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Electro-Osmotic Pulse Technology To Control Water Seepage: User Guide and Specifications

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Foreword

This study was conducted for the U.S. Army Center for Public Works (USACPW) under the Facilities Engineering Application Program (FEAP). The technical monitors were Malcolm McLeod, CECPW-ES and Fidel Rodriguez, CECPW-EB.

The work was performed by the Materials Science and Technology Division (FL-M) of the Facilities Technology Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). Appreciation is extended to Roger Hayes of DRYTONIC, Inc., Madison, WI. The USACERL principal investigator was Vincent F. Hock. Dr. Ilker R. Adiguzel is Acting Chief, CECER-FL-M; Donald F. Fournier is Acting Operations Chief, CECER-FL. The USACERL technical editor was Linda L. Wheatley, Technical Information Team.

Dr. Michael J. O'Connor is Director of USACERL.

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1 Executive Summary

Background

Subterranean moisture problems continue to frustrate the facility maintenance environment by causing concrete degradation, rebar corrosion, and personnel health and safety hazards. Also, because of the high humidity conditions associated with ever present standing water, corrosion of peripheral building mechanical equipment, pumps, boilers, and associated systems is accelerated, minimizing the opportunities for extending the useful life of those facilities. Finally, current management practices for the disposal of standing or subterranean water raises additional environmental concerns. For instance, water pumped from a sump pit in a mechanical room often has to be treated as "mixed waste" due to the possibility of oil drippings and lubricants from the mechanical systems mixing with water.

Traditional methods for abating high-moisture conditions within existing structures include external excavation, tiling, coatings, flow-down wells, and the installation of "french drains." These approaches are expensive and often provide little relief in abating high-moisture conditions within internal subterranean structures such as elevator shafts, service tunnels, electrical and mechanical rooms, or basement storage rooms. For example, exterior building trenching, tiling, and coating of a structure would cost approximately $36,000 for a typical starship barracks such as those at Fort Jackson, SC. Another example is Building 5, Health Clinic, McAlester Army Ammunition Plant, McAlester, OK, where conventional basement seepage control methods have failed. The cost of conventional trenching, tiling, and coating exceeded $30,000. A final example is the U.S. Army Tank Automotive Command (TACOM) in Warren, MI, which recently estimated it would cost over $300,000 to control the basement seepage in Building 212 (the Dynamometer building). A Facilities Engineering Application Program (FEAP) ad flyer describing this technology is included in this guide as an appendix.

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2 Pre-acquisition

Description of Technology

Electro-osmosis was originally described by F.F. Reuss in 1809. His experiment showed that water could be forced to flow through a clay-water system when an external electric field was applied to the soil. Research since then has shown that flow is initiated by the movement of cations in the pore fluid of clay or similar porous medium such as concrete. When the cations move, the water surrounding the cations moves with them. Electro-osmosis is a technique that can be used to arrest or cause flow of water as well as ions in the water. The technique has been used in civil engineering to dewater dredgings and other high-water content waste solids, consolidate clays, strengthen soft sensitive clays, and increase the capacity of pile foundations. Electro-osmosis has received significant attention in the last 5 years as a method to remove hazardous contaminants from groundwater or to arrest water flow.

To apply electro-osmosis commercially within concrete structures, a system has been developed that applies a pulsating direct current (DC) electric field combined with an off period. The pulsating or electro-osmotic pulse (EOP) system consists of a pulse of positive voltage (as seen from the dry side of the concrete wall), a pulse of negative voltage, and a period of rest when no voltage is applied. The pulse of positive voltage has the greatest duration. The amplitude of the signal is typically on the order of 20 to 40 Volts. The electrical pulse causes cations (e.g., Cl-) and associated water molecules to move from the dry side towards the wet side against the direction of flow induced by the hydraulic gradient, thus preventing water penetration through buried concrete structures.

The system consists of an electronic control unit that delivers electric pulses to positive electrodes (anodes) inserted into the concrete wall or floor. The anode is either rod shaped or in a cable form and covered with a special rubber-graphite coating. The negative electrode (cathode) is typically a copper rod staked into the exterior structure soil or buried within the concrete structure outside of the protected area. Figure 1 shows a schematic of the system described.

