety rules, which may apply to specific task assignments.

EMPLOYEE SAFETY AND HEALTH RESPONSIBILITIES

- Report all on the job injuries promptly.
- Report all equipment damage to your supervisor immediately.
- Don't take chances – use your safety equipment as directed.
- Follow instructions – ask questions of your supervisor if required.
- Observe and comply with all safety signs and regulations.
- Report all unsafe conditions or situations that are potentially hazardous.
- Operate only equipment you are qualified to operate. When in doubt, ask for directions.
- Talk to management about problems that affect your safety or work conditions.

The most important part of this program is the individual employee – You! Without your cooperation, the most stringent program can be ineffective. Protect yourself and your fellow worker by following the rules. Remember: Work safely so you can go home to your family and friends.

Don't take chances – THINK SAFETY FIRST!

PERSONAL WORK RULES

- Report every injury, no matter how slight, to your supervisor immediately.
- Horseplay, fighting, gambling, possession of firearms and possession or use of alcoholic beverages or drugs, except as prescribed by a qualified physician, are strictly forbidden.
- Running on any construction site is strictly prohibited except in extreme emergencies.
- Wear clothing suitable for the weather and your work. Torn, loose clothing, cuffs, sleeves, etc., are hazardous and could cause accidents.
- Jewelry (rings, bracelets, neck chains, etc.) shall not be worn.
- Hard hats must be worn in all required areas. ANSI Class III Safety Vests will be worn by all workers near Traffic
- Proper eye protection must be worn where you are exposed to flying objects, dust, harmful rays, chemicals, flying particles, etc.
- Proper footwear must be worn on all construction sites; safety boots are highly recommended. The wearing of sport shoes, sandals, dress shoes and similar footwear is strictly prohibited.
- Always use gloves, aprons or other protective clothing when handling rough materials, chemicals, and hot or cold objects.
- When spray painting, finish spraying, burning, exposed to large quantities of dust, or to other toxic hazards, always wear the correct respirators as required.
- Special safety equipment is for your protection. Use it when required. Keep it in good condition and report loss or damage of it immediately.
    1. Hard hats will be provided for visitors to used when entering areas designated as "Hard Hat Area." They will be kept in the construction site office and to be returned when leaving.
    2. Safety Glasses will be provided for visitors. They will be kept in the construction site office and to be returned when leaving.
    3. Ear Protection
    4. Subcontractors on site will be required to have their own equipment and use it as required for safety.

GENERAL SAFETY RULES

- Always store materials in a safe manner. Tie down or support piles if necessary to prevent falling, rolling or shifting.
- Fall protection gear shall be used whenever working at 6 feet or hight above the ground/floor in a space that is not properly pretected by guardrails and kick plates. If in question, review situation with Supervisor before proceeding with work.
- Shavings, dust, scraps, oil or grease should not be allowed to accumulate. Good housekeeping is a part of the job.
- Refuse piles must be removed as soon as possible. Refuse is a safety and fire hazard.
- Remove or clinch nails in lumber that has been used or removed from a structure.
- Immediately remove all loose materials from stairs, walkways, ramps, platforms, etc.
- Do not block aisles, traffic lanes, fire exits, gangways or stairs.
- Avoid shortcuts – use ramps, stairs, walkways, ladders, etc.
- Standard guardrails must be erected around all floor openings and excavations must be barricaded. Contact your supervisor for the correct specifications.
- Get help with heavy or bulky materials to avoid injury to you or damage to material.
- Keep all tools and materials away from the edges of scaffolding, platforms, shaft openings, etc.
- Do not use tools with split, broken or loose handles, burred or mushroomed heads. Keep cutting tools sharp and carry all tools in a container.
- Know the correct use of hand and power tools. Use the right tool for the job.
- All electrical power tools (unless double insulated), extension cords and equipment shall be properly grounded.
- All electrical power tools and extension cords shall be properly insulated. Damaged cords shall be replaced.

- Know the location/use of fire extinguishing equipment and the procedure for sounding an alarm.

- Flammable liquids shall be used only in small amounts at the work site, in approved safety cans.

- Proper guards or shields must be installed on all power tools before use. Do not use any tools without the guards in their proper working condition. No "homemade" handles or extensions (cheaters) will be used!

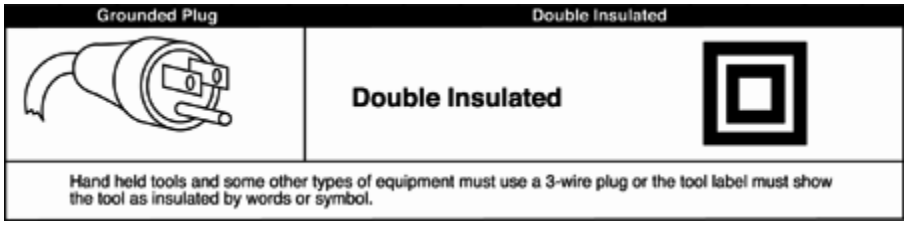
- Do not operate any power tool or equipment unless you are trained in its operation and authorized by your firm to do so.

- Use tools only for their designed purpose.

- Do not remove, deface or destroy any warning, danger sign or barricade, or interfere with any form of accident prevention device or practice provided for your use or that is being used by other workmen.

- All electrical power equipment and tools must be grounded or double insulated.

- Use tools only for their designed purpose.



WALK-AROUND SAFETY INSPECTIONS

Walk-around safety inspections will be conducted at the beginning of each job and at least weekly thereafter.

- The inspections will be conducted jointly by one member of management and one employee, elected by the employees, as their authorized representative.

- The inspections will be documented and the documentation will be made available for inspection by representatives of the Department of Labor and Industries.

- The records of the walk-around inspections will be maintained until the completion of the job.

SAFETY DISCIPLINARY POLICY

Bushman & Associates believes that a safety and health accident prevention program is unenforceable without some type of disciplinary policies. In order to maintain a safe and healthy workplace, employees must be aware of all company, State, and Federal safety and health regulations as they apply to specific job duties. The following disciplinary policy will be applied to all safety or health violations**.**

The following steps will be followed unless the seriousness of the violation would dictate going directly to Step 2 or Step 3.

1. A first time violation will be discussed orally between a manager and the employee under his/her supervision. This will be done as soon as possible. The purpose will be to educate the employee.

2. A second time offense will be followed up in written form and a copy of this written documentation entered into the employee's personnel folder.

3. A third time violation will result in time off or possible termination, depending upon the seriousness of the violation. This is per the personnel policy manual.

SAFETY DISCIPLINARY POLICY FOR SUBCONTRACTORS AND THEIR EMPLOYEES

The following steps will be followed unless the seriousness of the violation would dictate going directly to Step 2 or Step 3.

1. A first time violation will be discussed orally between site construction manager and subcontractor/subcontractor employee to educate him/her on the safety issue. A note in the Daily Report is to be made. Subcontractor's site manager to be informed for their safety meeting.

2. A second time offense by same subcontractor—a verbal reprimand followed up in writing to the Subcontractor and noted in the Daily Report. This action is dependent upon the severity of the offence.

3. A third time violation for a major offence – the worker will be requested to leave the job site and a call to the Subcontractor requiring this person to be replaced or not to return until permission is granted by Bushman & Associates .

LADDER SAFETY RULES

GENERAL

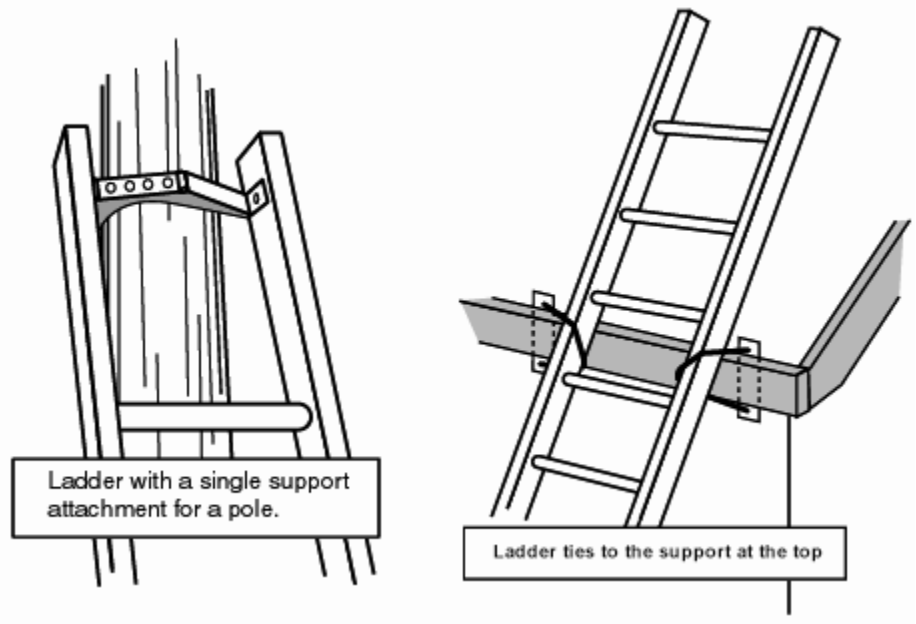
- Inspect for physical defects before use.
- Ladders are not to be painted except for numbering purposes.
- Do not use ladders for skids, braces, workbenches or any purpose other than climbing.
- When you are ascending or descending a ladder, do not carry objects that will prevent you from grasping the ladder with both hands.
- Always face the ladder when ascending or descending.
- If you must place a ladder over a doorway, barricade the door to prevent its use and post a warning sign.
- Only one person is allowed on a ladder at a time.
- Always keep both feet on the ladder rungs. Do not step laterally from a ladder onto another object.
- Do not jump from a ladder when descending.
- All joints between steps, rungs and side rails shall be tight.
- Safety feet shall be in good working order and in place.
- Rungs shall be free of grease and/or oil.
- Fall protection gear shall be used whenever working at 6 feet or hight above the ground/floor in a space that is not properly pretected by guardrails and kick plates. If in question, review situation with Supervisor before proceeding with work.

STRAIGHT TYPE OR EXTENSION LADDERS

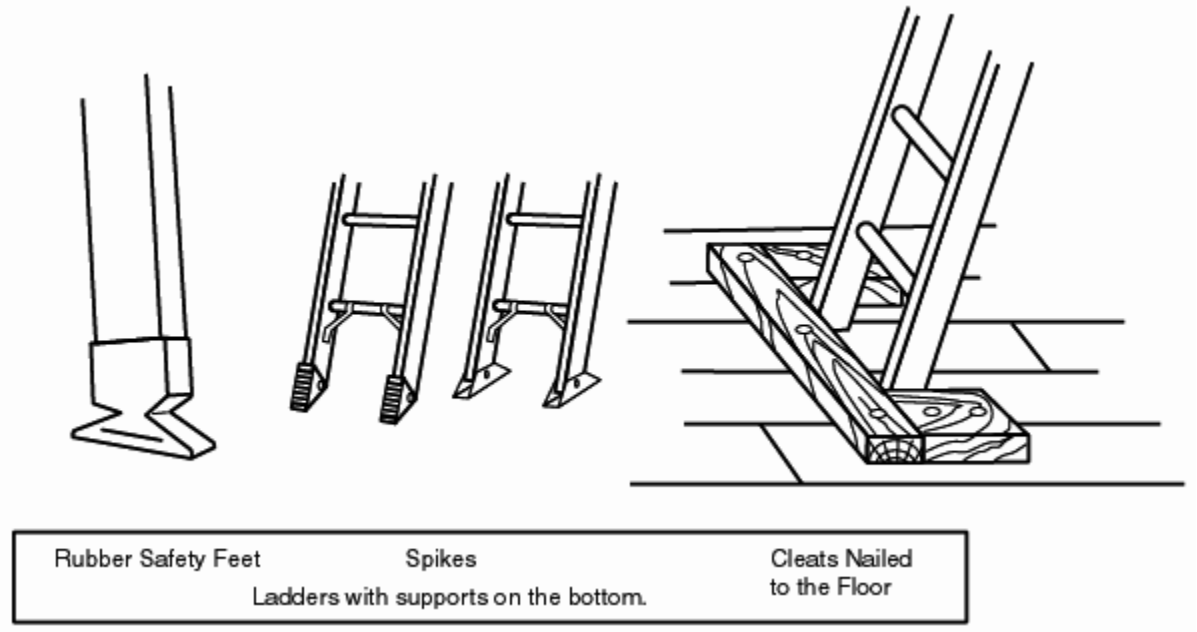
- All straight or extension ladders must be at least three feet beyond the supporting object when used as an access to an elevated work area.
- After raising the extension portion of a two or more stage ladders to the desired height, check to be sure that the safety dogs or latches are engaged.
- All extension or straight ladders must be secured or tied off at the top.
- All ladders must be equipped with safety (non-skid) feet.
- Portable ladders shall be used at such a pitch that the horizontal distance from the top support to the foot of the ladder is about one-quarter of the working length of the ladder.

STEPLADDERS

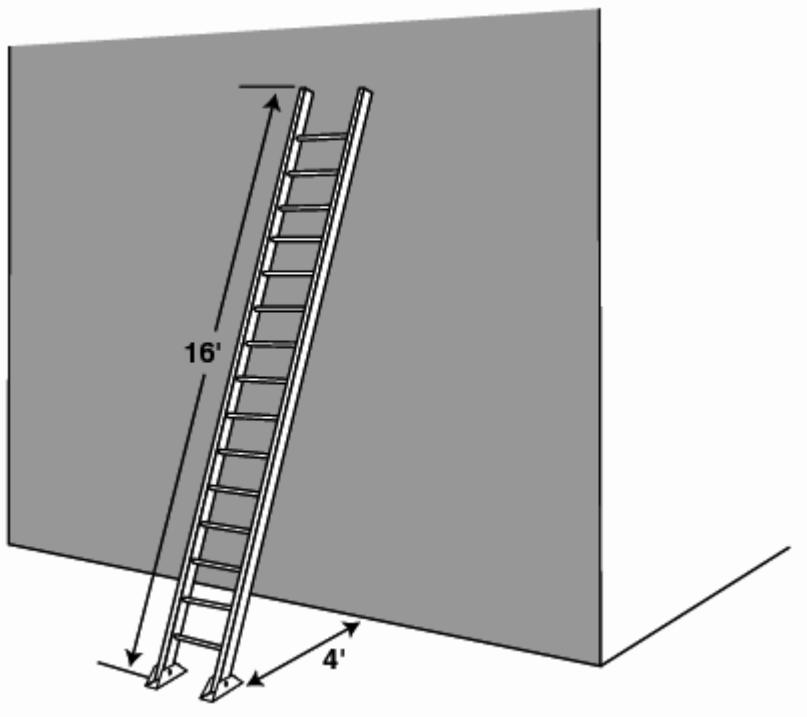
- Do not place tools or materials on the steps or platform of a stepladder.
- Do not use the top two steps or ladder cap of a stepladder as a step or stand.
- Always level all four feet and lock spreaders in place.
- Do not use a stepladder as a straight ladder.



- All ladders must be equipped with safety (non-skid) feet.



