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G4090 OTHER SITE ELECTRICAL SYSTEMS

RECORD OF REVISIONS

Rev	Date	Description	POC	OIC
0	06/28/99	Rewritten and reformatted to support LIR 220-03-01. Superseded Facilities Engineering Standards, Volume 6, Electrical, Manual Rev 15, 6/26/98.	David W. Powell, *PM-2*	Dennis McLain, *FWO-FE*
1	11/18/02	General revision and addition of endnotes. Replaces Subsections 245.2.1, 245.2.2, 245.2.3, 245.4.1, and 245.8.	David W. Powell, *FWO-SEM*	Kurt Beckman, *FWO-SEM*
2	10/27/06	Administrative changes only. Organization and contract reference updates from LANS transition. IMP and ISD number changes based on new Conduct of Engineering IMP 341. Master Spec number/title updates. Other administrative changes.	David W. Powell, *FM&E-DES*	Kirk Christensen, *CENG*
3	04/28/23	For cathodic protection, removed requirement for above ground systems and updated NACE standards numbers. For grounding, restructured article; clarified scope, need of a 4/0 bare conductor in a duct bank, and requirements for fence grounding; removed soil contact resistance requirements and associated testing requirements; and added ground contact resistance testing guidance. Added Requirements ID Log references (LANL internal-use log posted with chapter).	Eric Stromberg, *ES-DO*	Michael Richardson, *ES-DO*

G4090 OTHER SITE ELECTRICAL SYSTEMS

1.0 CATHODIC PROTECTION

1.1 General

A. Design, furnish and install cathodic-protection (CP) systems for direct-buried or submerged ferrous structures, such as steel tanks and pipelines, in accordance with the following codes, standards and this section:[1] (Requirement 7-0100)

1. 40 CFR, Part 280, *Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST).*
2. 49 CFR, Part 192, *Transportation of Natural Gas and other Gas by Pipeline*.
3. 49 CFR, Part 195, *Transportation of Hazardous Liquids by Pipeline.*
4. AWWA D104, *Automatically Controlled, Impressed-Current Cathodic Protection for the Interior of Steel Water Tanks.*
5. National Association of Corrosion Engineers (NACE) Standard RP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems.*
6. NACE Standard SP0177, *Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems.*
7. NACE Standard SP0193, *External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms.*
8. NACE Standard SP0285, *Corrosion Control of Underground Storage Tank Systems by Cathodic Protection.*
9. NACE Standard SP0286, *Electrical Isolation of Cathodically Protected Pipelines.*
10. NACE Standard SP0388, *Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks.*

B. *Guidance: Consider CP applicability on all projects; provide a CP system where applicable.[2] CP is a functional requirement for virtually all projects involving new aboveground water tanks, direct-buried or submerged metallic structures, or the repair or replacement of similar existing structures.*

C. *Informational Note: MIL-HDBK-1004/10 is a valuable design guide and reference for cathodic protection principles and practices.*

1.2 CP Designer Qualifications and Responsibilities

A. Use a "corrosion expert" to perform all pre-design surveys, CP designs, and acceptance tests and inspections. The "corrosion expert" must have one or more of the following qualifications (Requirement 7-0101):

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[1] Numerous direct-buried and submerged ferrous metallic structures have been installed at LANL without cathodic protection to reduce first costs or to stay within budget. Leaks due to corrosion can cause environmental damage. Installing a low maintenance cathodic protection system where and when it is required benefits not only LANL but also the public and the environment. Certain types of systems, used for fuels and natural gas, pose safety problems if cathodic protection is not installed and maintained.
[2] Refer to section 3 in NACE SP0169-2013

1. NACE Accredited Corrosion Specialist,
2. NACE Certified CP Specialist, or
3. Registered professional engineer with documented education and experience in corrosion control of buried or submerged metallic piping and tank systems.

B. As part of the CP design provide economic justification for selection of the type of CP system (sacrificial or impressed), soil corrosiveness (e.g., resistivity, pH) data, current requirement tests (if applicable), potential survey data (if applicable to existing structures), and all design calculations for CP in the basis of design (Requirement 7-0102).

C. Use a life cycle cost analysis to select pipe material if more than one pipe material (e.g., copper, steel, non-metallic) is feasible (Requirement 7-0103).[3] If the ferrous metallic system requires CP, include the cost of that CP design and installation in the life cycle cost analysis comparison.