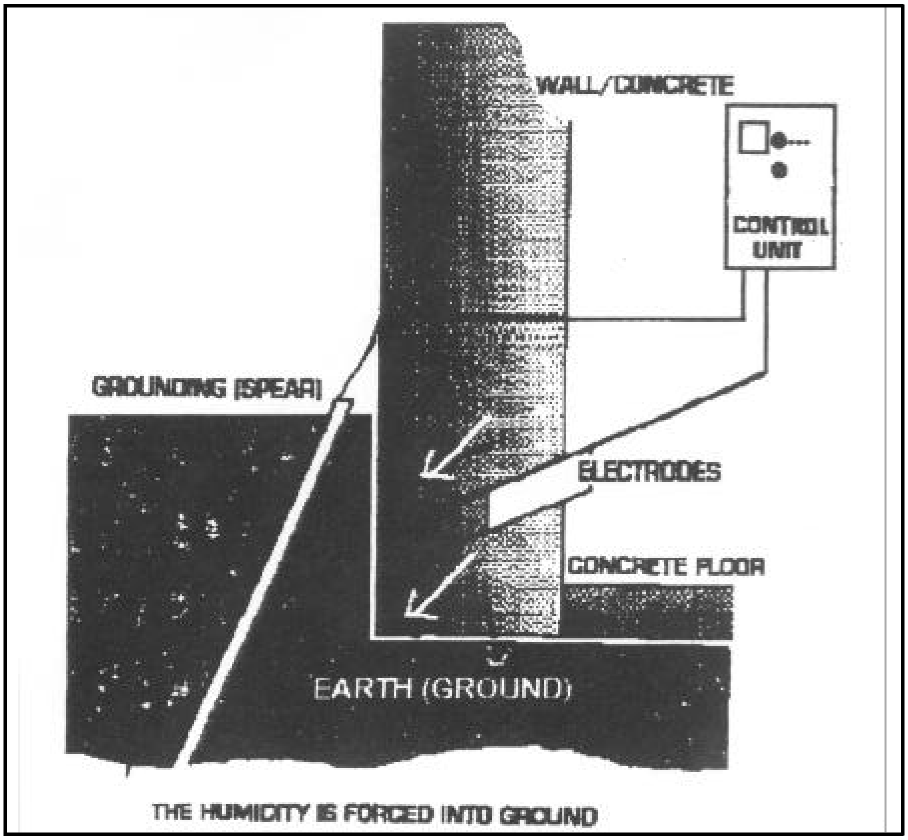

Figure 1. The electro-osmotic pulse system.

Life-Cycle Costs and Benefits

The EOP technology can reduce the amount spent on failed mechanical systems and equipment that result from corrosion caused by high moisture conditions. Cost reductions in the abatement of moisture problems within concrete structures can be achieved by eliminating the need for external excavation, which can cost more than $315 per linear foot (lf). The technology provides a new set of problem-solving tools for high-moisture conditions in facility areas that are not accessible from the exterior, or that are susceptible to moisture seeping through concrete floors.

In the case of the Fort Jackson barracks facility, the EOP system abated the moisture problem at a cost of $187 per linear foot. Exterior building trenching, tiling, and coating of the structure would have cost approximately $315 per linear foot; however, the moisture caused by seepage through the concrete floor would not have been reduced. Also, a corresponding reduction of relative humidity within the mechanical room would not have occurred, so no opportunity would have been available to minimize equipment corrosion. Post-installation energy costs associated with the control unit are estimated at less than $4.00 per year. The preliminary return on investment estimate from McAlester Army Ammunition

Plant shows an EOP installation cost of $190 per lf as compared with the $315 per lf cost of traditional methods of seepage control such as tiling, trenching, and coating the exterior walls. The percent savings (based on capital costs) of approximately 60 percent is a comparison between the cost of the EOP technology and the conventional method of water seepage control. Reduced mechanical maintenance will also produce additional savings as a result of lower humidity levels that will result in minimizing corrosion of mechanical parts.

The other concern at McAlester is poor indoor air quality, especially in the environmental health office located in the basement. The EOP system will significantly improve the room air quality by lowering the humidity (30 percent) and eliminating water seepage. Similar savings of 50 to 60 percent have been estimated for other Army sites such as Building 212 at TACOM. The EOP technology is applicable to any steel-reinforced or nonreinforced concrete substructure (i.e., mechanical room basements) that are subject to flooding or seepage.

3 Acquisition/Procurement

Potential Funding Sources

U.S. Army installations can use the Maintenance and Repair "K" account funds to procure the EOP technology or any associated components.

Technology Components and Sources

Each installation requiring the technology will be responsible for the acquisition and assembly of the EOP system components. System components and other necessary parts for the demonstration at Fort Jackson were provided by these suppliers:

DRYTRONIC, Inc.
P.O. Box 8636
Madison, WI 53708-8636
800/497-0579

DRYTRONIC, Inc., Federal Division
8000 Towers Crescent Drive
Suite 1350
Vienna, VA 22182
703/760-7847

Bassett Engineering
RR4, Box 3528
Stigler, OK 74462
918/429-8585

Procurement Documents

USACERL Draft Technical Report, *Electro-Osmotic Pulse (EOP) Technology to Control Water Seepage in Concrete Structures* (due for distribution in Fiscal Year 1997) evaluates the EOP technology for controlling water seepage into concrete basement structures at the Fort Jackson and Fort McAlester demonstration sites. This technical report will provide the information necessary to make performance comparisons between a given installation and those of the demonstration sites.

Performance plans and specifications, including hardware and wiring modifications, are subject to applicable sections of the National Electrical Code (NFPA-70) and Corps of Engineers Guide Specification 16415, *Electrical Work, Interior*. Typical wiring diagrams have been provided in this user guide for general guidance only.

Designs

The EOP system is designed to be either wall mounted in a wiremold raceway or buried within the wall when situations require a concealed installation. Concealed installations might be appropriate, for instance, when a lower level apartment is experiencing moisture problems.

The EOP system control unit at Fort Jackson was wall mounted and serviced by a standard 110 Volt power outlet. The unit may be hard-wired or plugged into a 110-Volt service outlet junction box. Figure 2 illustrates the concept of EOP technology, while Figure 3 shows a simplified version of a typical system setup. System setup will vary based on the configuration of the concrete structure to be protected.

Anodes are wired in series with redundant connections to the EOP central control unit. Anodes are provided with an ethylene propylene diene monomer (EPDM) coating.