- Portable ladders must be used at such a pitch that the horizontal distance from the top support to the foot of the ladder is about one-quarter of the working length of the ladder.



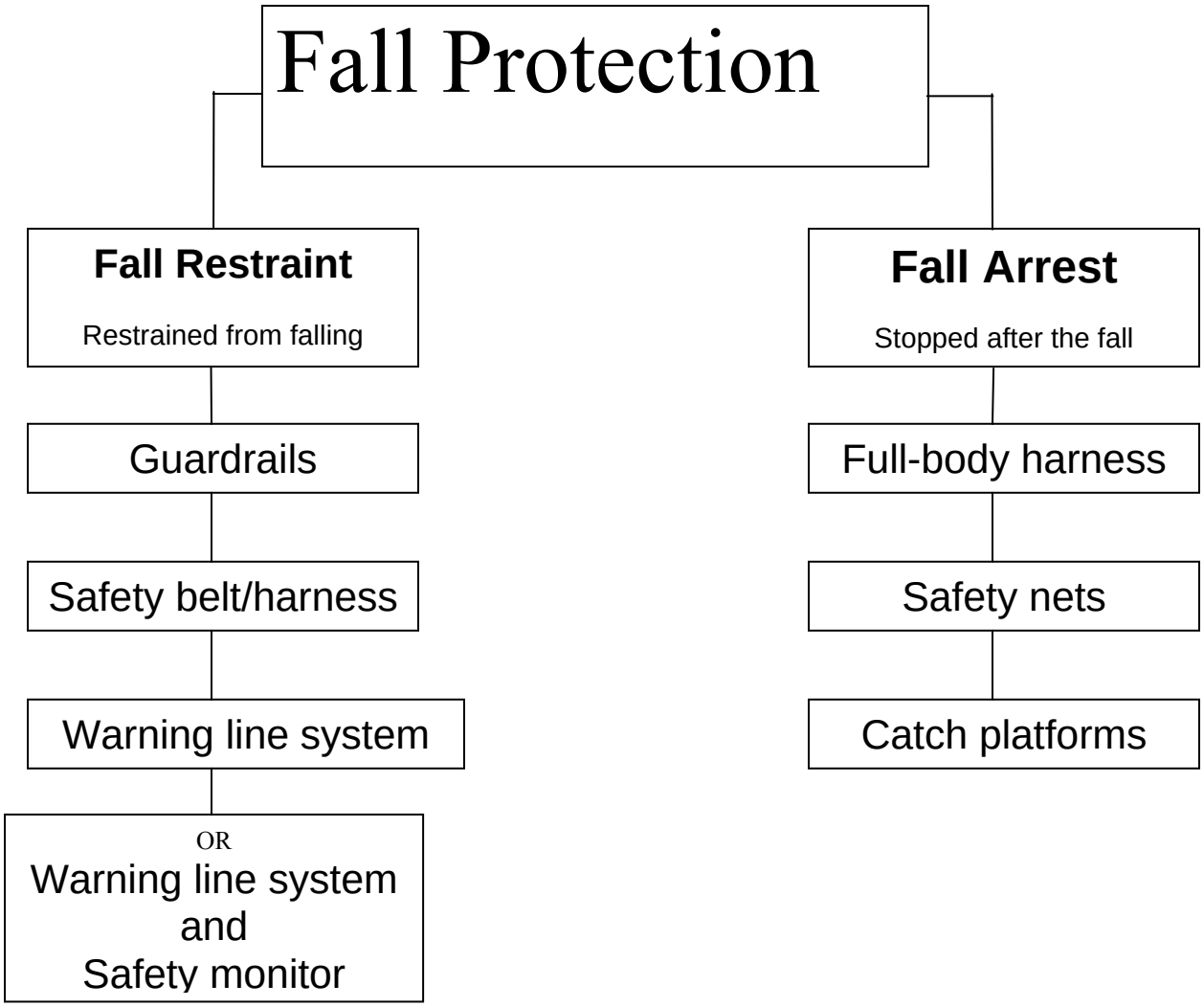
Fall Protection Safety Rules

Falls from elevation are a major cause of injuries and deaths in the construction industry. We at Bushman & Associates are committed to eliminating injuries caused by fall hazards by instituting a program of 100% fall protection for all fall hazards 10 feet or greater.

All work sites with fall hazards of 6 feet or more will have a site-specific fall protection work plan completed before any employees begin work. The employees on that specific job will be trained in the fall hazards and the method used to implement fall protection. The attached training guide will be used to train employees in the inspection and maintenance of their fall protection equipment, as well as fall protection selection criteria. All employees will use fall protection when there is exposure to a fall hazard of 6 feet or more. Employees who fail to follow this policy are subject to disciplinary action, up to and including dismissal.

The evaluation of the jobsite and the completion of the fall protection work plan will be done by a designated “competent person,” who has an understanding of OSHA fall protection requirements, the fall protection systems available for use, and has the authority to take corrective action to eliminate employee exposure to fall hazards.

Fall protection will be provided either through the use of a fall arrest system or a fall restraint system as shown below and thoroughly described in the fall protection work plan available on site for review.


Fall Protection
Fall Restraint
Restrained from falling
Guardrails
Safety belt/harness
Warning line system
OR
Warning line system
and
Safety monitor
Fall Arrest
Stopped after the fall
Full-body harness
Safety nets
Catch platforms

FALL PROTECTION TRAINING GUIDE FOR EMPLOYEES

Safety Belt, Harness and Lanyard Inspection and Maintenance

I. ANSI Classification:

Class I	Body belts – used to restrain a person from falling.
Class II	Chest harness – used for restraint purposes (NOT for vertical free fall hazards).
Class III	Full body harness – used for fall arrest purposes. Can also be used for fall restraint.
Class IV	Suspension/position belt – used to suspend or support the worker. If a fall arrest hazard exists this must be supplemented by use of a safety harness.

II. Inspection Guidelines:

To maintain their service life and high performance, all belts and harnesses must be inspected prior to each use for mildew, wear, damage and other deteriorations. Visual inspection before each use is just common sense. Periodic tests by a trained inspector for wear, damage or corrosion should be part of the safety program. Inspect your equipment daily and replace it if any of the defective conditions in this manual are found.

Belt inspection:

1. Beginning at one end, holding the body side of the belt toward you, grasp the belt with your hands six to eight inches apart. Bend the belt in an inverted "U" . The resulting surface tension makes damaged fibers or cuts easier to see.

2. Follow this procedure the entire length of the belt or harness. Watch for frayed edges, broken fibers, pulled stitches, cuts, or chemical damage.

3. Special attention should be given to the attachment of buckles and Dee Rings to webbing. Note any unusual wear, frayed or cut fibers, or distortion of the buckles or Dees.

4. Inspect for frayed or broken strands. Broken webbing strands generally appear as tufts on the webbing surface. Any broken, cut, or burned stitches will be readily seen.

5. Rivets should be tight and immovable with fingers. Body side rivet base and outside rivet burr should be flat against the material. Bent rivets will fail under stress.

   Especially note condition of Dee Ring rivets and Dee Ring metal wear pads (if any). Discolored, pitted or cracked rivets indicate chemical corrosion.

6. The tongue, or billet, of the belt receives heavy wear from repeated buckling and unbuckling. Inspect for loose, distorted, or broken grommets. Belts using punched holes without grommets should be checked for torn or elongated holes, causing slippage of the buckle tongue.

7. Tongue Buckle:

   Buckle tongues should be free of distortion in shape and motion. They should overlap the buckle frame and move freely back and forth in their socket. Roller should turn freely on frame. Check for distortion or sharp edges.

8. Friction Buckle:

   Inspect the buckle for distortion. The outer bars and center bars must be straight. Pay special attention to corners and attachment to points of the center bar.

9. Sliding Bar Buckle:
   Inspect buckle frame and sliding bar for cracks, distortions, or sharp edges.
   Sliding bar should move freely. Knurled edge will slip if worn smooth. Pay special attention to

corners and ends of sliding bar.

FALL PROTECTION TRAINING GUIDE FOR EMPLOYEES
Safety Belt, Harness and Lanyard Inspection and Maintenance (continued)

Lanyard inspection:

When inspecting lanyards, begin at one end and work to the opposite end. Slowly rotate the lanyard so that the entire circumference is checked. Spliced ends require particular attention. Hardware should be examined under procedures also detailed below, i.e., Snaps, Dee Ring, and Thimbles.

1. Steel

   While rotating the steel lanyard, watch for cuts, frayed areas, or unusual wearing patterns on the wire. Broken strands will separate from the body of the lanyards.

2. Webbing

   While bending webbing over a pipe or mandrel, observe each side of the webbed lanyard. This will reveal any cuts or breaks. Swelling, discolorations, cracks, and charring are obvious signs of chemical or heat damage. Observe closely for any breaks in stitching.

3. Rope

   Rotation of the rope lanyard while inspecting from end to end will bring to light any fuzzy, worn, broken, or cut fibers. Weakened areas from extreme loads will appear as a noticeable change in original diameter. The rope diameter should be uniform throughout, following a short break-in-period.

FALL PROTECTION TRAINING GUIDE FOR EMPLOYEES (continued)

Guidelines for worker protection where fall arrest or fall restraint systems are used.

1. Selection and use considerations:

   The kind of personal fall arrest system selected should match the particular work situation, and any possible free fall distance should be kept to a minimum. Consideration should be given to the particular work environment. For example, the presence of acids, dirt, moisture, oil, grease, etc., and their effect on the system, should be evaluated. Hot or cold environments may also have an adverse affect on the system. Wire rope should not be used where an electrical hazard is anticipated. As required by the standard, the employer must plan to have means available to promptly rescue an employee should a fall occur, since the suspended employee may not be able to reach a work level independently.

   Where lanyards, connectors, and lifelines are subject to damage by work operations such as welding, chemical cleaning, and sandblasting, the component should be protected, or other securing systems should be used. The employer should fully evaluate the work conditions and environment (including seasonal weather changes) before selecting the appropriate personal fall protection system. Once in use, the system's effectiveness should be monitored. In some cases, a program for cleaning and maintenance of the system may be necessary.

2. Testing considerations:

   Before purchasing or putting into use a personal fall arrest system, an employer should obtain from the supplier information about the system based on its performance during testing so that the employer can know if the system meets this standard. Testing should be done using recognized test methods. Not all systems may need to be individually tested; the performance of some systems may be based on data and calculations derived from testing of similar systems, provided that enough information is available to demonstrate similarity of function and design.

FALL PROTECTION TRAINING GUIDE FOR EMPLOYEES

Fall Protection System Considerations (continued)

3. Component compatibility considerations:

Ideally, a personal fall arrest system is designed, tested, and supplied as a complete system. However, it is common practice for lanyards, connectors, lifelines, deceleration devices, and body harnesses to be interchanged since some components wear out before others. The employer and employee should realize that not all components are interchangeable. For instance, a lanyard should not be connected between a body harness and a deceleration device of the self-retracting type since this can result in additional free fall for which the system was not designed. Any substitution or change to a personal fall arrest system should be fully evaluated or tested by a competent person to determine that it meets the standard, before the modified system is put in use.

4. Employee training considerations:

Thorough employee training in the selection and use of personal fall arrest systems is imperative. As stated in the standard, before the equipment is used, employees must be trained in the safe use of the system. This should include the following: Application limits; proper anchoring and tie-off techniques; estimation of free fall distance, including determination of deceleration distance, and total fall distance to prevent striking a lower level; methods of use; and inspection and storage of the system. Careless or improper use of the equipment can result in serious injury or death. Employers and employees should become familiar with this material, as well as manufacturer's recommendations, before a system is used. Of uppermost importance is the reduction in strength caused by certain tie-offs (such as using knots, tying around sharp edges, etc.) and maximum permitted free fall distance. Also, to be stressed are the importance of inspections prior to use, the limitations of the equipment, and unique conditions at the worksite which may be important in determining the type of system to use.

5. Instruction considerations:

Employers should obtain comprehensive instructions from the supplier as to the system's proper use and application, including, where applicable:

a. The force measured during the sample force test;
b. The maximum elongation measured for lanyards during the force test;
c. The deceleration distance measured for deceleration devices during the force test;
d. Caution statements on critical use limitations;
e. Application limits;
f. Proper hook-up, anchoring and tie-off techniques, including the proper dee-ring or other attachment point to use on the body harness for fall arrest;
g. Proper climbing techniques;
h. Methods of inspection, use, cleaning, and storage; and
i. Specific lifelines that may be used. This information should be provided to employees during training.

6. Inspection considerations:

Personal fall arrest systems must be regularly inspected. Any component with any significant defect, such as cuts, tears, abrasions, mold, or undue stretching; alterations or additions which might affect its efficiency; damage due to deterioration; contact with fire, acids, or other corrosives; distorted hooks or faulty hook springs; tongues unfitted to the shoulder of buckles; loose or damaged mountings; nonfunctioning parts; or wearing or internal deterioration in the ropes must be withdrawn from service immediately, and should be tagged or marked as unusable, or destroyed.

7. Rescue considerations:
When personal fall arrest systems are used, the employer must assure that employees can be promptly rescued or can rescue themselves should a fall occur. The availability of rescue personnel, ladders or other rescue equipment should be evaluated. In some situations, equipment that allows employees to

rescue themselves after the fall has been arrested may be desirable, such as devices that have descent capability.

FALL PROTECTION TRAINING GUIDE FOR EMPLOYEES

Fall Protection System Considerations (continued)

8. Tie-off considerations:

a. One of the most important aspects of personal fall protection systems is fully planning the system before it is put into use. Probably the most overlooked component is planning for suitable anchorage points. Such planning should ideally be done before the structure or building is constructed so that anchorage points can be incorporated during construction for use later for window cleaning or other building maintenance. If properly planned, these anchorage points may be used during construction, as well as afterwards.

b. Employers and employees should at all times be aware that the strength of a personal fall arrest system is based on its being attached to an anchoring system which does not significantly reduce the strength of the system (such as a properly dimensioned eye-bolt/snap-hook anchorage). Therefore, if a means of attachment is used that will reduce the strength of the system, that component should be replaced by a stronger one, but one that will also maintain the appropriate maximum arrest force characteristics.

c. Tie-off using a knot in a rope lanyard or lifeline (at any location) can reduce the lifeline or lanyard strength by 50 percent or more. Therefore, a stronger lanyard or lifeline should be used to compensate for the weakening effect of the knot, or the lanyard length should be reduced (or the tie-off location raised) to minimize free fall distance, or the lanyard or lifeline should be replaced by one which has an appropriately incorporated connector to eliminate the need for a knot.

d. Tie-off of a rope lanyard or lifeline around an "H" or "I" beam or similar support can reduce its strength as much as 70 percent due to the cutting action of the beam edges. Therefore, a webbing lanyard or wire core lifeline should be used around the beam; or the lanyard or lifeline should be protected from the edge; or free fall distance should be greatly minimized.

e. Tie-off where the line passes over or around rough or sharp surfaces reduces strength drastically. Such a tie-off should be avoided or an alternative tie-off rigging should be used. Such alternatives may include use of a snap-hook/dee-ring connection, wire rope tie-off, an effective padding of the surfaces, or an abrasion-resistance strap around or over the problem surface.

f. Horizontal lifelines may, depending on their geometry and angle of sag, be subjected to greater loads than the impact load imposed by an attached component. When the angle of horizontal lifeline sag is less than 30 degrees, the impact force imparted to the lifeline by an attached lanyard is greatly amplified. For example, with a sag angle of 15 degrees, the force amplification is about 2:1 and at 5 degrees sag, it is about 6:1. Depending on the angle of sag, and the line's elasticity, the strength of the horizontal lifeline and the anchorages to which it is attached should be increased a number of times over that of the lanyard. Extreme care should be taken in considering a horizontal lifeline for multiple tie-offs. The reason for this is that in multiple tie-offs to a horizontal lifeline, if one employee falls, the movement of the falling employee and the horizontal lifeline during arrest of the fall may cause other employees to also fall. Horizontal lifeline and anchorage strength should be increased for each additional employee to be tied-off. For these and other reasons, the design of systems using horizontal lifelines must only be done by qualified persons. Testing of installed lifelines and anchors prior to use is recommended.

g. The strength of an eye-bolt is rated along the axis of the bolt and its strength is greatly reduced if the force is applied at an angle to this axis (in the direction of shear). Also, care should be exercised in selecting the proper diameter of the eye to avoid accidental disengagement of snap-hooks not designed to be compatible for the connection.