D. Identify optimum locations of anodes, rectifiers, test stations, junction boxes, wiring, other associated equipment, installation details, insulators, bond connections, for the structure or component connected to the cathodic protection. Coordinate with mechanical, site and other disciplines (Requirement 7-0104).

E. Identify locations where interference testing is warranted (e.g., all pipe that passes within 305 meters of an impressed current anode bed and then crosses the cathodically protected line, Requirement 7-0105).

F. Identify locations where structure-to-soil potential measurements are needed to ensure complete protection and/or allowed potentials are below maximums (Requirement 7-0106).

G. Determine appropriate testing of isolation and bonding of structures and piping systems (Requirement 7-0107).

H. Provide recommended tests, formats, required methodology, and any other necessary information for the commissioning, final acceptance, and long-term maintenance of the CP System (Requirement 7-0108).

1.3 CP Design

A. Base CP designs on historical knowledge and specific field tests made at the proposed construction site (Requirement 7-0109). *Tests should include, but not be limited to:*

1. *Soil or water corrosivity (resistivity),*
2. *Current requirements,*
3. *Potential surveys,*
4. *Stray current interference potential, and*
5. *Water chemistry/corrosivity (pH).*

B. Base CP system designs on providing a protective potential to meet the requirements of NACE SP0169 or SP0285, as applicable (Requirement 7-0110). *All steel structure-to-earth potentials should be measured in accordance with NACE SP0169 using either minus 850 mV instant off potential and/or 100 mV of cathodic polarization shift.*

C. Provide both CP and protective coatings for the following buried/submerged ferrous metallic structures, regardless of soil or water resistivity:

1. Natural gas and propane piping (Requirement 7-0100)
2. Liquid fuel piping (Requirement 7-0100)
3. Oxygen, hydrogen, nitrogen, argon, and similar gas piping (Requirement 7-0111)
4. Underground storage tanks (Requirement 7-0100)
5. Fire protection piping (Requirement 7-0112)
6. Ductile or cast-iron pressurized piping under floor (slab on grade) in soil (Requirement 7-0113)
7. Other structures with hazardous products as identified by the user of the facility (Requirement 7-0114).

D. Provide CP for cast iron pipe as follows (Requirement 7-0115):

1. For soil resistivities below 10,000 ohm-cm at pipeline installation depth provide CP, bonded joints, and protective coatings.
2. When soil resistivity is between 10,000 and 30,000 ohm-cm at pipeline installation depth, provide bonded joints only.

E. Provide CP and/or bonded or unbonded coatings for ductile iron piping systems if indicated by the results of economic analysis and the recommendation by a "corrosion expert" (Requirement 7-0115).

F. Dielectrically isolate copper water service lines from ferrous pipe in accordance with NACE SP0286 (Requirement 7-0116).

G. Provide CP and protective coatings for the following structures if indicated by the results of economic analysis and the recommendation by a "corrosion expert" (Requirement 7-0115):

1. Gravity sewer lines, regardless of soil resistivity
2. Potable water lines in soil resistivities above 10,000 ohm-cm
3. Other buried/submerged ferrous metallic structures not covered above in soil resistivities above 10,000 ohm-cm.

H. Provide interior cathodic protection for steel water storage tanks using automatic impressed current systems in accordance with AWWA D104 and NACE SP0388 (Requirement 7-0117).

I. Design CP for ferrous metallic underground storage tanks as though two and one-half percent (2.5%) of the tank is bare metal. Use either magnesium or zinc sacrificial anodes. *Composite type underground storage tanks with a 3.2 mm minimum thick layer of fiberglass coating in accordance with UL 1746 and holiday tested at 35,000 volts are exempt from CP requirements* (Requirement 7-0115).

J. Install ferrous metallic pipe passing through concrete so it will not be in contact with the concrete; provide a non-metallic sleeve or a sleeve with waterproof dielectric insulation between the ferrous metal pipe and the sleeve (Requirement 7-0115).

K. Where ferrous metal piping passes through a concrete thrust block or concrete anchor block, either insulate the pipe from the concrete or provide CP (Requirement 7-0115).

L. Using appropriate testing and inspection procedures, verify that CP criteria have been met prior to acceptance of the CP system (Requirement 7-0118).

M. Provide as-built drawings of the CP system showing the location of rectifiers, test stations, anodes, insulated fittings, etc., as applicable. Reference CP component locations to two permanent facilities or marker points (Requirement 7-0119).