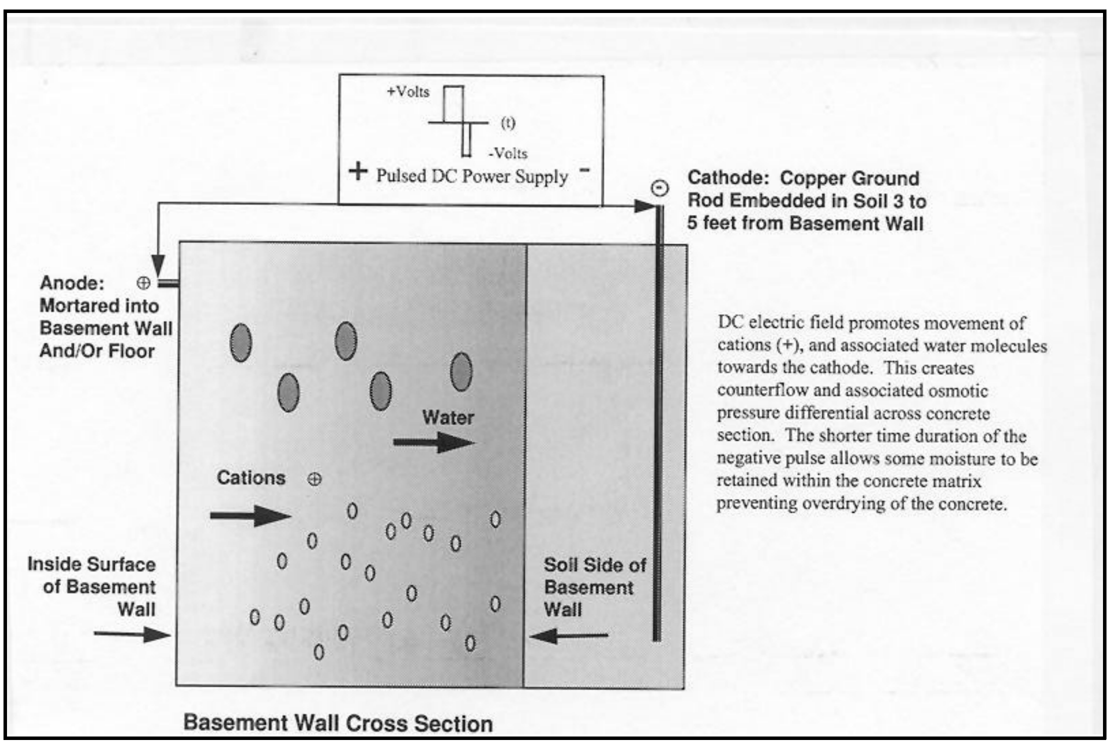

Figure 2. Cross section showing the EOP system process.

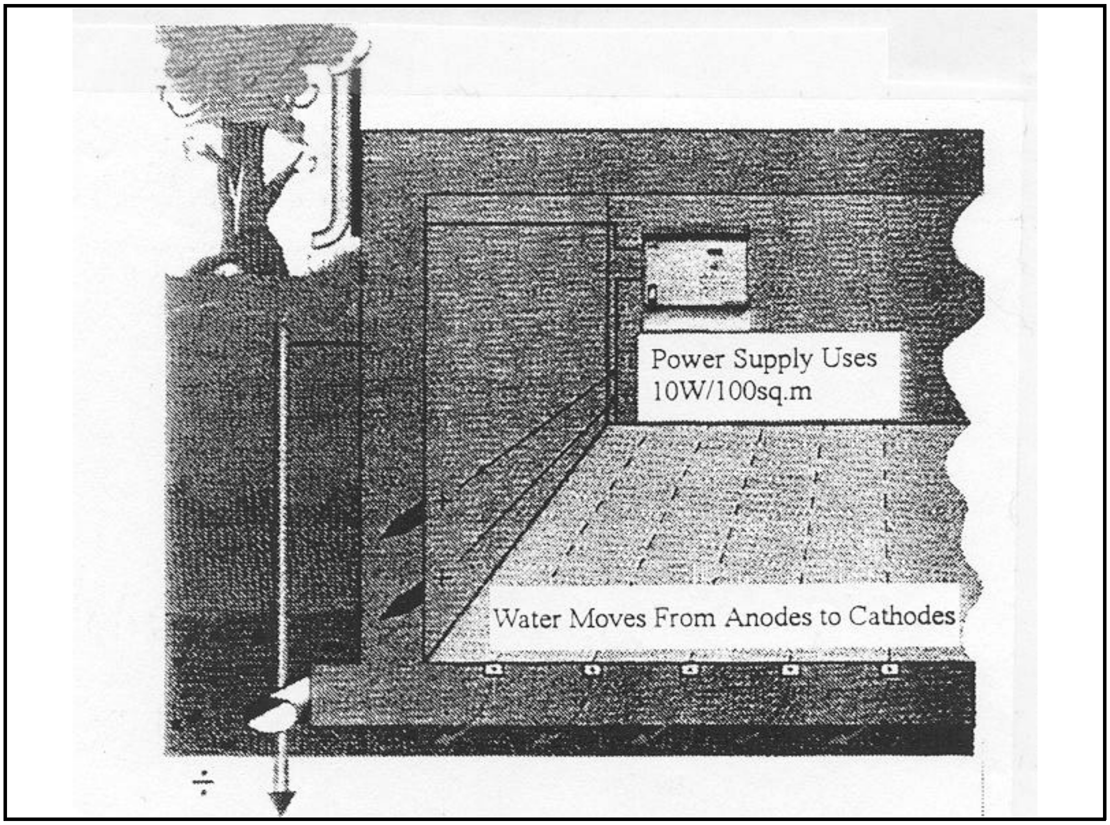

Figure 3. A typical EOP system setup.