FALL PROTECTION TRAINING GUIDE FOR EMPLOYEES

Fall Protection System Considerations (continued)

h. Due to the significant reduction in the strength of the lifeline/lanyard (in some cases, as much as a 70 percent reduction), the sliding hitch knot should not be used for lifeline/lanyard connections except in emergency situations where no other available system is practical. The "one-and-one" sliding hitch knot should never be used because it is unreliable in stopping a fall. The "two-and-two," or "three-and-three" knot (preferable), may be used in emergency situations; however, care should be taken to limit free fall distance to a minimum because of reduced lifeline/lanyard strength.

9. Vertical lifeline considerations.

As required by the standard, each employee must have a separate lifeline when the lifeline is vertical. The reason for this is that in multiple tie-offs to a single lifeline, if one employee falls, the movement of the lifeline during the arrest of the fall may pull other employees' lanyards, causing them to fall as well.

10. Snap-hook considerations:

a. Required by this standard for all connections, locking snap-hooks incorporate a positive locking mechanism in addition to the spring loaded keeper, which will not allow the keeper to open under moderate pressure without someone first releasing the mechanism. Such a feature, properly designed, effectively prevents roll-out from occurring.

b. The following connections must be avoided (unless properly designed locking snap-hooks are used) because they are conditions which can result in roll-out when a nonlocking snap-hook is used:

- Direct connection of a snap-hook to a horizontal lifeline.
- Two (or more) snap-hooks connected to one dee-ring.
- Two snap-hooks connected to each other.
- A snap-hook connected back on its integral lanyard.
- A snap-hook connected to a webbing loop or webbing lanyard.
- Improper dimensions of the dee-ring, rebar, or other connection point in relation to the snap-hook dimensions which would allow the snap-hook keeper to be depressed by a turning motion of the snap-hook.

11. Free fall considerations:

The employer and employee should at all times be aware that a system's maximum arresting force is evaluated under normal use conditions established by the manufacturer, and in no case using a free fall distance in excess of 6 feet (1.8 m). A few extra feet of free fall can significantly increase the arresting force on the employee, possibly to the point of causing injury. Because of this, the free fall distance should be kept at a minimum, and, as required by the standard, in no case greater than 6 feet (1.8 m). To help assure this, the tie-off attachment point to the lifeline or anchor should be located at or above the connection point of the fall arrest equipment to harness. (Since otherwise additional free fall distance is added to the length of the connecting means (i.e. lanyard).) Attaching to the working surface will often result in a free fall greater than 6 feet (1.8 m). For instance, if a 6-foot (1.8 m) lanyard is used, the total free fall distance will be the distance from the working level to the body harness attachment point plus the 6 feet (1.8 m) of lanyard length. Another important consideration is that the arresting force that the fall system must withstand also goes up with greater distances of free fall, possibly exceeding the strength of the system.

FALL PROTECTION TRAINING GUIDE FOR EMPLOYEES

Fall Protection System Considerations cont'd

12. Elongation and deceleration distance considerations. Other factors involved in a proper tie-off are elongation and deceleration distance. During the arresting of a fall, a lanyard will experience a length of stretching or elongation, whereas activation of a deceleration device will result in a certain stopping distance. These distances should be available with the lanyard or device's instructions and must be added to the free fall distance to arrive at the total fall distance before an employee is fully stopped. The additional stopping distance may be very significant if the lanyard or deceleration device is attached near or at the end of a long lifeline, which may itself add considerable distance due to its own elongation. As required by the standard, sufficient distance to allow for all of these factors must also be maintained between the employee and obstructions below, to prevent an injury due to impact before the system fully arrests the fall. In addition, a minimum of 12 feet (3.7 m) of lifeline should be allowed below the securing point of a rope grab type deceleration device, and the end terminated to prevent the device from sliding off the lifeline. Alternatively, the lifeline should extend to the ground or the next working level below. These measures are suggested to prevent the worker from inadvertently moving past the end of the lifeline and having the rope grab become disengaged from the lifeline.

13. Obstruction considerations:

    The location of the tie-off should also consider the hazard of obstructions in the potential fall path of the employee. Tie-offs that minimize the possibilities of exaggerated swinging should be considered.

14. Other considerations:

    Because of the design of some personal fall arrest systems, additional considerations may be required for proper tie-off. For example, heavy deceleration devices of the self-retracting type should be secured overhead in order to avoid the weight of the device having to be supported by the employee. Also, if self-retracting equipment is connected to a horizontal lifeline, the sag in the lifeline should be minimized to prevent the device from sliding down the lifeline to a position that creates a swing hazard during fall arrest. In all cases, manufacturer's instructions should be followed.

SCAFFOLD SAFETY RULES

General (only qualified and authorized persons may assemble/disassemble scaffolds).

- Before starting work on a scaffold, inspect it for the following:
  - Are guardrails, toe boards and planking in place and secure?
  - Are locking pins at each joint in place?
  - Are all wheels on moveable scaffolds locked?

- Do not attempt to gain access to a scaffold by climbing on it (unless it is specifically designed for climbing), always use a ladder.

- Scaffolds and their components shall be capable of supporting four times the maximum intended load.

- Any scaffold including accessories such as braces, brackets, trusses, screw legs, ladders, etc., damaged or weakened in any way shall be immediately repaired or replaced.

- Scaffold planks shall extend over their end supports not less than six inches or more than 12 inches, unless otherwise specifically required.

- Scaffold platforms shall not be less than 18 inches wide unless otherwise specifically required or exempted.

- Where persons are required to work or pass under the scaffold, scaffolds shall be provided with a screen between the toe board and guardrail, extending along the entire opening, of No. 18 gauge U.S. Standard wire 1/2 inch mesh or equivalent protection.

- All scaffolds must be erected level and plumb, and on a solid footing.

- Do not change or remove scaffold members unless authorized.

- Do not allow workmen to ride on a rolling scaffold when it is being moved. Remove or secure all materials and tools on deck before moving.

- Do not alter any scaffold member by welding, burning, cutting, drilling or bending.

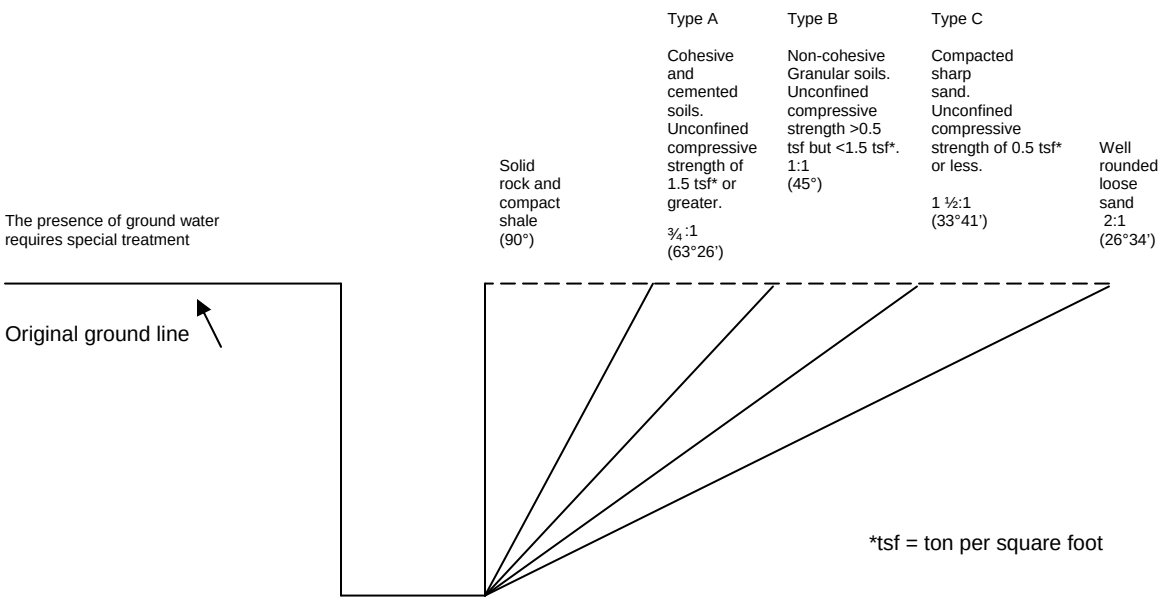
MOTORIZED VEHICLES AND EQUIPMENT SAFETY RULES

- Do not ride on motorized vehicles or equipment unless a proper seat is provided for each rider.
- Always be seated when riding authorized vehicles (unless they are designed for standing.)
- Always use your seat belts in the correct manner.
- Obey all speed limits and other traffic regulations.
- Always be aware of pedestrians and give them the right-of-way.
- Always inspect your vehicle or equipment before and after daily use.
- Never mount or dismount vehicles or equipment while they are still in motion.
- Do not dismount any vehicle without first shutting down the engine, setting the parking brake, and securing the load.
- Do not allow other persons to ride the hook or block, dump box, forks, bucket, or shovel of any equipment.
- Each operator must be knowledgeable of all hand signals and obey them. Any equipment used on site needing communication with another for operation – all parities operating the equipment to review the hand signals to be used and meanings of each prior to using the equipment
- Each operator is responsible for the stability and security of their load.

TRENCHING AND EXCAVATING SAFETY RULES

1. The determination of the angle of repose and design of the supporting system shall be based on careful evaluation of pertinent factors such as:
2. Depth and/or cut/soils.
3. Possible variation in water content of the material while excavation is open.
4. Anticipated changes in materials from exposure to air, sun, water or freezing.
5. Loading imposed by structures, equipment, overlaying material or stored material.
6. Vibration from equipment, blasting, traffic or other sources.

For sloping of sides of excavations



7. Walkways or bridges with standard railings shall be provided when employees or equipment are required to cross over excavations.
8. The walls and faces of all excavations in which employees are exposed to danger from moving ground shall be guarded by a shoring system, sloping of the ground or some other equivalent means.
9. **No person shall be permitted under loads** handled by power shovels, derricks or hoists.
10. **All employees shall be protected with personal protective equipment** for the protection of the head, eyes, respiratory system, hands, feet and other parts of the body.

HAZARD COMMUNICATION PROGRAM

PURPOSE:

The purpose of the Hazard Communication Program is to evaluate the hazards of all chemicals produced or imported by chemical manufacturers or importers. Information concerning their hazards shall be transmitted to affected employers and employees before they use the products.

The code specifically requires employers to train employees in the protective practices implemented in their workplace, the labeling system used, how to obtain and use MSDSs, the physical and health hazards of the chemicals, and the recognition, avoidance and prevention of accidental entrance of hazardous chemicals into the work environment.

PROCEDURE:

- Inventory Lists - Know the hazardous chemicals in your workplace that are a potential physical or health hazard. Make an inventory list of these hazardous chemicals; this list is part of Bushman & Associates ~SE's written program.
- MSDS - Make sure there is a material safety data sheet (MSDS) for each chemical and that the inventory list and labeling system reference the corresponding MSDS for each chemical.
- Labeling System - Each container entering the workplace must be properly labeled with the identity of the product, the hazardous warning, and the name and address of the manufacturer.
- Information and Training – Determine appropriate ways in which to inform and train employees on the specific chemicals in your workplace and their hazards.
- Written Program - Develop, implement and maintain a comprehensive written hazard communication program that includes provisions for container labeling, material safety data sheets, and an employee training program.

CONTAINER LABELING

Containers received for use will be clearly labeled as to the contents, include the appropriate hazard warning, and list the name and address of the manufacturer.

The supervisor in each section will label all secondary containers with either an extra copy of the original manufacturer's label or with labels that have the identity and the appropriate hazard warning. For help with labeling, see the office manager or area supervisor.

NOTE: If written alternatives to in-plant container labeling are used, add a description of the system used.

MATERIAL SAFETY DATA SHEETS (MSDS)

The Office Manager or Human Resources Manager is responsible for establishing and monitoring Bushman & Associates ~SE's MSDS program. He/she will make sure procedures are developed to obtain the necessary information and will review incoming MSDSs for new or significant health and safety information. He/she will see that any new information is passed on to affected employees**.** If an MSDS is not available, please let him/her know.

NOTE: If an alternative to printed material safety data sheets is used (such as computer data) provide a description of the format.

The Office Manager or Human Resources Manager is responsible for Bushman & Associates ~SE's employee training program. He/she will see that all program elements specified below are carried out.

Prior to starting work, each new employee will attend a health and safety orientation that includes the following information and training:

- An overview of the requirements contained in the Hazard Communications Program.
- Hazardous chemicals present at his/her workplace.
- Physical and health risk of the hazardous chemical.
- The symptoms of overexposure. Procedures to follow if employees are overexposed to hazardous chemicals.
- How to determine the presence or release of hazardous chemicals in his/her work area.
- How to reduce or prevent exposure to hazardous chemicals through use of control procedures, work practices and personal protective equipment.
- Steps the company has taken to reduce or prevent exposure to hazardous chemicals.
- Location of the MSDS file and written hazard communication program

Prior to introducing a new chemical hazard into any section of this company, each employee in that section will be given information and training as outlined above for the new chemical hazard.

MATERIAL SAFETY DATA SHEETS (MSDS)

HAZARDOUS NON-ROUTINE TASKS

Periodically, employees are required to perform hazardous non-routine tasks. Some examples of non-routine tasks are: confined space entry, operation of compressed air equipment, working next to the edge of the roof. Prior to starting work on such projects, each affected employee will be given information by the manager about the hazardous chemicals he or she may encounter during such activity. This information will include specific chemical hazards, and protective and safety measures the employee can use. Also included will be steps Bushman & Associates ~SE is using to reduce hazards, including ventilation, respirators, presence of another employee and emergency procedures.