2.0 GROUNDING

2.1 General

A. Install grounding systems in accordance with (Requirement 7-0120):

1. The NEC, for installations on the customer side of the service point,
2. NESC, for installations on the utility side of the service point,
3. IEEE 80, for utility substations,
4. NFPA 780, for lightning protection system installations, and
5. This section.

B. For further guidance, see LANL Master Specification Section 26 0526, *Grounding and Bonding for Electrical Systems* (Requirement 7-0121).

2.2 Grounding Electrode System

A. For installations on the customer side of the service point, install the grounding electrode systems per NFPA 70 Article 250 Part III and New Mexico Amendments to NFPA 70 (Requirement 7-0120).

B. For utility outdoor substations, install a ground grid to limit touch and step potentials. Comply with requirements in the NESC and IEEE Std 80 (Requirement 7-0120).

2.3 Duct Bank Grounding

A. Install a 4/0 AWG bare copper ground conductor in the concrete envelope of each utility or telecommunications duct bank. This is in addition to equipment grounding conductors that may be installed within the ducts. Connect to manhole grounds and equipment grounds. A 4/0 bare copper ground conductor shall not be installed in the concrete envelope of low-voltage, concrete-encased duct banks. (Requirement 7-0125). Use materials and installation methods described in LANL Master Specifications Section 33 7119, *Electrical Underground Ducts and Manholes* (Requirement 7-0126).

2.4 Fence Grounding

A. Non-Utility: Ground permanent metallic fences crossed by overhead power lines at every third post that is within 50 ft of the line crossing.[4] *Chain link or metal security fences with steel posts set in concrete may be considered as adequately grounded*. (Requirement 7-0127).

B. Utility (e.g., substations): Comply with the NESC and IEEE Std 80 (Requirement 7-0129).

2.5 Ground Contact Resistance Testing (Guidance)

Contact resistance (resistance between the grounding electrode system and the soil) is important for distribution and transmission but serves very little purpose for low voltage premises wiring systems other than as a discharge path for lightning strike events.

Whereas it is possible to measure the contact resistance of a single ground rod, it can prove to be quite difficult, if not impossible, to measure the contact resistance of a complete grounding electrode system (ground grid).

Excerpt from IEEE 142 4.4.2 Methods for Measuring:
"The three-point method, in which the resistance to earth of the electrode under test and of the auxiliary electrodes is measured two electrodes at a time, in series. This method is suitable for measuring the resistance to earth of isolated ground electrodes or small grounding installations. It is not suitable for the measurement of low-resistance installations."

- Methods of contact resistance testing
  - Three point fall of potential
    - Two test electrodes are placed. Those, in addition to the grounding electrode being tested, give three points. The first probe, the current probe is placed some distance from the electrode being tested. The second probe, the voltage probe, is placed at 5/8 the distance of the current probe. The meter causes a current to flow between the electrode being tested and the furthest probe. The voltage drop is measured at the voltage probe and the resistance of the electrode being tested is calculated based on that voltage drop. For this system to be accurate, the voltage probe must be outside the spheres of influence of both the electrode being tested and the current probe. For this reason, the distance between them can get quite large. Also, the soil between the probes should be free of underground systems. Because a complete ground grid installation can have a rather large sphere of influence, this method can be impractical. The most practical method of testing an installed ground grid is to have a test rod at one point on the system with a test well. Whenever the test is to be performed, the ground grid is disconnected from the test rod and the test rod is tested by itself. The results are then used to extrapolate the value to the overall ground grid using analysis software such as ETAP or SKM.

[4] Adequate grounding of fences will limit touch, step, and transferred voltages and will promote high-speed fault clearing by overcurrent devices should an overhead power line fall on the fence. See NFPA 70 250.194

- Although NFPA 780, *Standard for the Installation of Lightning Protection Systems,* does not require groundresistance measurements to be made, Annex E provides information for measuring the soil contact resistance of the grounding systems for lightning protection systems.[5]

- Clamp-on tester
  - Clamp-on ground testers are intended to be connected between that which is being tested and remote earth. For this reason, the connection to remote earth must be of negligible resistance. A good example of where a Clamp-on meter is useful is in measuring a single pole ground in a utility system. On one side of the meter is the pole ground being tested; on the other side of the meter is the entire utility grounding system. The Clamp-on meter measures the resistance of the entire loop. If one side is not of negligible resistance, it will affect the readings accordingly.

[5] Statement taken from the NFPA 780 Handbook Annex E, *Ground Measurement Techniques*. The Handbook is a good source of explanatory information on the text of NFPA 780.