Appendix B gives a generalized guide specification for the EOP system. System requirements and specifications will vary depending on the size of application. The Fort Jackson demonstration provided the basis for the formulation of the guide specification presented in Appendix B.

Preliminary work consists of performing an on-site evaluation to determine the extent of the moisture problem. This inspection is necessary in order to determine the necessary electrical requirement and subsequent system design. The demonstration at Fort Jackson required the use of a 10-Amp EOP Central Control Unit. Installations that have floor and wall surface areas greater than 15,000 square feet will require a 20-Amp EOP Central Control Unit.

Procurement Scheduling

The lead time required to implement the EOP system depends on the availability of parts and the time required to evaluate the proposed installation site. The implementation of the EOP system at Fort Jackson was accomplished in less than 4 months following the initial site inspection. This implementation period included design, fabrication, and installation of the EOP system. The generalized guide specification in Appendix B can serve as the basis for the statement of work.

4 Post Acquisition

Initial Implementation

Appendix B provides a generic procedure for both wall and floor installation. The installation of the EOP system at Fort Jackson, which was accomplished in less than 1 week, serves as an example. The installation consisted of the following steps:

1. Existing cracks were repaired by chiseling them out and then resealing the affected areas with hydraulic cement.

2. Holes were drilled into the perimeter walls in order to insert rubber-coated electrodes (anodes). These electrodes were cemented into the wall. The electrodes were positioned 18 in. from each other and 5 in. from the floor. In addition to the 83 electrodes used, 24 feet of rubber-graphite conductive cable was installed around the base of a concrete pad that supported steel water tanks in the room.

3. Three copper grounding rods (cathodes) were driven into the exterior ground.

4. The EOP Central Control Unit was mounted on one wall, and all associated wiring from the anodes and cathodes was wired into the unit.

5. The patching of certain wall areas that require corrective maintenance may be required before system startup.

Operation and Maintenance

The EOP system may initially exhibit high power consumption depending on the amount of water (saturation level) in the concrete structure. The anode current at Fort Jackson varied from 0.75 Amps DC (ADC) for a high humidity environment to 0.2 ADC for a low humidity environment.

Monitoring of the system and slight adjustments to the EOP waveform might be required during the first few months of operation, until the moisture level of the concrete reaches its nominal EOP operational level. After the system reaches this level, no maintenance is required.

Service and Support Requirements

The EOP system requires a standard 110-Volt power outlet for service. The EOP Central Control Unit can be either hard-wired or plugged into a 110-Volt service outlet.

Performance Monitoring

Electrical consumption of the EOP system can be monitored to analyze system operation and performance. Indoor humidity levels and the water table also can be monitored to evaluate system performance.

Electromagnetic Compatibility Issues

Since the EOP system uses pulsed electrical currents, the possibility exists for electromagnetic interference (EMI) and radio frequency interference (RFI) to nearby electrical and electronic systems. (DC current flowing in the wires will produce a magnetic field which might cause EMI. The switching of the current from positive to negative and vice versa will radiate an electromagnetic wave which could cause RFI.) Unshielded systems should be kept at least 1 foot away from EOP system wiring and electrodes. Wiring for especially susceptible systems (e.g., telephone, data, and alarm) should not be run parallel to EOP system conductors for any length and should be kept at least 1 foot away.

Appendix A: FEAP Ad Flyer "Electro-Osmotic Pulse Technology to Control Water Seepage"

FEAP
FACILITIES ENGINEERING APPLICATIONS PROGRAM

Innovative Ideas for the Operation, Maintenance, & Repair of Army Facilities

Electro-Osmotic Pulse Technology to Control Water Seepage

Left: *Standing water was a common occurrence in the basement at Barracks Building 3265, Fort Jackson, SC, before Electro-Osmotic Pulse technology was installed.*

Below: *Less than 6 months after the EOP demonstration began, the same basement is dry. Electrical requirements dropped to a minimum at this point.*

Right: *The electrodes are installed directly into the concrete walls of Fort Jackson's basement.*

New Approach To Preventing Moisture

PROBLEM: Water seepage into buildings causes structural damage and poor air quality.

TECHNOLOGY: Electrodes placed inside concrete walls produce an electric field that promotes a flow of ions and water opposing the seepage flow.

DEMO SITE: Fort Jackson, SC – FY94-96

BENEFITS:

- Prevents structural damage from rebar corrosion, concrete cracking
- Improves air quality for occupants
- Costs about half as much as traditional treatments – estimated 40% savings at Fort Jackson

BD-10/Sep 95

Technology Improves Building Safety

Below-ground concrete facilities such as basements, elevator shafts, and subways can sustain structural damage when they have chronic water seepage through the walls. The moisture causes steel reinforcement bars to corrode and the concrete to crack. The high humidity also causes corrosion of any mechanical equipment in the area. In addition, water seepage causes problems such as efflorescence and unacceptable air quality for occupants.

Traditional methods to correct water seepage involve using sealants or retiling. When the seepage rates are very high, concrete sealants may not help. In those cases, remediation involves costly excavation to place drainage tiles around the facility exterior.