MULTI-EMPLOYER WORKPLACES

It is the responsibility of the manager to provide other employers, with employees at the work site, copies of MSDSs (or make them available at a central location) for any hazardous chemicals that the employee may be exposed to. The manager will also inform other employers of any precautionary measures that need to be taken to protect employees during normal operating conditions or in foreseeable emergencies, and provide an explanation of the labeling system that is used at the work site.

LIST OF HAZARDOUS CHEMICALS

The following is a list of all known hazardous chemicals used by our employees. Further information on each chemical may be obtained by reviewing MSDSs located in Addendum 1 (Tab 11 of Appendix). If no list is provided, then no hazardous chemicals are known to be used by our employees with respect to the work on this project.

MATERIAL SAFETY DATA SHEETS (MSDS) (continued)

EMPLOYEE ORIENTATION CHECKLIST - HAZARDOUS SUBSTANCES

Employee Name: _____ **Title:** _____ **Date:** _____

This checklist is to inform employees of Bushman & Associates's Hazard Communication Program. Place a check in each box to indicate that the subject has been covered.

o The purpose of the Hazard Communication Program is to require chemical manufacturers or importers to assess the hazards of chemicals they produce or import. All employers must provide information to their employees about the hazardous chemicals to which they may be exposed.

  Employees must be informed about the Hazard Communication Program; labels, and other forms of warning; material safety data sheets; and they must have training on the hazardous substances they may encounter.

o The supervisor has reviewed the hazardous chemical list with the employee.

o The supervisor has shown the employee the:

  - o Location of hazardous chemicals within the employee's worksite.
  - o Location of the written Hazard Communication Program.
  - o Location of the material safety data sheets for all hazardous chemicals in the employee's assigned work area.
  - o Location of the list of persons trained and authorized to handle the hazardous chemicals.

The signatures below document that the appropriate elements have been discussed to the satisfaction of both the supervisor and employee and that both accept responsibility for maintaining a safe and healthful work environment.

_____ _____

Date signed Employee Signature

_____ _____

Date signed Supervisor Signature

NOTE TO SUPERVISOR: If this employee is expected to actually handle chemicals, please provide for training before employee begins actual work.

FIRST AID TRAINING, KITS, AND POSTER

PURPOSE:

To afford employees immediate and effective attention should an injury result, Bushman & Associates ~SE will attempt to have at least one first aid certified employee available. To meet these objectives, the following procedures will be followed:

- All supervisors or persons in charge of crews will be trained in first aid unless their duties require them to be away from the job site, whereby other persons will be designated as the recognized first aid trained employee.

- Other persons will be trained as designated by management in order to augment or surpass the standard requirements.

- Valid first aid cards are recognized as those that include both first aid and cardiopulmonary resuscitation (CPR) and have not reached the expiration date.

First aid kits will be in accordance with OSHA requirements and will be located at convenient locations.

Posters listing emergency numbers, procedures, etc., will be strategically located, such as on the first aid kits, at telephones, etc.

SAFETY BULLETIN BOARD

PURPOSE:

The Safety Bulletin Board is an important vehicle to increase employee awareness of safety and health policy and communicate management's safety message.

PROCEDURE:

- The Safety Bulletin Board is located in the job site office and will be maintained by the Safety Committee Representative in each office.

- Posters, Safety Committee minutes, and other information that becomes dated or worn should be changed periodically.

- The following items are required to be posted:

    - Industrial Insurance Poster LI-210-191
    - Notice (to report all injuries) LI-416-80
    - Citation and Notice (as appropriate)
    - OSHA-200 Summary (specifically during the month of February)

FIRST AID PROCEDURES IN CONSTRUCTION

First aid at the job site is done on a Good Samaritan basis. If employees are involved in a situation involving blood, they should:

- Avoid skin contact with blood/OPIM (other potentially infectious materials) by letting the victim help as much as possible, and using gloves provided in first aid kit.
- Remove clothing, etc., with blood on it after rendering help.
- Wash thoroughly with soap and water to remove blood. A 10% chlorine bleach solution is good for disinfecting the area contaminated with blood (spills, etc.).
- Report such first aid incidents within the shift to supervisors (time, date, blood presence, exposure, those helping).

The employee should receive full Hepatitis B vaccinations as soon as possible, but no later than 24 hours, after the first aid incident. If an exposure incident occurs, the following steps should be followed: a post exposure evaluation, follow-up treatment, follow-up as listed in CDC guidelines.

Training covering the above information should be conducted at job site safety meetings.

PROCEDURE FOR INJURY OR ILLNESS ON THE JOB

Owner or supervisor shall immediately take charge.

- Call 911 EMS.
- Render Good Samaritan first aid, if possible by a first aid certified employee.
- Arrange for transportation (ambulance, helicopter, company vehicle, etc.), depending on seriousness.
- Notify top management if not already present. Superintendent and/or Project Administrative Assistant
- Do not move anything unless necessary, pending investigation of accident.
- Accompany or take injured person to doctor, hospital, home, etc. (depending on extent of injuries).
- Take injured person to family doctor if available.

FIRST AID PROCEDURES IN CONSTRUCTION (continued)

- Remain with injured until relieved.

- When the injured person's immediate family is known by the management or supervisor, they should properly notify these people, preferably in person, or have an appropriate person do so.

DOCUMENTATION PROCEDURES:

- Minor Injuries *(requiring doctor/outpatient care):*
  After the employee receives medical attention following an accident, the immediate supervisor along with any witness to the accident will conduct an investigation. The findings of the investigation shall be documented on accident investigation forms. Copies of the completed investigation reports shall be given to the Managing Principal and the Safety Committee Chairperson.

- Major Injuries *(fatality or multiple hospitalization):*

  In addition to the procedures listed for Minor Injuries, the Managing Principal, Supervisor, and Safety Committee Chairperson are to be notified immediately and begin an investigation.

  In the case of a fatality or if two or more employees are hospitalized, the accident shall be reported to the nearest office of the Department of Labor & Industries, or call the toll-free telephone number, 1-800-423-7233, within 24 hours after the occurrence of the accident. The report shall relate the circumstances, the number of fatalities and the extent of any injuries.

  Note: Any equipment involved in an accident resulting in an immediate fatality is not to be moved until a representative of the Department of Labor & Industries has inspected it. If, however, it is necessary to move the equipment to prevent further accidents or to remove the victim, the equipment may be moved as required.

- Near-Misses *(likelihood of personal injury or property damage):*
  To the greatest extent possible, all "near-miss" accidents shall be investigated by the Managing Principal (if situation warrants), supervisor, and Safety Committee Chairperson. Documentation will be made on the firm's accident investigation forms. A near-miss accident is defined as any unplanned event where damage did not result, but the likelihood of personal injury to the employee was great. If the conditions, which permitted the near miss to exist, are not eliminated, they will continue to be potential causes of an accident, which could eventually result in personal injury.

OCCUPATIONAL INJURY AND ILLNESS RECORDKEEPING

PURPOSE:

In accordance with applicable requirements of OSHA's standards, Bushman & Associates ~SE's records will be kept by Engineered Lining Systems, Inc. They will keep the appropriate records as follows:

- Maintain a log and Summary of Occupational Injuries and Illness on OSHA 300 forms. Recordable cases include:
  - Every occupational death.
  - Every occupational illness.
  - Every occupational injury that involves: unconsciousness; inability to perform all phases of the regular job; inability to work full-time on a regular job; temporary assignments to another job; medical treatment other than first aid.

- Keep copies of all reports generated when an employee is injured on the job.

- During the month of February, post on the Safety Bulletin Board the completed summary portion of the OSHA 300 form for the previous year.

- Maintain records for five years following the year the injury occurred.

- Enter each recordable injury or illness on the log as early as feasible, but no later than six working days after receiving the information that a recordable case has occurred.

- In addition to the OSHA 300, a supplementary record for each occupational injury or illness (OSHA 101) will be maintained. Other reports, such as worker's compensation forms, are acceptable alternatives for the OSHA 101 if they contain the information required by the OSHA 101.

ACCIDENT INVESTIGATION AND REPORTING

The purpose of an investigation is to find the cause of an accident and prevent future occurrences, NOT to fix blame. An unbiased approach is necessary to obtain objective findings. A manager/supervisor shall complete an Accident Report (Supervisor) and the employee shall complete an Accident Report (Employee).

- Write down all details of the accident immediately, no matter how small or apparently insignificant they may seem. Remember that the longer the time lapse between the accident and the report, the hazier the witnesses' memories become and the less accurate the report.

- Write down the names and statements of the witnesses. Interview witnesses one at a time (try to keep witnesses from talking to each other before you interview them). Talk with anyone who has knowledge of the accident, even if they did not actually witness the mishap. Consider taking signed statements in cases where facts are unclear or there is an element of controversy.

- If possible, interview the injured worker at the scene of the accident and "walk" him/her through a reenactment. Be careful not to actually repeat the act that caused the injury.

- Graphically document details of the accident; area, tools, and equipment. Use sketches, diagrams and photos as needed, and take measurements when appropriate. Note the object, tool, machine, building detail, or chemical substance associated with the accident.

- Note the condition of the object associated with the accident - was it in a safe or unsafe condition at the time of the accident?

- Identify the type of accident. Give details such as whether the individual fell into the machinery, was struck by the object, etc.

- Indicate any unsafe acts on the part of the person involved which may have precipitated the accident or been a contributing element.

- Incorporate in the report any recommendation for future safety, the date of the recommendation, and the date of its initial institution. How will you prevent such accidents in the future? Every investigation should include an action plan.

- Focus on causes and hazards. Develop an analysis of what happened, how it happened and how it could have been prevented. Determine what caused the accident itself, not just the injury.

- If a third party or defective product contributed to the accident, save any evidence. It could be critical to the recovery of the claim costs.

HOW TO HOLD A *GOOD* SAFETY MEETING

- Be certain everyone knows the time and location of the next meeting.
- Insist that everyone attend. Before the next meeting, remind those that were late or failed to attend that ***attendance is not an option.***
- Pick an appropriate topic.
- Start the meeting on time.
- Don't waste time - give the meeting your undivided attention.
- Discuss the topic you have chosen and prepared. Don't wait until the meeting to choose your topic.
- Use handouts or posters to illustrate your topic.
- Discuss current job safety events, accidents and close calls.
- Encourage employees to discuss safety problems as they arise. Do not save safety concerns for the meetings. Allow some time for employee questions or input at the end of the meeting.
- Invite managers or owners to speak. Ask fellow employees to speak on a safety topic.
- If you prevented one accident, it is time well spent. Your topic may be one that some employees have heard many times, but there may be one person who is new or has never been told of the safety requirement for the topic. Repeating topics several times during the course of a project is beneficial as long as it applies to the work being done.
- Follow up on employee concerns or questions and get back to them with the answer before the next meeting.
- Be certain to document the attendance and the topics discussed.

CREW LEADER MEETINGS

We believe that there is no magic formula for the prevention of accidents - hard work and perseverance are required, with the crew leader being the key to a successful result.

- Purpose: To assist in the detection and elimination of unsafe conditions and work procedures.

- Weekly meetings: These meetings should be held in accordance with the various circumstances involved or when necessity dictates. No set pattern will suit all cases. It is important, however, that the leader talk daily on accident prevention and immediately on witnessing an unsafe act.
  - Safety meetings shall be held at least once a week.
  - The attendance and subjects discussed shall be documented and maintained on file for one year.
  - Copies of the minutes should be made available to the employees by posting or other means.

SCOPE OF ACTIVITIES:

- Certain employees as may be designated by their supervisors will assist.

- Conduct in-house safety inspections with supervisor concerned.

- Accident investigation to uncover trends.

- Review accident reports to determine means or elimination.

- Accept and evaluate employee suggestions.

- Review job procedures and recommend improvements.

- Monitor the safety program's effectiveness.

- Promote and publicize safety.

Documentation: The following form is available to assist in documentation activities of crew/leader meetings: Crew Leader Safety Meeting, Form F411-049-000.

APPENDICES

The following Forms, Checklists and Guides are intended as aids. They are samples that may be used on the project as the manager sees fit. One exception is the OSHA Record keeping forms. These are required of all firms with more than ten employees.

- OSHA Form 300 – Log of Work Related Injuries & Illness
- Supervisor's Accident Investigation Forms
- Employee Accident Investigation Forms
- Crew Leader Meeting Documentation Forms
- Health & Safety Inspection Checklist
- Safety Inspection Guide
- Barometer of Safety Attitudes - Construction Self-Inspection Guide
- Equipment Safety Inspection Checklist and Sample Form
- Job Safety Analysis Worksheet
- Fall Protection Work Plan, Sample (Site Specific)
- ☐ MSDS Sheets—Attached if needed for project
- ☐ Emergency Procedures – Job / Site Specific

  Evacuation Procedure

  Emergency Contact List—Employees

  Emergency Hospital Route from Fort Carson to Memorial Hospital, Colorado Springs, CO

□ **OSHA FORM 300 HERE**

BUSHMAN & ASSOCIATES
ACCIDENT REPORT (SUPERVISOR)

Supervisor's name: _____ Title: _____

Exact date/time accident reported to you: _____ / _____

Injured employee's name/title: _____ / _____

Who reported it? _____

Names of witnesses: _____

Describe the accident (attach additional page(s) if necessary): _____

_____

_____

_____

Was first aid required? _____ Did the accident require a doctor's treatment? _____

Date/time of next doctor appointment: _____ / _____

Was this employee competent and skillful in his/her job? _____

What were the causes? _____

_____

_____

Will this be a time loss case? _____

If so, was the employee instructed to keep the company informed of his/her progress? _____

If not, why? _____

Has this employee had other injuries? _____ If yes, how many? _____

EXPLAIN IN DETAIL: What part of the body was injured? _____

_____

_____

Other details of the accident: _____

_____

_____

Supervisor's signature: _____ Date: _____

BUSHMAN & ASSOCIATES
ACCIDENT REPORT (EMPLOYEE)

Employee's name: _____ Title: _____

Exact time of injury: _____ Date of injury: _____

Location where injury occurred: _____

Name of person to whom this incident was reported: _____ Time: _____

Names of witnesses: _____

Summarize what you think happened: _____

_____

_____

What could have been done to avoid this accident? _____

_____

_____

EXPLAIN IN DETAIL: What part of your body was injured? BE SPECIFIC _____

_____

_____

Is this an original injury or a re-injury? _____

If a re-injury, who was the employer? _____ Claim number _____

Would you be willing to perform light-duty work during your recovery? _____

Date/time you sought medical attention _____ / _____

Whom did you see? _____ Office/hospital: _____

Employee signature: _____ Date: _____

This form is to be returned to your employer as soon as possible.

Signature / date of person receiving report _____ / _____

BUSHMAN & ASSOCIATES
CREW LEADER SAFETY MEETING MINUTES

Project:	
Project No.:	
Minutes of Meeting No.:	
Date:	
Location:	

Present Y/N	Attendees (Name)	Company	Phone Number

Item	Description	Status	Opened	Due	Action By

The preceding is presumed to be a complete and correct record of the significant items and actions agreed upon at the above meeting. Work is proceeding on the basis of this record. Please advise the writer immediately of any additions or corrections to these minutes.

Prepared by: Bushman & Associates ~SE, Inc.