Electro-Osmotic Pulse (EOP) technology represents a promising alternative to conventional methods for preventing water seepage into facilities. It uses electrodes which are mortared directly into the concrete walls. A current applied to the electrodes produces an electric field in the walls. The electrical pulse causes the water to move from the dry side toward the wet side against the direction of flow induced by the hydraulic gradient. This prevents water penetration through the concrete.

Barracks Drier in One Week

Barracks Building 3265 at Fort Jackson, SC, had a history of seepage in the basement. The moisture produced a corrosive environment for the mechanical equipment located there which is used to heat water for the barracks.

In August 1994, small electrodes were installed in the concrete walls and a current was applied. The basement was noticeably drier within one week and, by mid-January (less than 6 months), the humidity level had dropped from an initial range of 92 - 98%to a range of 43 - 68%. Once the walls dried, the electrical power use dropped automatically due to the concrete's lack of moisture and increased resistance.

Costs and Benefits

At Fort Jackson, the demonstration cost about $26K. A team from the U.S. Army Construction Engineering Research Laboratories (USACERL) installed the system, along with instruments to measure its performance over time.

Digging and installing tiles for a similar sized facility would have cost over $40K, or about 40% more than the EOP technology at Fort Jackson. The electrical use was negligible – estimated at $4/year.

By preventing moisture in the barracks basement, Fort Jackson will avoid costly structural repairs as well as damage to its mechanical equipment.

Procurement

Dry-Tec, Inc., of Janesville, WI, holds the exclusive license for the patented EOP technology in North America. Nor-Tec, based in Norway, has the patent.

Points of Contact

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Fidel Rodriguez or Malcolm McLeod, U.S. Army Center for Public Works (CPW), 7701 Telegraph Road, Alexandria, VA 22310-3862, COMM 703-806-5979 or -5196.

Frank Cooper, Fort Jackson, SC, COMM 803-751-4817.

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Appendix B: Generalized Guide Specifications

GUIDE SPECIFICATION FOR MILITARY CONSTRUCTION

ELECTRO-OSMOTIC PULSE TECHNOLOGY TO CONTROL WATER SEEPAGE
INTO CONCRETE STRUCTURES
(August 1997)

PART 1 GENERAL

1.1 REFERENCES

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA TC 2	(1990) Electrical Polyvinyl Chloride (PVC) Tubing (EPT) and Conduit (EPC-40 and EPC-80)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(1996) National Electrical Code

UNDERWRITERS LABORATORIES (UL)

UL 6	(1993) Rigid Metal Conduit

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D 1248	(1984; 1989) Polyethylene Plastics Molding and Extrusion Materials

1.2 GENERAL REQUIREMENTS

A complete, operating electro-osmotic water seepage protection system in accordance with applicable Federal, state, and local regulations, NFPA 70 (National Electrical Code), and the requirements of this contract shall be provided. The project shall include pre-installation inspection of the site, development of site-specific plans and specifications, installation of the EOP system, and adjustment and testing of the protection system. *Buy American Act* provisions must be followed as well as conforming to applicable standards (e.g., ASTM, NFPA, and UL) and regulations.

PART 2 PRODUCTS

2.1 ANODES

2.1.1 Rubber Graphite Anodes

Anodes shall be of the rubber graphite type. Anodes are located based on the relative humidity of the material in which they are to be installed. Probe anodes are connected in series with no more than 20 anodes per string. Wire anodes are no more than 6 m (20 ft) in length. Power is supplied in a redundant fashion by attaching the feed wire to both ends of the string.

2.1.2 Rubber Graphite Characteristics

The rubber graphite characteristics shall meet the minimum requirements established by the designer of the system. These requirements include acceptable hardness, tensile and tear strength, and weather resistance. The rubber coating shall be in the form of ethylene propylene diene monomer (EPDM). Table B1 shows characteristics of the electrode rubber coating.

2.2 CATHODES

Cathodes shall be copper clad steel rods which shall meet the minimum requirements for grounding of electrical systems per NFPA 70. Rods shall be buried so that the bottom of the rod will be at least as deep as the floor of the structure being protected. The top of the rod shall be at least 12 in. below grade.

2.3 EOP CONTROL UNIT

2.3.1 Control Unit

The EOP control unit supplies a dc voltage with alternating polarity to the anodes and the cathodes. Control units shall have a programmable output pulse pattern and an LED readout. Readout must be capable of displaying output current.

The dc power delivered by the unit shall be within manufacturer's specifications and shall meet the system designer’s specifications. For large installations, it may be necessary to have multiple units in order to meet the dc power requirement.

The unit shall use a standard 120 Volt ac power source. An external ac power switch must be provided and appropriately labeled. The labeling for this switch must clearly identify which position is off. The control unit can be either hard-wired or plugged into a 120 Volt outlet. If metal, the outlet box is required to be grounded.

Table B1. Electrode rubber coating characteristics.