Signed: _____

Dated: _____

Attachments:

Safety and Health Inspection Check List

Office _____ Date _____

This format is intended only as a reminder to look for unsafe practices, accidents, potential and/or near miss accidents, and then report them to the Safety Committee.

(S) indicates satisfactory (U) indicates unsatisfactory

Date of Inspection / walk around												
Machinery												
Point of operations guard												
Belts, pulleys, gears, shafts, etc.												
Oiling, cleaning, and adjusting												
Maintenance and oil leaks												
Pressure equipment												
Steam equipment												
Air Receivers and Compressors												
Gas cylinders and hoses												
Unsafe practices												
Excessive speed of vehicles												
Improper lifting												
Smoking in dangerous areas												
Horseplay												
Running in aisles or on stairs												
Improper use of air hoses												
Removing machine or other guards												
Working under suspended loads												
Working on machines in motion												
First Aid												
First aid kits and rooms												
Stretchers and fire blankets												
Emergency showers												
Eyewash Stations												
All injuries and illness reported												
Hazard Communications												
Acids and caustics												
Solvents												
Dust, vapors, or fumes												
Radiation												
New chemicals / processes												

Safety and Health Inspection Check List --Page 2

(date of inspection / walk around) _____

Tools
- Power tools, wiring, and grounding
- Hand tools (condition)
- Use and storage of tools

Personal Protective Equipment
- Goggles or face shield
- Safety shoes
- Hard hats
- Gloves
- Respirators or gas masks
- Protective clothing

Fire protection
- Extinguishing equipment
- Standpipes, hoses, sprinkler heads, valves
- Exits, stairs, and signs
- Storage of flammable materials

Material handling equipment
- Ladders and scaffolds
- Power trucks, hand trucks
- Elevators
- Cranes and hoists
- Conveyors
- Cables, ropes, chains, slings

Housekeeping
- Aisles, stairs, and floors
- Storage and piling of material
- Wash and locker rooms
- Light and ventilation
- Disposal of waste
- Yards and parking lots

Bulletin boards
- Only safety and health materials posted
- Neat and attractive
- Display regularly changed
- Well-illuminated

SAFETY INSPECTION GUIDE

A - Adequate at the time of the inspection **B** - Needs immediate attention

A	B	
		JOB SITE INFORMATION
o	o	OSHA and other job site warning posters posted
o	o	Scheduled safety meetings held and documented
o	o	Adequate employee training - general and specific
o	o	Medical services, first aid equipment, stretchers, and a qualified first aid certified employee
o	o	Emergency telephone numbers, such as police department, fire department, doctor, hospital and ambulance, posted
		HOUSEKEEPING AND SANITATION
o	o	Working areas generally neat
o	o	Waste and trash regularly disposed
o	o	Enclosed chute provided when material dropped outside of building from over 20 feet
o	o	Lighting adequate for all work tasks
o	o	Projecting nails removed or bent over
o	o	Oil and grease removed from walkways and stairs
o	o	Waste containers provided and used
o	o	Passageways and walkways clear
o	o	Sanitary facilities adequate and clean
o	o	Potable water available for drinking
o	o	Disposable drinking cups and containers for used cups provided
		FIRE PREVENTION
o	o	Fire protection program developed
o	o	Fire instructions provided to employees
o	o	Adequate fire extinguishers, identified, checked and accessible
o	o	Phone number of fire department posted
o	o	Hydrants clear, access open
o	o	Good housekeeping in evidence
o	o	NO SMOKING signs posted and enforced (where needed)
o	o	Temporary heating devices safe; adequate ventilation provided
o	o	Proper fire extinguishers provided
		ELECTRICAL INSTALLATIONS
o	o	Adequate wiring, well insulated, grounded, protected from damage
o	o	Assured Grounding program followed
o	o	(or) Ground fault circuit interceptors used
o	o	Terminal boxes equipped with required covers
		HAND TOOLS
o	o	Proper tools being used for each job
o	o	Safe carrying practices used
o	o	Company and employees' tools regularly inspected and maintained

SAFETY INSPECTION GUIDE (continued)

POWER TOOLS

o o Good housekeeping where tools are used
o o Tools and cords in good condition
o o Proper grounding of all tools
o o Proper instruction in use provided
o o All mechanical safeguards in use
o o Tools neatly stored when not in use
o o Right tool being used for the job at hand
o o Wiring properly installed

POWER-ACTIVATED TOOLS

o o All operators licensed
o o Tools and charges protected from unauthorized use
o o Competent instruction and supervision provided
o o Tools used only on recommended materials
o o Safety goggles or face shields worn
o o Flying hazards checked by backing up, removal of personnel, or use of captive stud tool

LADDERS

o o Ladders inspected and in good condition
o o Ladders properly secured to prevent slipping, sliding or falling
o o Side rails extended 36" above the top of the landing
o o Job-built ladders properly constructed
o o Stepladders fully open when in use
o o Metal ladders not used around electrical hazards
o o Ladders not painted
o o Ladders properly stored
o o Ladder safety feet in use

SCAFFOLDING

o o Erection properly supervised
o o All structural members meet safety factors
o o All connectors secure
o o Scaffold tied to the structure when required
o o Working areas free of debris, snow, ice and grease
o o Foot sills and mud sills provided
o o Workers protected from falling objects
o o Scaffold plumb and square, with cross-bracing
o o Guard rails, intermediate rails and toeboards in place
o o Adequate, sound planking provided
o o Scaffold equipment in good working order
o o Ropes and cables in good condition

HEAVY EQUIPMENT

o o Inspection and maintenance records up to date
o o Lights, brakes, warning signals operative
o o Wheels chocked when necessary
o o Haul roads well maintained and properly laid out
o o Equipment is properly secured when not in use
o o Shut off devices on hose air lines, in case of hose failure
o o Noise arresters in use

o o ROPS in place

SAFETY INSPECTION GUIDE (continued)

MOTOR VEHICLES

o	o	Floor and wall openings planked over or barricaded
o	o	Roadways or walkway hazards effectively barricaded
o	o	Barricades illuminated or reflectorized at night
o	o	Traffic control devices used when appropriate
o	o	Inspection and maintenance records up to date
o	o	Operators qualified for vehicle in use
o	o	Local and state vehicle laws and regulations observed
o	o	Brakes, lights, warning devices operative
o	o	Weight limits and load sizes controlled
o	o	Personnel transported in a safe manner
o	o	All glass in good condition
o	o	Back-up signals provided
o	o	Fire extinguishers installed where required
o	o	SLOW MOVING VEHICLE signs used when required

REPAIR SHOPS AND GARAGES

o	o	Fire hazards eliminated
o	o	Fuels and lubricants dispensed in a safe location
o	o	Good housekeeping maintained
o	o	Lighting adequate for work tasks
o	o	Carbon monoxide vented to outside and adequate ventilation provided inside
o	o	All fuels and lubricants in proper containers

HOISTS, CRANES AND DERRICKS

o	o	Cables and sheaves regularly inspected
o	o	Slings and chains, hooks and eyes inspected before each use
o	o	Equipment firmly supported
o	o	Outriggers used if needed
o	o	Power lines inactivated, removed, or at a safe distance
o	o	Proper loading for capacity at lifting radius. Rated load capacities posted?
o	o	All equipment properly lubricated and maintained
o	o	Signalmen where needed
o	o	Signals posted, understood and observed
o	o	Inspection and maintenance logs maintained
o	o	Hazard signs posted and visible to operator

BARRICADES

o	o	Floor and wall openings planked over or barricaded
o	o	Roadways or walkway hazards effectively barricaded
o	o	Barricades illuminated or reflectorized at night
o	o	Traffic control devices used when appropriate

HANDLING AND STORAGE OF MATERIALS

o	o	Materials properly stored or stacked
o	o	Passageways clear
o	o	Stacks on firm footing, not too high
o	o	Materials protected against weather conditions
o	o	Trash chutes safeguarded and properly used
o	o	Dust protection observed
o	o	Traffic controlled in the storage area

SAFETY INSPECTION GUIDE (continued)

EXPLOSIVES

o o Qualified operators and supervision during all explosives operations
o o Proper transport vehicles as required by DOT and OSHA
o o State and local laws and regulations observed
o o Storage magazines constructed per regulations
o o Cases opened ONLY with wooden tools
o o NO SMOKING signs posted and observed where appropriate
o o Detonators tested before each shot
o o All personnel familiar with signals; signals properly used at all times
o o Inspection after each shot
o o Proper protection and accounting for all explosives at all times
o o Proper disposition of wrappings, waste and scrap
o o Nearby residents advised of blasting cap danger
o o Radio frequency hazards checked

FLAMMABLE GASES AND LIQUIDS

o o All containers approved and clearly identified
o o Proper storage practices observed
o o Fire hazards checked
o o Proper types and number of extinguishers nearby
o o Proper method for moving cylinders used

WELDING AND CUTTING

o o Operators qualified
o o Screens and shields used when needed
o o Goggles, welding helmets, gloves, clothing used as required
o o Equipment in safe operating condition
o o Electrical equipment grounded
o o Power cables and hoses protected and in good repair
o o Fire extinguishers of proper type nearby
o o Surrounding area inspected for fire hazards
o o Flammable materials protected or removed
o o Gas cylinders secured upright
o o Cylinder caps in use

EXCAVATION AND SHORING

o o Adjacent structures properly shored
o o Excavation shored or cutback (angle of repose) as required
o o Roads and sidewalks supported and protected
o o Material stored away from excavations
o o Excavation barricades and fighting adequate
o o Equipment a safe distance from edge of excavation
o o Ladders provided
o o Equipment ramps adequate
o o Observer provided during trenching operations

DEMOLITION

o o Written Demolition Plan
o o Protection of adjacent structures
o o Material chutes used; floor openings for material disposal barricaded

- o o Sidewalk and other public protection provided
- o o Clear opening space for trucks and other vehicles
- o o Adequate access ladders or stairs maintained

SAFETY INSPECTION GUIDE (continued)

PILE DRIVING

o o Stored piles properly secured
o o Unloading only by properly instructed workers
o o Steam lines, slings, etc., in safe operating condition
o o Piledriving rigs properly supported
o o Cofferdams maintained and inspected
o o Adequate pumping available

STEEL ERECTION

o o Fall protection provided with safety nets, planked floors or personnel resistant devices
o o Hard hats worn as required
o o Tools and materials secured from falling
o o Fire hazards at rivet, forge and welding operations eliminated
o o Floor openings covered or barricaded
o o Ladders, stairs, or other safe access provided
o o Daily inspection of hoisting apparatus
o o Employees prohibited from riding the ball or loads

HIGHWAY RIGHT OF WAY CONSTRUCTION

o o Laws and ordinances observed
o o Competent flaggers properly instructed, dressed, area posted
o o Adequate traffic control devices used through construction area
o o Equipment cleared from right-of-way
o o Adequate marking and maintenance of detours approaching construction area
o o Dust controlled
o o Adequate lighting for night crews

CONCRETE CONSTRUCTION

o o Forms properly installed and braced
o o Adequate shoring, plumbed and cross-braced
o o Shoring remains in place until strength is attained
o o Proper curing period and procedures followed
o o Heating devices checked for fire safety
o o Mixing and transport equipment supported; traffic planned and routed
o o Adequate runways and ramps provided for concrete placement equipment
o o Employees protected from cement dust
o o Hard hats, boots, gloves, eye protection, and skin protection worn at all times
o o Nails bent over or removed and stripped material removed from area

MASONRY

o o Scaffolding procedures meet at least minimum requirements
o o Masonry saws equipped and grounded, dust protection provided
o o Hoisting equipment in safe operating condition and used by qualified personnel
o o Limited access zone established
o o Walls over 8 feet in height adequately braced

BACK SAFETY

o o Team lifting used for heavy or awkward loads
o o Mechanical lifting devices used when appropriate
o o Back care training provided to all employees
o o Bent-knee lifting used by workers
o o Back support belts worn when appropriate
o o Work hardening program used for returning time-loss employees
o o Employees do "warm-up" exercises before strenuous work

SAFETY INSPECTION GUIDE (continued)

PERSONAL PROTECTIVE EQUIPMENT MONITORED BY SUPERVISOR

o	o	Eye protection
o	o	Face shields
o	o	Written respirator program; respirators fit tested; replaced cartridges; cleaning and maintenance
o	o	Helmets and hoods
o	o	Foot protection
o	o	Rubber or plastic gloves, aprons, and sleeves for chemical protection
o	o	Electrician's rubber gloves and protectors

HAZARD COMMUNICATION PROGRAM

o	o	Chemical inventory list developed and maintained
o	o	Containers properly labeled
o	o	Material Safety and Data Sheets collected and available
o	o	Adequate employee information and training provided
o	o	Written program available
o	o	Employee training certificates signed

CONFINED SPACE

o	o	Written Confined Space Program
o	o	Competent instruction and supervision provided
o	o	Hot work permits obtained if needed prior to entry and work
o	o	Evaluation and monitoring; sampling devices adequate, calibrated, used
o	o	Adequate ventilation; testing and monitoring during operation
o	o	Respirators, standby person, harness/lifeline at the site
o	o	Employee training certificates signed

Note: Categories or items on this checklist may be added to or eliminated if they do not pertain to your operation.

BAROMETER OF SAFETY ATTITUDES
CONSTRUCTION SELF INSPECTION GUIDE

- Power lines: Minimum 10' clearance / insulate – de-energize, under 50 kw; over 50 kw.
- Trench/excavation: Any trench four feet or more must be sloped, shored or braced.
- Guardrails: Any opening four feet or more above ground level must be guarded.
- Standard guardrail: Top rail = 36" - 42" above working surface, Mid rail = 18" - 22" with toe board
- Scaffold/guardrail: Fully planked
- Flights of stairs: Four or more risers must have handrails
- Fall protection: Any exposure to the hazard of falling from elevations 6' or greater must be eliminated by the use of safety harness/belt, lanyard or lifeline, horizontal lines, or centenary lines. Positive fall protection must be used at all times.
- Open belts and pulleys, chains and sprockets and points of operation must be guarded to prevent accidental contact. Air compressors and electric motor pulleys are most common hazards.
- Radial saws: Cutting head must return easily to start position when released; blade must not extend past the edge of the work table; off/on switch should be at front of operator's position.
- Table saws: Upper hood guard; anti-kickback, push stick, belt, pulley
- Circular saws: Blade guard instantly returns to covering position
- Never wedge or pin a guard
- Chainsaw: Ballistic nylon leg protection; eye, ear, face protection; hard hat
- Angle grinders; 180' guard required
- Ladders: Extend 36" above landing and secure to prevent displacement
- Articulating boom lift: Safety at all times
- Floor holes/openings covered, secured; be sure no tripping hazards in area
- Extension cords/electric power tools, marked/covered by Assured Grounding Program
- Minimum of short sleeve shirts, long pants and substantial footwear - no recreation shoes
- Hard hat readily accessible/worn when overhead hazards exist
- Oxygen/acetylene storage areas chained and separated
- Personal protective equipment: head, eye, ear respiratory, and leg protection, high visibility vests
- Housekeeping: Workers responsible for own areas of exposure
- First aid kit - Fire extinguishers
- Minimum of one person at all times - first aid and CPR trained
- Accident prevention program
- Crew leader meetings: Meetings specifically tailored to each subcontractor
- Chemical hazard communication program

EQUIPMENT SAFETY INSPECTION CHECKLIST

- This form is used as a checklist for equipment coming into a project.
- The items to be checked are listed and are required to be checked as a minimum pre-work inspection.
- Any item that needs attention will be corrected before the equipment is put to work on the project.
- The report will be filed at the Field Office for the duration of the project. A copy will also be sent to the main office.
- These forms will be inspected by company safety personnel, as well as governmental safety representatives.
- The Project Manager is responsible for ensuring that the pre-operating safety check is properly done.

EQUIPMENT SAFETY INSPECTION CHECKLIST

Date:_____

Equipment Number/Name:_____

Project:_____

All guards and fenders _____OK _____ Needs Repair
Brakes _____OK _____ Needs Repair
Lights—Front, Rear, Side
Dash _____ OK _____ Needs Repair
Bakup Alarm – Horn _____ OK _____ Needs Repair
Ladders / Stairs /
Hand Holds _____ OK _____ Needs Repair
ROPS _____ OK _____ Needs Repair
Seat Belts _____ OK _____ Needs Repair
Fire Extinguisher _____ OK _____ Needs Repair
Glass _____ OK _____ Needs Repair
Tires _____ OK _____ Needs Repair

Other Items Checked:

Oil – Level & Leaks _____ OK _____ Needs Repair _____Add _____Change
Antifreez – Level
& Leaks _____ OK _____ Needs Repair _____Add _____Change

Fuel – Level & Leaks_____ OK _____ Needs Repair _____Add _____Change
Hydraulic Oil Level
& Leaks _____ OK _____ Needs Repair _____Add _____Change
First Aid Kit _____ OK _____ Needs Repairs _____Add _____Change

Checked By:_____
Date

Repaired By:_____
Date

JOB SAFETY ANALYSIS WORKSHEET

TITLE OF JOB
OPERATION_____Date_____

Position/Tile of person who does job _____

Employee Observed _____Location_____

Analysis made by _____Analysis approved by_____

Sequence of basic job steps	Potential accidents or hazards	Recommended safe job procedure

Personal protective equipment required:

FALL PROTECTION WORK PLAN

SITE SPECIFIC

Job Name _____ Date Prepared _____

Person approving plan _____ Title Job Superintendent

Activities: Inspection and coordination of work performed or being performed.

Identify hazards in the work area: Uneven surfaces, debris, holes, overhead structural members, electrical, piping, and/or other installed systems.

Check methods of fall restraint or arrest to be used:

___ Standard guardrail top, middle & toe board
___ Horizontal lifeline
___ Secured to existing strut
___ Shock absorber lanyard
___ Drop line-rope grab
___ Boom lift
___ Double lanyard system
___ Full body harness
___ Tie off point capable of 5,000 lb. load
___ Retractable lanyard
___ Scaffold-with guardrail and toe boards
___ Other (specify) Lanyard
___ Safety net(s)
___ Float
___ Restraint line
___ Beam seat
___ Scissor lift

Describe procedures for assembly, maintenance, inspection and disassembly system (attach separate sheet if more space is needed).

Describe procedures for handling and securing tools and equipment, and providing overhead protection for employees (attach separate sheet if more space is needed).

FALL PROTECTION WORK PLAN

SITE SPECIFIC (continued)

Describe method for prompt, safe removal of an injured employee(s).

Provide stick drawings of system configuration

I certify that I received fall protection orientation including the material covered in this plan.
Employee(s) signature and date:

_____ _____

_____ _____

_____ _____

_____ _____

This plan has been prepared as a general guideline.

Site Safety Officers

Depending on the Phase of the Job, one of the following persons on-site will be the Safety Officer for Bushman & Associates:

- Mr. James B. Bushman, President, Bushman & Associates, Inc.
- Mr. N. Dennis Burke, President, Burke & Associates, Inc.
- Mr. William P. Carlson, President, Cathodic Protection Management, Inc.

In the absence of the following three (3) individuals, the current senior manager for Bushman & Associates or their Prime Subcontractor for that phase of work will be the designated Safety Officer:

–

Fall Protection Work Plan Overview

Job Name: _____ Date: _____
Site Address: _____

Fall Hazards	Type of Fall Protection	Specific Location
Structural Steel Connection	_____	_____
Bolting	_____	_____
Decking	_____	_____
Welding	_____	_____
Acetylene Burning	_____	_____
Crane Supported Platforms	_____	_____
Boom Lift	_____	_____
Scissor Lift	_____	_____
Perimeter	_____	_____
Roof	_____	_____
Stairwells	_____	_____
Ladders	_____	_____
Scaffolds over 10 feet	_____	_____
Rolling Scaffolds	_____	_____
Exterior Scaffolds	_____	_____
Elevator Shafts	_____	_____
Wall Openings	_____	_____
Upper Floor material	_____	_____
Loading/unloading area	_____	_____

Check Fall Protection to be used

A – Standard guardrail
Top, middle & toe board
B – Horizontal lifeline
C – Secured to existing strut
D – Shock absorber lanyard
E – Drop line – rope grab
F – Boom lift
G – Double lanyard system
H – Full body harness
I - Tie off point capable
of 5,000 lb. Load
J – Retractable lanyard
K – Scaffold w/guardrail
L – Safety net(s)
M – Float
N – Restraint line
O – Beam seat
P – Scissor lift
Q – Other

Fall Protection Work Plan Overview
(continued)

Daily Inspection A visual inspection of all safety equipment shall be done daily or prior to each use. Defective equipment is to be tagged and removed from use immediately. The manufactures' recommendations for maintenance, inspection and for assemble and disassembly of equipment must be followed.

Overhead Protection Hardhats are required on all job sites and shall be worn. Warning signs, barricades and/or warning tape must be used to caution workers of existing hazards whenever present. Floor openings must be covered with wood or metal. In some cases debris nets or covered walkways may be used if the hazards warrant additional protection.

Tools and Materials Equipment is to be stored in tool shed or some other means of lock and key area each night and handed out daily, as needed. Power tools and cords shall be unplugged and locked up at night. Ladders may be secured to the existing structures when conditions impose a hazard. All materials are to be stored in a neat and orderly manner to avoid causing hazards blocking access and egress. All materials and equipment must be secured to restrict mobility from adverse weather conditions.

Removal of an injured worker First aid procedures should be performed as the situation requires. If the area is safe for entry first aid procedures should be started. Summon additional help, as needed, ambulance, fire or medical aid.

Dial 9-1-1

Telephone Location _____

Job Site Address _____

First Aid Kit Location _____

Training and Instruction Program All new employees are given instruction on the proper use and care of fall-protection devices before they begin work and must sign a training form stating that they have received this training.

This site-specific fall-protection program will be reviewed before work begins on the job site. The employee's attendance record will be signed and fall protection equipment use will be reviewed on a regular basis.

SIGNED OFF BY: _____
(Project Supervisor)

DATE: _____

Summary: 7.9 miles (15 minutes)

Time	Mile	Instruction	For	Toward
9:00 AM	**0.0**	**Depart 1801 Barkeley Ave, Colorado Springs, CO 80913 on Moore St (North-East)**	**21 yds**	
9:00 AM	0.1	Turn LEFT (West) onto Magrath Ave	0.1 mi	
9:00 AM	0.1	Take Ramp (RIGHT) onto SR-83 [S Academy Blvd]	1.2 mi	CO-83
9:02 AM	1.3	Turn LEFT (North) onto Local road(s)	32 yds	
9:02 AM	1.3	Take Ramp onto I-25	3.1 mi	I-25 / Colorado Springs
9:05 AM	4.5	Take Ramp [139] (RIGHT) onto US-24	0.8 mi	US-24 / Limon
9:06 AM	5.2	Keep RIGHT onto Ramp	0.2 mi	Union Blvd
9:06 AM	5.4	Keep LEFT to stay on Ramp	54 yds	
9:07 AM	5.5	Keep STRAIGHT onto Local road(s)	32 yds	
9:07 AM	5.5	Turn LEFT (North) onto (S) Union Blvd	2.1 mi	
9:13 AM	7.5	Turn LEFT (West) onto E Boulder St	0.2 mi	
9:15 AM	7.8	Turn RIGHT (North) onto Local road(s)	0.1 mi	
9:15 AM	**7.9**	**Arrive Memorial Hospital, 1400 E Boulder St, Colorado Springs, CO 80909, (719) 365-5000]**		

SUMMARY

Driving distance: 7.9 miles
Trip duration: 15 minutes
Driving time: 15 minutes
Cost: $0.73

Appendix J: Soil Analysis

FORT CARSON, CO
SOIL CHEMISTRY ANALYSIS

Field Sample No.	1	2	3
Sample Location	Twin Reservoirs	SW Bldg 3703	Twin Reservoirs
Soil Description	Medium Brown Gray Loam Mixed with Gravel	Gray Loam with Small Gravel	Medium Brown, Most Gravel Some Loam
As Received Resistivity	25,000	4,900	57,000
Saturated with distilled Water Resistivity	4,800	1,100	9,200
pH	7.00	7.00	7.20
Chloride Ions (ppm)	33	33	22
Oxidation/ Reduction Potential (ORP in mV)	72.0	48.0	82.0
Alkalinity (PPM)	110	110	110
Average Uniform Corrosion Rate 3 LPR Scans (mpy)	3.930	5.950	1.114

FORT CARSON, CO
SOIL CHEMISTRY ANALYSIS

Field Sample No.	4	5	6
Sample Location	WS Sherman S of St. Lo DR.	N/E Fire Hyd #00501C N of Motor Pool Bldg	Gas Pit # 24
Soil Description	Brown Loam Organic Matter	Brown Gray Loam Clay No Stone	Loam Gray Color No Gravel Some Organic
As Received Resistivity	3,600	6,700	7,100
Saturated with distilled Water Resistivity	230	2,200	1,200
pH	6.60	6.40	6.70
Chloride Ions (ppm)	46	15	97
Oxidation/ Reduction Potential (ORP in mV)	33.0	82.0	136.0
Alkalinity (PPM)	250	80	100
Average Uniform Corrosion Rate 3 LPR Scans (mpy)	9.576	6.468	13.778

FORT CARSON, CO
SOIL CHEMISTRY ANALYSIS

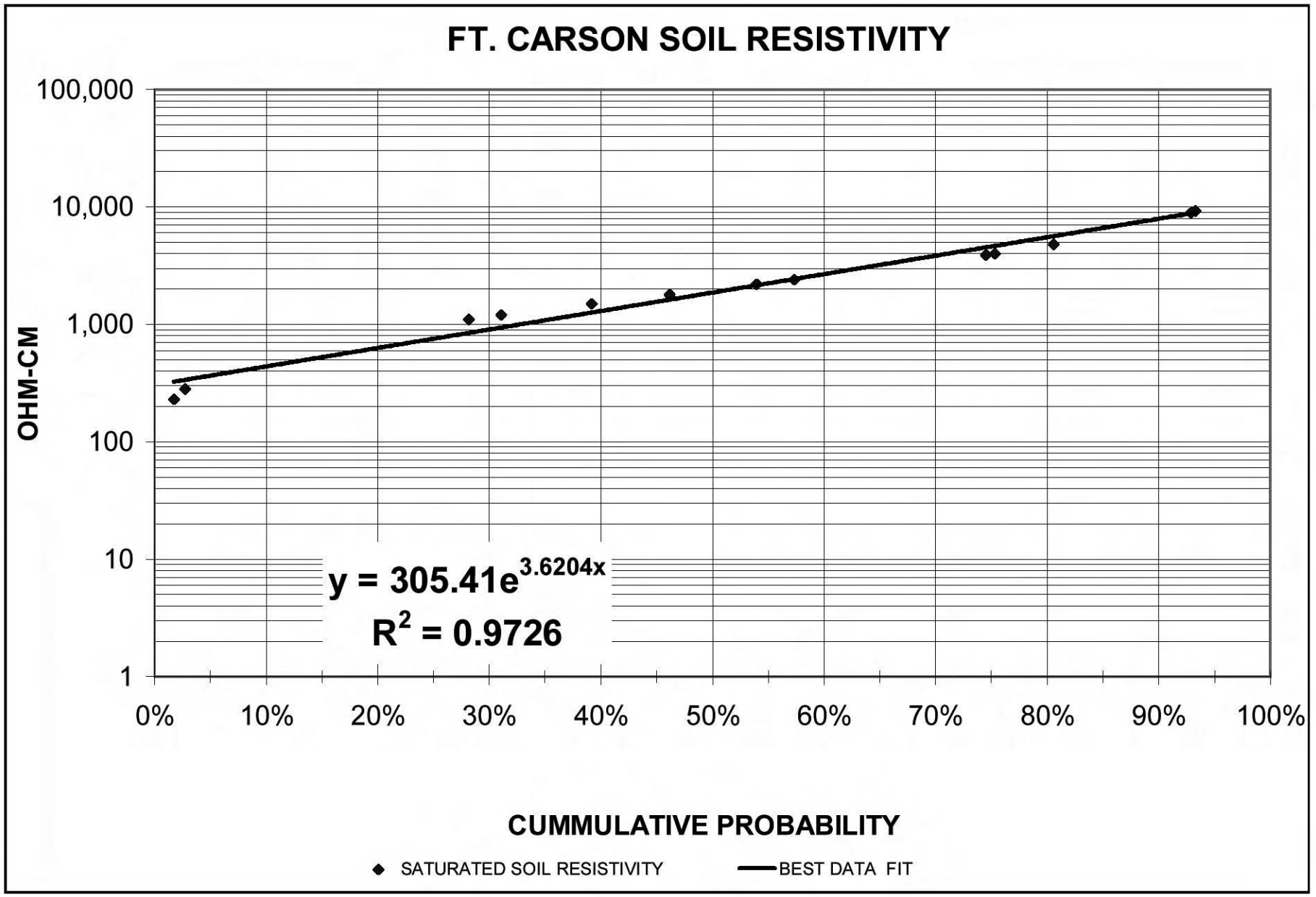
Field Sample No.	7	8	9
Sample Location	Harr Ave South of Resevoir Rd	1,000,000 Gallon Tank	Gasline Pit #10A
Soil Description	Meduim Brown Lite Clay Loam Mix With Gravel	Light Brown Clay Loam Mix With Lite Gravel	Clay Like Loose, No Gravel
As Received Resistivity	14,000	34,000	4,600
Saturated with distilled Water Resistivity	4,000	8,900	2,400
pH	6.60	6.60	7.00
Chloride Ions (ppm)	9	17	13
Oxidation/ Reduction Potential (ORP in mV)	77.0	79.0	86.0
Alkalinity (PPM)	110	110	110
Average Uniform Corrosion Rate 3 LPR Scans (mpy)	2.230	7.968	3.317