Rubber Type : EPDM
Color : Black

Quality : EP-98
Item No. : 37270

	Unit	Value		Test Standard
Hardness	IRHD	75±5		ISO 1818 ISO 48 ISO 1400
Spec. Gravity	g/cm^3	1,22		
Tensile Strength min	MPa	10,5	Good	ISO 37
Elongation min	%	350	Good	ISO 37
Tear Strength min	N/mm	30	Good	ISO 34 Method C
Compression Set (Permanent Deformation) 22 hours, +70 °C max 22 hours, +70 °C max	 % %	 15 15	 Good Medium	ISO 815 ISO 1653
Oil Resistance 70 hours, +100 °C ASTM Oil I Vol. Change ASTM Oil III Vol. Change	 % %		 Limited	ISO 1817
Aging 3 days, +100 °C Change in Hardness Change in Tensile Change in Elongation	 IRHD % %	 ± 5 ± 10 ± 20		ISO 188
Working Temperature min max	°C °C	- 40 +100		
Weather Resistance	Excellent			
Ozone Resistance	Excellent			
Other Properties	See overleaf			

The properties are characterized as follows: Excellent, Good, Medium, Limited, and Poor.

All electrical connections must be enclosed, either within the control unit itself or within a separate enclosure.

2.3.2 Circuit Protection

Overcurrent protection of the ac input shall be fully contained within the unit itself. The output of each unit shall have short circuit protection.

2.3.3 Wiring

Installation of ac supply wiring shall be in accordance with NFPA 70.

2.3.4 Wiring Diagram

A complete electrical connection diagram showing both the ac and the dc connections to the power supply shall be posted on the inside cover of the unit or its enclosure.

2.3.5 Control Unit Panel Cover

The control panel of the EOP control unit shall have a lockable cover which will also allow viewing of the panel display. If a cover is not available on the unit itself, then a separate enclosure to house the entire unit shall be provided. The enclosure shall have a lockable hinged door which will permit viewing of the control panel display when closed. The enclosure shall not interfere with the cooling requirements of the unit. Holes, conduit knockouts, or threaded hubs of sufficient size and number shall be conveniently located in the enclosure.

2.4 ANODE AND CATHODE ELECTRICAL WIRING

All interior and exterior wiring shall be enclosed in either conduit, raceways, or tubing and shall be installed in accordance with NFPA 70. Conduit shall be securely fastened at 2.4-m (8-ft) intervals or less. Splices shall be made inside outlet fittings only. Conductors shall be color coded and labeled for easy identification.

Anode supply wires shall have insulation UL rated for at least 600 Volts. Wires from the power supply to the anode junction boxes shall be at least 12 AWG and have red insulation. No more than 20 amps should be handled by the 12 AWG wire. The wire from the junction box to the anode string shall be at least 14 AWG and have blue insulation. Wire enclosures, including raceways, conduits, and junction boxes, within the anode system shall be nonmetallic. The wire from the junction box to the anode shall be connected to the anode with an in-line crimp type splice connector. The connector shall be protected with thermal heat shrink insulated tubing containing a sealant to provide an air tight seal for the connection. Wires in the junction boxes shall have markers designating the circuit letter and anode number permanently attached to facilitate testing and repair.

Wires from the power supply to the cathodes shall be at least 10 AWG with type RHH or RHW insulation. Wires shall be connected to the cathodes using exothermic welds: brazing, “Cadweld,” Burndy “Thermo-Weld,” or approved equal. Use of these materials shall be in accordance with the manufacturer’s recommendations. The welded area shall be suitably protected so that only the ground rod and insulated wire are exposed. Buried cathode wires shall be encased in rigid nonmetallic conduit suitable for burial. Wiring used for the cathodes shall have black colored insulation.

All exposed wiring and conduits shall be clearly marked as an EOP system. Label spacing is up to the judgment of the installer, but there should be at least one label per room. All labeling shall be in English.

2.4.1 Conduit

Rigid galvanized steel conduit and accessories shall conform to UL 6. Nonmetallic conduit shall conform to NEMA TC 2.

PART 3 DOCUMENTATION

A user's guide and operating manual for the EOP control unit shall be provided. Drawings that document the as-built installation of the system shall be provided.

PART 4 INSTALLATION

4.1 REPAIR OF CRACKS OR VOIDS

Any cracks or voids where obvious water penetration is occurring shall be repaired. This repair is done with either mortar, foams or epoxies depending upon conditions. All materials will be compatible with the EOP system.

4.2 CONCRETE AND SOIL CONDUCTIVITY

A test of the concrete and soil conductivity is done to determine both the amount and location of the anodes and cathodes. This testing is done by using a temporary power source to an EOP Control Unit. One anode and cathode are hooked up to the unit and used for testing conductivity.

4.3 ANODES

Two types of anodes are used, probe or wire. The probe anode consists of a copper electrode encased in rubber graphite with overall dimensions of about 15 cm (6 in) long by 2 cm (0.75 in) diameter and having two wire leads (for redundancy), while the wire anode is a copper wire encased in rubber graphite.

4.3.1 Probe Anodes

Once an anode pattern is determined, holes are drilled into the structure in the required locations. The depth of the holes will be the lesser of the anode length or one half the structure thickness. The hole diameter should be at least 32 mm (1/8 in.) larger than the anode diameter. When drilling on vertical walls, the holes are drilled at a downward angle of at least 10 degrees so that the mortar used to hold the anode in place will not run out. Anodes are located no closer than 5 cm (2 in.) to any rebar embedded in the structure. Anodes are placed in the holes and packed with a mortar that is compatible with the EOP system. The anode will be completely encased in the hole. The electrical connection between the anode lead wire and the anode feed wire is sealed. The seal extends to the insulated portion of the feed wire. If it is necessary to cut the anode to meet the thickness requirements, the anode shall be no shorter than one-half the original length (not including lead wires). The lead and supply wires will be protected by enclosing them in a plastic raceway or flexible nonmetallic conduit.