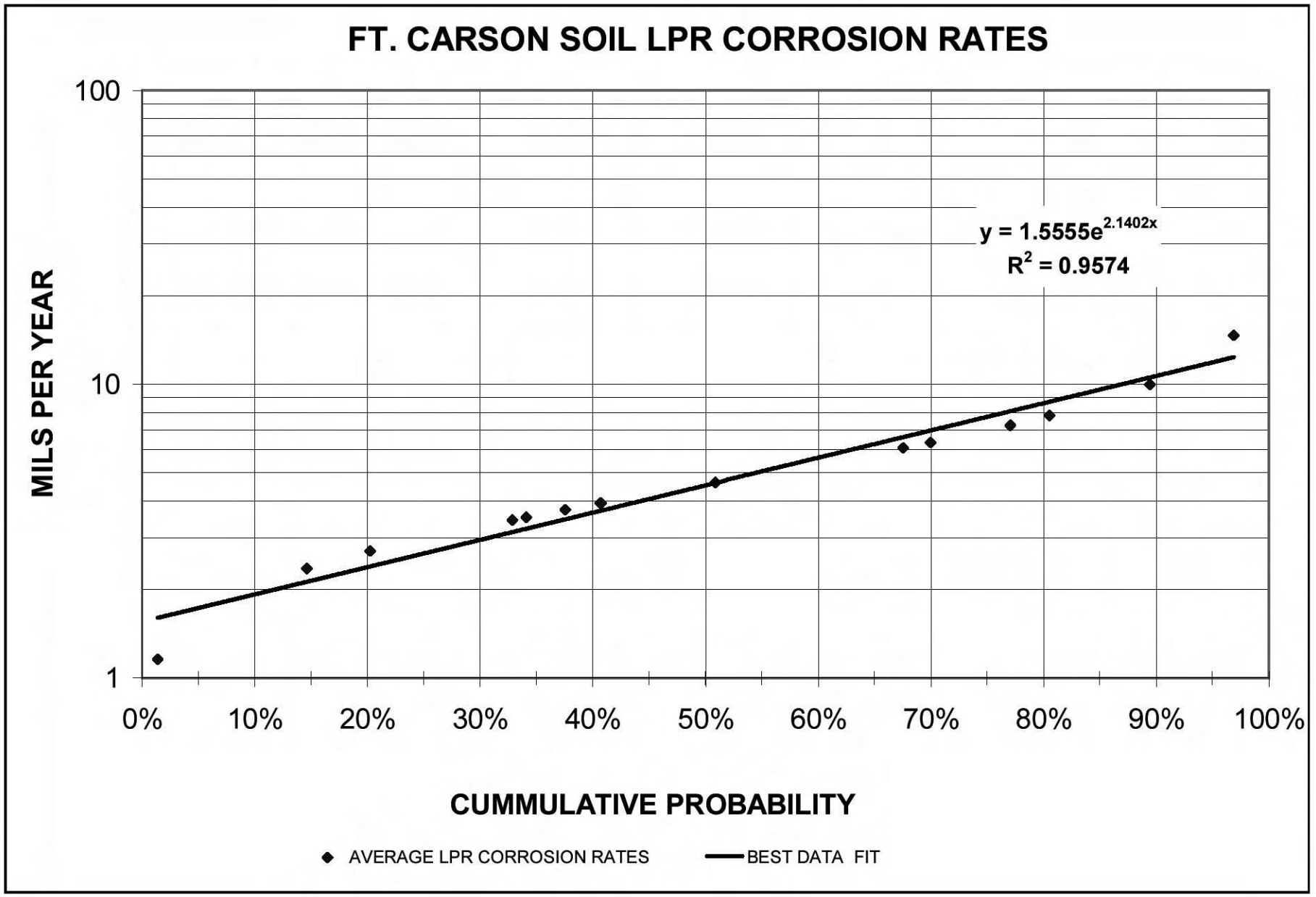
FORT CARSON, CO
SOIL CHEMISTRY ANALYSIS

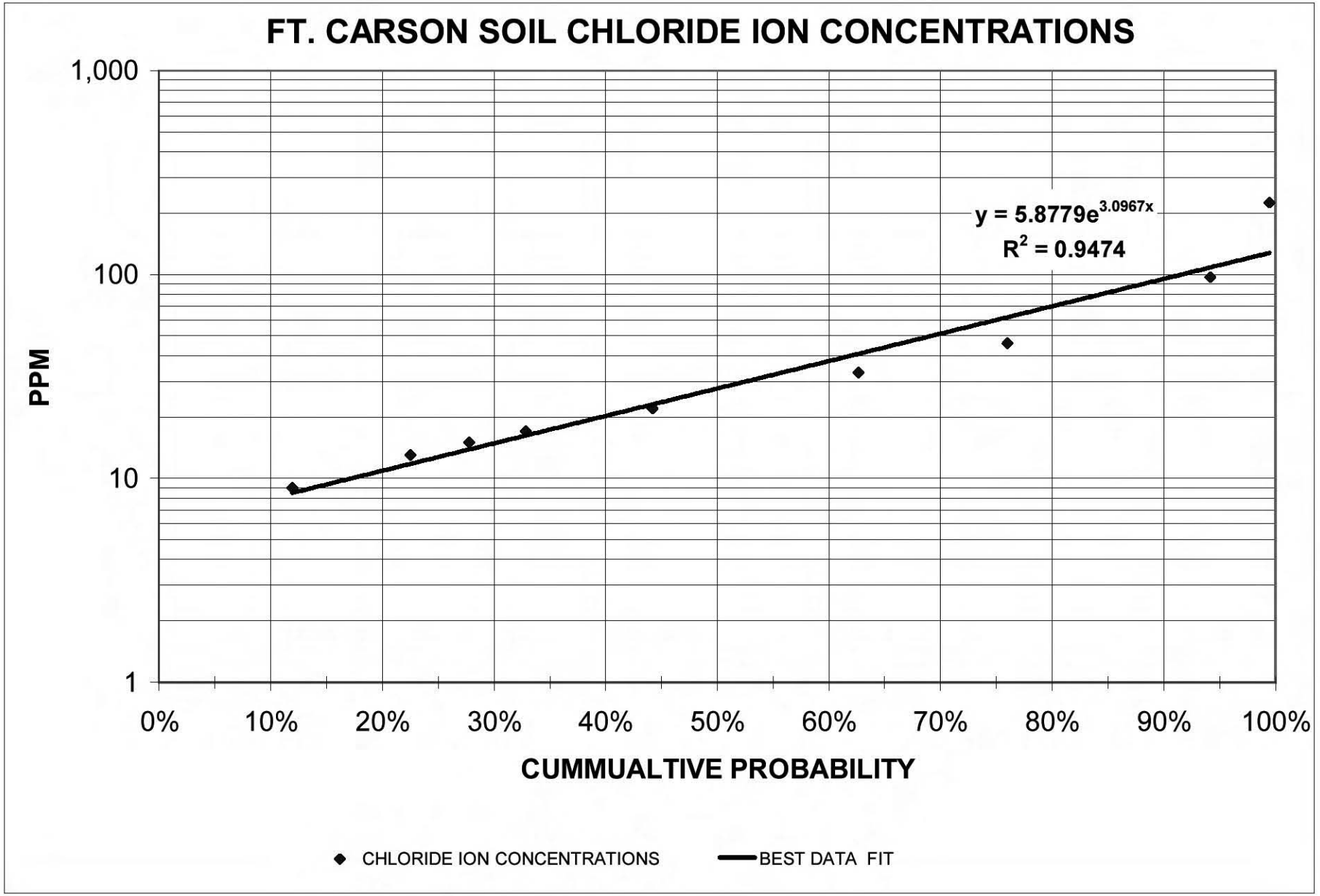
Field Sample No.	10	11	12
Sample Location	E Side of Specker - ~10' E of FH 520C	Titus Ave and Sherman Ave	TS-16 Gas Vault
Soil Description	Gray Loam Medium Size Gravel Some Organic	Grey Fine Loam Some Pea Gravel	Brown Loam Some Gravel Loose Grain
As Received Resistivity	13,000	110,000	23,000
Saturated with distilled Water Resistivity	2,400	1,500	2,200
pH	6.40	6.80	6.80
Chloride Ions (ppm)	22	9	22
Oxidation/ Reduction Potential (ORP in mV)	63.0	71.0	91.0
Alkalinity (PPM)	100	120	80
Average Uniform Corrosion Rate 3 LPR Scans (mpy)	4.238	3.418	3.897

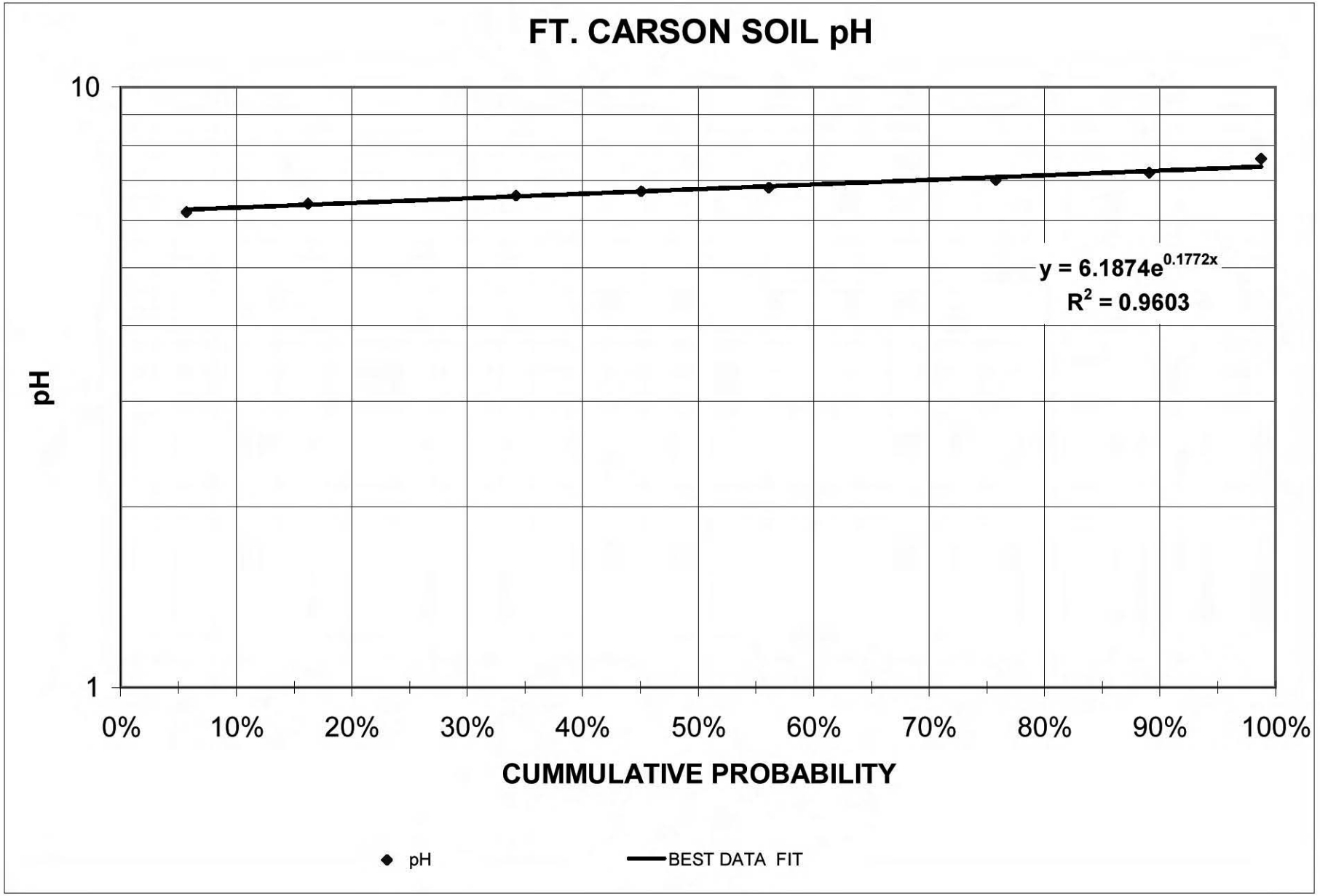
FORT CARSON, CO
SOIL CHEMISTRY ANALYSIS

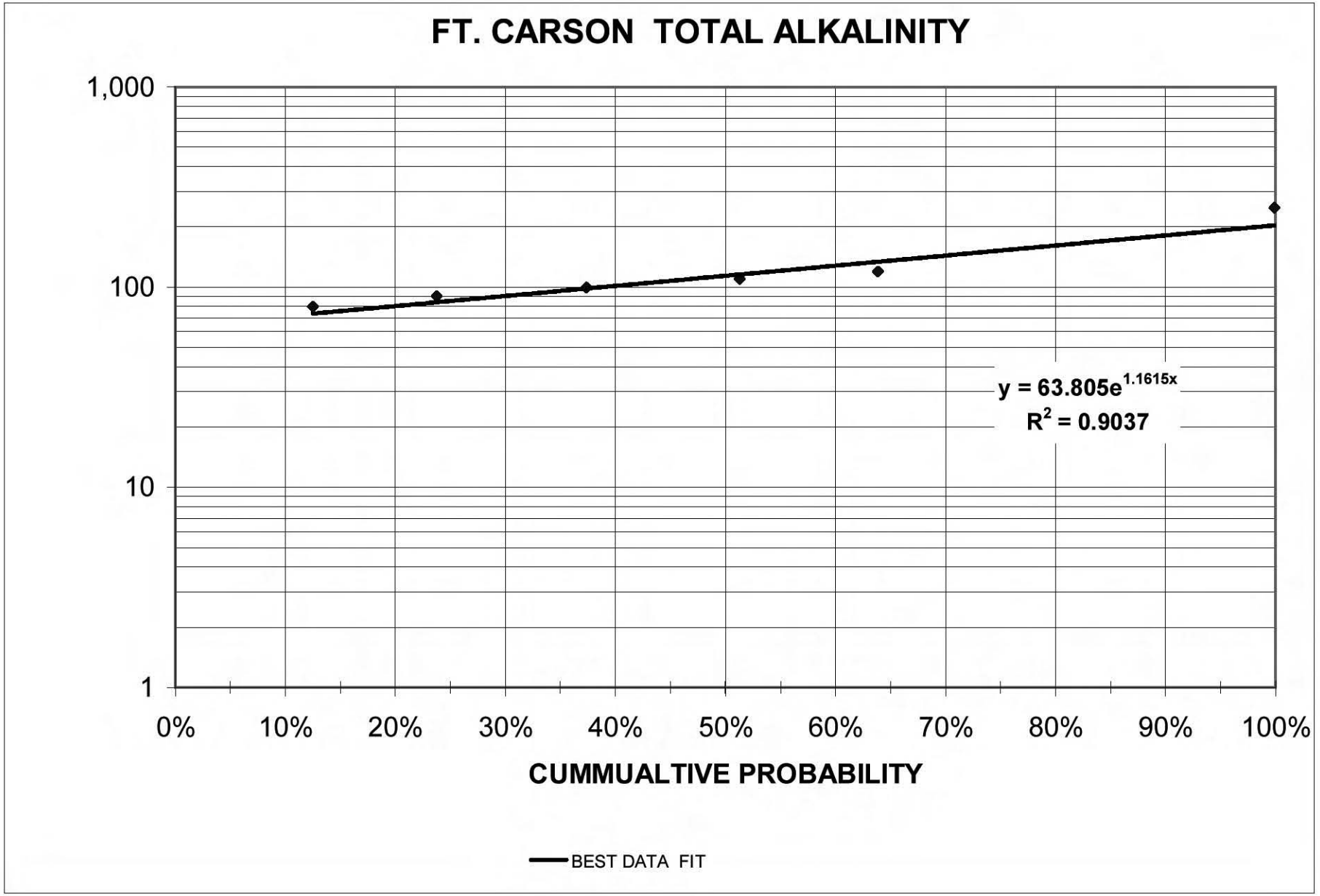
Field Sample No.	13	14	15
Sample Location	West of Brown Rd South of Titus Ave	Evans Hospital NW of Emergency Entrance	Butz Air Field North of Bldg 9611
Soil Description	Brown Loam, Pea Gravel	Brown Loam, Pea Gravel, Some Stones 3-5%	Red Mud With 4-5% Gravel Wet
As Received Resistivity	11,000	5,400	3,100
Saturated with distilled Water Resistivity	1,800	1,500	3,900
pH	6.20	6.40	7.60
Chloride Ions (ppm)	17	226	17
Oxidation/ Reduction Potential (ORP in mV)	105.0	119.0	-78.0
Alkalinity (PPM)	90	110	300+
Average Uniform Corrosion Rate 3 LPR Scans (mpy)	6.856	3.610	2.710