4.3.2 Wire Anodes

Grooves are cut into the floor or wall using a pattern which is determined from conductivity testing. The grooves vary in width and depth depending upon the type of anode cable that is being installed. The groove depth shall allow for sufficient filler material to protect the wire from external damage. After all wiring is placed in the grooves, a mortar compatible with the EOP system is used to fill the grooves. The wire anode installation detail is depicted in Figure 4.1. In visible areas where it is necessary for the final surface to be smooth, the grooves are filled with mortar to within 50 mm (0.25 in.) to 100 mm (0.50 in.) of the surface; then a leveling agent is used to achieve a smooth surface.

4.4 CATHODES

Cathodes are installed adjacent to the structure, which may include beneath the floor. They may be placed around the exterior of the building when conditions permit, or may be installed through the structure. This installation is accomplished by drilling a hole through the structure, inserting the cathode into the hole, and then driving it into the exterior soil. Wall and floor installation details for the cathodes are depicted in Figures 4.2 and 4.3, respectively. For optimum system operation, electrical isolation must be maintained between the structure material and the cathode. For exterior-driven

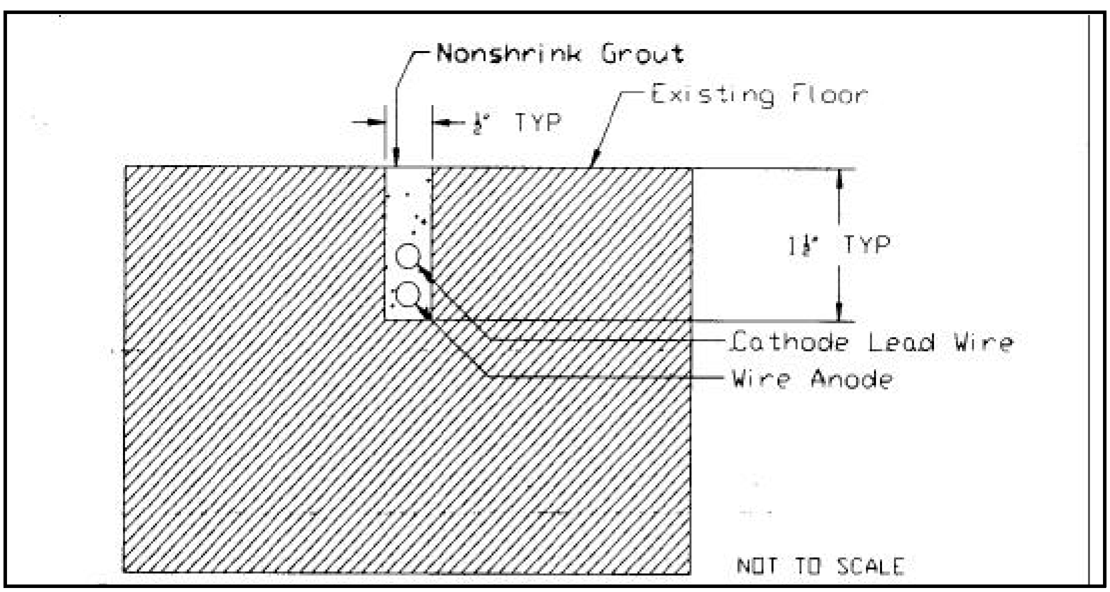

Figure 4.1. Anode installation detail.

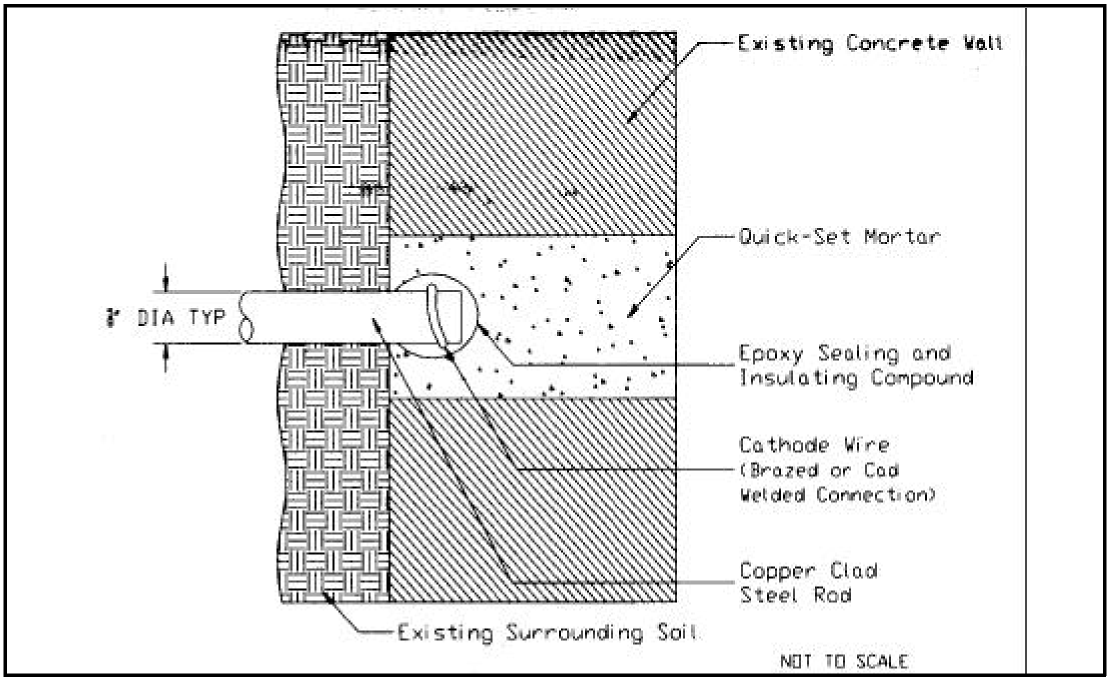

Figure 4.2. Cathode wall installation detail.