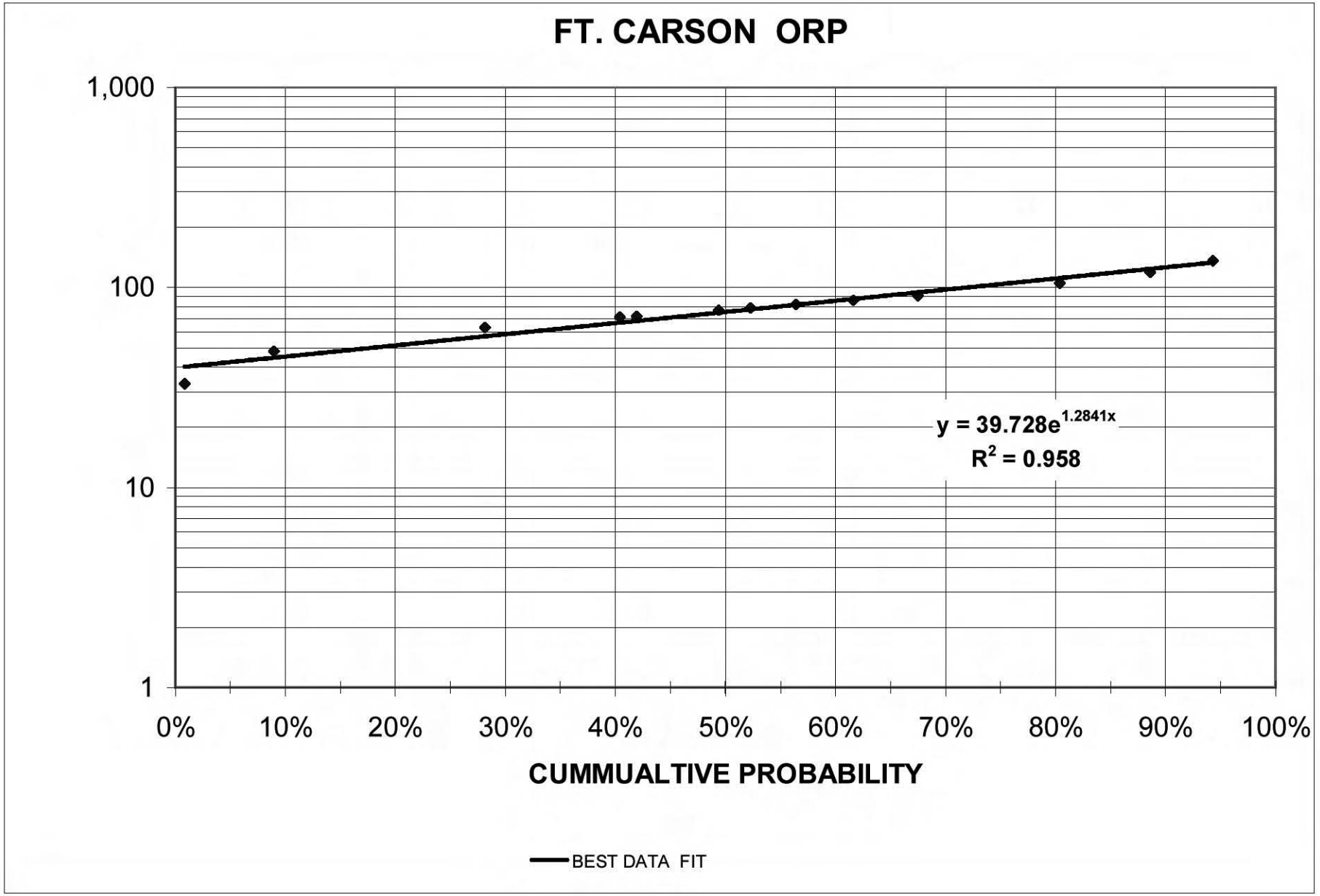

FT. CARSON SOIL RESISTIVITY
100,000
10,000
1,000
100
10
1
OHM-CM
y = 305.41e^3.6204x
R^2 = 0.9726
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
CUMMULATIVE PROBABILITY
SATURATED SOIL RESISTIVITY
BEST DATA FIT


FT. CARSON SOIL LPR CORROSION RATES
100
10
1
MILS PER YEAR
y = 1.5555e^2.1402x
R^2 = 0.9574
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
CUMMULATIVE PROBABILITY
AVERAGE LPR CORROSION RATES
BEST DATA FIT


FT. CARSON SOIL CHLORIDE ION CONCENTRATIONS
1,000
100
10
1
PPM
y = 5.8779e3.0967x
R2 = 0.9474
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
CUMMUALTIVE PROBABILITY
CHLORIDE ION CONCENTRATIONS
BEST DATA FIT


FT. CARSON SOIL pH
10
1
pH
y = 6.1874e^0.1772x
R^2 = 0.9603
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
CUMMULATIVE PROBABILITY
pH
BEST DATA FIT


FT. CARSON TOTAL ALKALINITY
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
CUMMUALTIVE PROBABILITY
y = 63.805e^1.1615x
R^2 = 0.9037
BEST DATA FIT


FT. CARSON ORP
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
y = 39.728e^1.2841x
R^2 = 0.958
CUMMUALTIVE PROBABILITY
BEST DATA FIT

APPENDIX OF SOIL CORROSION PARAMETERS

Resistivity

Resistivity is a physical property of a material used to indicate its ability to conduct electrical currents. The transfer of electrons between anodic and cathodic sites is a direct electrical current and the rate of electron flow determined by the resistivity of the soil. C. P. Dillon for NACE International, Romanoff for the Bureau of Standards and others have reported general relationships between resistivity and corrosion of ferrous metals. The following table is from Romanoff's work:

Resistivity and Arbitrary Ranges of Corrosion[1]

Soil Corrosivity Group	Resistivity	Approximate Pit Depth
1	>10,000 ohm-cm	<100 mils
2	5,000 to 9,999 ohm-cm	101 to 125 mils
3	2,000 to 4,999 ohm-cm	126 to 150 mils
4	1,000 to 1,999 ohm-cm	151 to 200 mils
5	<1,000	>200 mils

[1] Excerpted from Underground Corrosion, Melvin Romanoff, National Bureau of Standards Circular 579, Table 99, April 1957

Moisture content in the soil impacts on the soil resistivity as shown in the work of the National Bureau of Standards by Rommanoff.

Choride Ions

Chloride ions both reduce soil resistivity and depolarize the anode sites. The following table is a guide to evaluating the corrosion rate contribution of chloride ions in soil:

Chloride Ion Induced Corrosion Activity of Ferrous Metals	Concentration (ppm)
Extreme Corrosion Activity	>1000
Very High Corrosion Activity	500 – 1000
High Corrosion Activity	200 – 500
Moderate Corrosion Activity	50 – 200
Minimal Impact on Corrosion Activity	<50

pH

The pH value is a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, with values greater than 7 progressing towards increasing alkalinity, and increasing acidity for values less than 7. The pH scale commonly in use ranges from 0 to 14.

APPENDIX OF SOIL CORROSION PARAMETERS

Impact of pH on Corrosion Activity (Ferrous Metals)[1]	pH Range
Extremely High Corrosion Activity	0 – 2
Very High Corrosion Activity	2 – 4
No Impact on Corrosion Activity	4 – 8.5
Decreasing Corrosion Activity	8.5 – 11.5
Almost Complete Cessation of Corrosion Activity	11.5 – 13.5
Rapidly Increasing Corrosion Activity	13.5 – 14.0
[1] **Uhlig's Corrosion Handbook, John Wiley & Sons**	

Alkalinity

The alkalinity of water or the moisture in soil is its quantitative acid-neutralizing capacity. It is the sum, generally measured in parts per million (ppm) of all soluble base elements in the soil. Generally, the higher the alkalinity, the greater the buffering capacity of the moisture and therefore, the probability of low pH induced corrosion activity is substantially reduced.

Oxidation-Reduction Potential (ORP)

ORP measurements are obtained between a platinum noble metal electrode and a saturated calomel reference electrode immersed in the soil sample. The range of the ORP meter is between (-) 1000 and (+) 1000 mV. ORP readings are used to assess the probability for Anaerobic Bacterial Corrosion. A guide for data interpretation is presented below:

Probability of Anaerobic Activity[1]	ORP Value (mV)
High Probability of Anaerobic Corrosion	Negative values
Possible Chance of Anaerobic Corrosion	+0 to +50
Minimal Chance of Anaerobic Corrosion	+50 to +100
Aerated Soil	>+100
[1] ***Corrosion Considerations for Ductile Iron Pipe***, Bill Spickelmire, Materials Performance, July 2002	

Linear Polarization Rate (LPR)

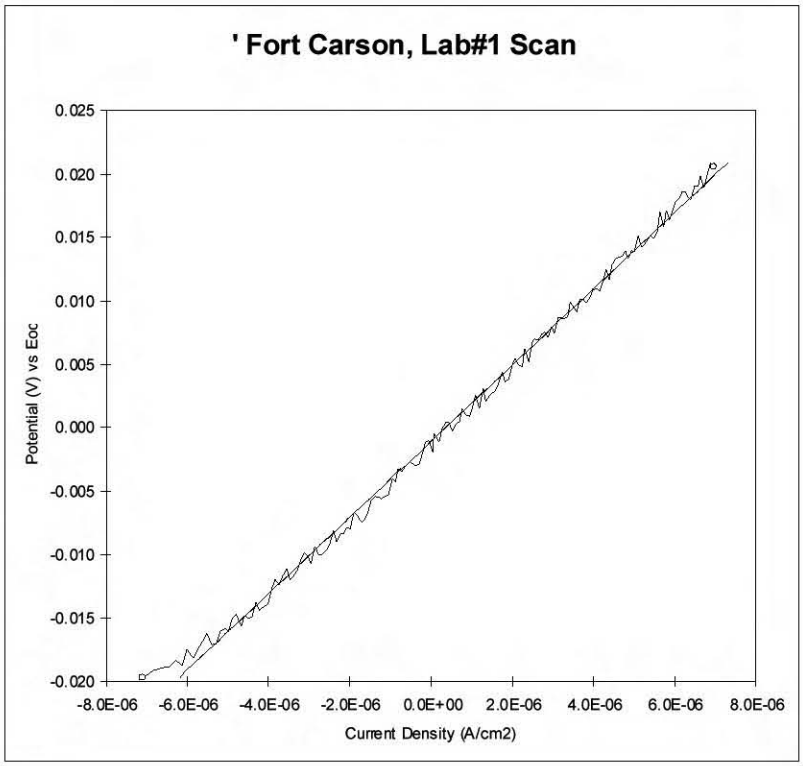
LPR is probably a common test method used in assessing the corrosivity of an environment to a metal. The test equipment consists of microcomputer controlled DC power supply. The computer automatically calculates the average corrosion rate over the surface area of the metal sample tested. LPR involves the use of extremely small amounts of current applied from an inert counter electrode to a prepared metal test specimen, the working electrode of the same metal alloy as the structure of concern. During the LPR scan, potential of the metal specimen is measured in millivolts by a reference electrode (generally a saturated calomel electrode). The applied current is controlled to vary the potential of the metal specimen in a series of steps from 20 millivolt less than the free corrosion potential to a value 20 millivolt more positive than the free corrosion potential. A linear relationship on a logarithmic scale between the potential versus the applied test current is observed.

The slope of the LPR is used to calculate a theoretical corrosion current for the specimen in the soil sample. Based on the surface area of the sample, a current density is calculated and a uniform corrosion rate calculated using Faraday's Law for the consumption of the sample metal.

Pstat: PStat3

Scan: -0.02 V to 0.02 V,
0.125 mV/s, 2 s/pt
EOC: -0.651679 V
Area: 45.72 cm2
Electrode: 7.87 gm/cm3,
27.92 g/equiv
Conditioning: OFF
Delay: OFF
IR Comp.: OFF

RESULTS
Region = -19.7 mV to
20.5 mV
BetaC = 120.0
mV/Decade
BetaA = 120.0
mV/Decade
Ecorr = -652.8 mV
Icorr = 8.681E-06
A/cm2
Rp = 3.002E+03 Ohm cm2
CorrRate = 3.966 mpy



REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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June 2007	Final	

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5a. CONTRACT NUMBER
F09750-03-D001

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
Corrosion Prevention and Control

6. AUTHOR(S)
L.D. Stephenson, Ashok Kumar, J. Bushman

5d. PROJECT NUMBER
CPC AR-F-321

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PO Box 9005
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13. SUPPLEMENTARY NOTES

14. ABSTRACT

This project demonstrated and implemented emerging corrosion protection technologies for utilities at Fort Carson, CO, consisting of six deep anode impressed current cathodic protection (ICCP) systems, 106 drive-by type remote monitoring units for existing test stations, and 26 drive-by type remote monitoring units for existing and new rectifiers. ICCP rectifiers and groundbeds were installed on one natural gas main, one steam main, one water storage reservoir, and three separate water supply mains. The remote monitoring units have reduced the amount of time that it takes the contractor who maintains the ICCP systems at Fort Carson to obtain readings from 2 months to 2 days. The automated data are saved in a format that allows him to establish trends for early signs of problems with the system that needs immediate attention.

Other Army and DoD Installations have experienced similar problems with the need to upgrade and maintain their cathodic protection systems. It is therefore, recommended that these installations implement cathodic protection upgrades and remote monitoring technologies to extend the service life of the utility system.

15. SUBJECT TERMS
Fort Carson, CO; corrosion prevention; cathodic protection; impressed current cathodic protection (ICCP)

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified		215	