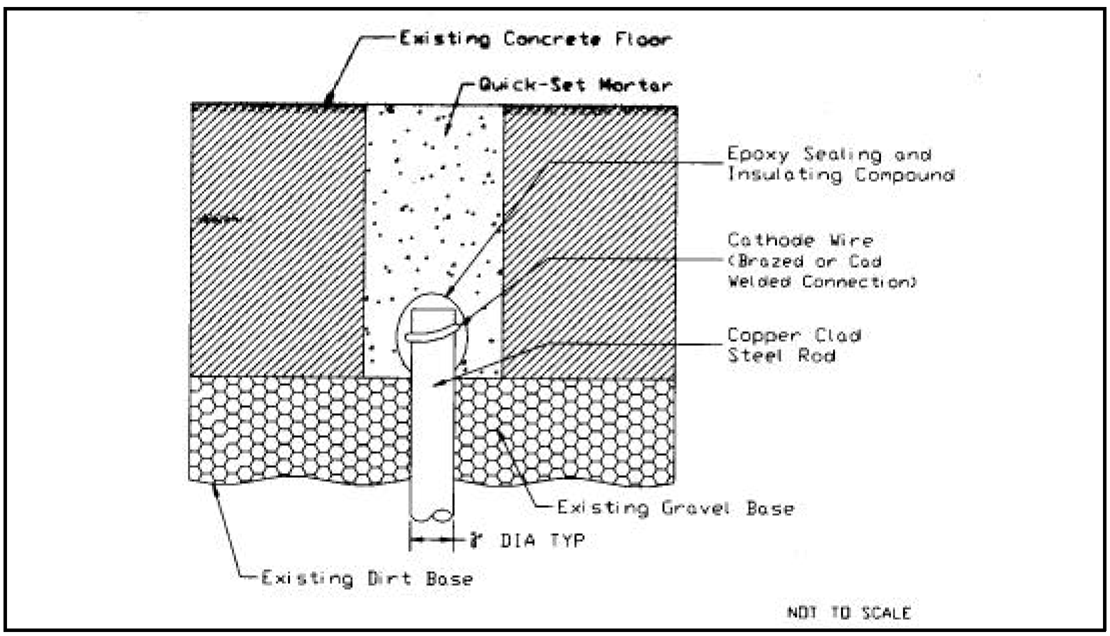

Figure 4.3. Cathode floor installation detail.

cathodes, the soil grade shall be restored after placement of the cathodes.

4.5 EOP CONTROL UNIT

The EOP Control Unit is mounted in an area that is suitable to both the user and the installer. Wiring is run from the unit to both the anodes and cathodes. This wire may be mounted using any of the following methods: surface mount with plastic wire mold;

conduit and junction boxes; or by embedding within the wall and encasing with mortar, which results in a flush-to-surface condition. After the unit is turned on, it is adjusted and calibrated. The system is now operational.

PART 5 OPERATION

5.1 PERFORMANCE MONITORING

The EOP Control Unit output voltage and current may be monitored. Normal operating output voltage is ± 30 to 40 Vdc. Because each installation is different and load current depends on the number of anodes (for probe anodes), or the length of wire (for wire anodes), and moisture content of the structure material, only qualitative performance criteria can be given—current will be greater for high moisture conditions than for low moisture conditions. A significant drop in current will be observed during the first few months of operation as the moisture is slowly driven out of the structure material. When the moisture level reaches its nominal EOP operating level, the load current will become nearly constant.

5.2 ALTERNATE PERFORMANCE MONITORING

5.2.1 Humidity Monitoring

The EOP Control Unit output current depends upon the moisture level of the structure. Moisture readings may be taken at the structure surface and presented as the percent relative humidity of the material. To be an effective aid in monitoring EOP system performance, humidity readings should be performed at several locations along the structure perimeter. Also, these readings should be taken at various time intervals to check for trends.

5.2.2 Water Table Monitoring

Monitoring the water table can also be an effective way to evaluate EOP system performance. If the level of the water table rises above the lowest level of the structure being protected (e.g. basement floor) and the structure remains dry, then it can be inferred that the EOP system is providing the necessary protection from water intrusion. (Note that the load current should rise when the water table rises above the lowest part of the structure.)

5.2.3 Rainfall Monitoring

Another method used to determine EOP's effectiveness is to compare rainfall data with monitoring well and/or load current data. Months with greater rainfall should correlate to increased water tables and increased load currents.

PART 6 MAINTENANCE

6.1 PREVENTIVE AND CORRECTIVE MAINTENANCE

Preventive maintenance of EOP system components is minimal due to the simple construction of the system. By monitoring system performance using any of the methods described in Part 5, any disparity in performance can alert the technician to the need for corrective maintenance, if necessary.