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G4010 SITE ELECTRICAL DISTRIBUTION

RECORD OF REVISIONS

Rev	Date	Description	POC	OIC
0	11/18/02	Standard created - initial issue.	David W. Powell, *FWO-SEM*	Kurt Beckman, *FWO-SEM*
1	10/27/06	Clarified respective roles of design engineer, constructor, and LANL SSS on facility construction projects; added description of typical distribution system configurations; updated referenced standards; added requirement for pole grounding calculations; added requirements for drawings showing padmount equipment clearances, access, and protection; added IEEE Std 1410 as requirement; clarified transformer peak loading capacity calculation; clarified transformer location and access requirements; updated references to LANL Master Specifications; added references to LANL Standard Drawings.	David W. Powell, *FM&E-DES*	Kirk Christensen, *CENG-OFF*

G4010 SITE ELECTRICAL DISTRIBUTION

1.0 INTRODUCTION

1.1 Scope

A. This Section covers the supply lines, equipment, and associated work practices employed by the LANL Utilities and Infrastructure Group in the exercise of its function as a utility including:

1. Overhead power distribution *(13.8 kV, typically)* and transmission *(115 kV, typically)*
2. Underground power distribution
3. Ductbanks and manholes
4. Unit substations (primary switch and transformer)
5. Overhead service laterals
6. Grounding

B. This Section covers the LANL utility equipment up to the service point[1].

C. The requirements of this Section apply to all new systems and modifications to existing systems, except those waived or modified by the Authority Having Jurisdiction (AHJ) or the LANL ESM Electrical Point of Contact (POC).

D. This Section does not apply to:

1. Low-voltage systems "downstream" of the service point, except to the extent that these systems may be installed in risers or share pole space with the distribution systems under a joint use arrangement.
2. LANL 115 kV utility substations (ETA, WTA, TA-3, TA-53)
3. LANL communication lines, except to the extent that these systems may share pole space with the distribution systems under a joint use agreement. Refer to Section G4030.
4. Systems constructed for temporary experimental purposes and not connected to the laboratory distribution or transmission system

1.2 Intent

A. *This Section outlines the requirements for Site Electrical Distribution at the Los Alamos National Laboratory that were applicable at the time of publication. LANL recognizes that the state of the art in electrical materials, equipment and design practices continues to*

[1] The service point is defined in ESM Section D5010, Section 2.2.

advance. To take advantage of these advances, LANL may, on a case-by-case basis, consider alternative methods to the practices presented here. Such alternate methods must be approved in writing by the Utilities and Infrastructure Group and the Chapter 7 POC in advance of their implementation.

B. Within this Section, *italicized* text indicates provisions considered desirable, but not mandatory.

1.3 Execution

A. The LANL Support Services Subcontractor will furnish, install, test, operate, and maintain electrical utility equipment such as pad-mounted transformers, pad-mounted sectionalizing switchgear, medium-voltage cable, and aerial distribution material.

B. In facility construction projects, the design engineer will calculate electrical loads; select utility equipment; coordinate electrical service requirements with the LANL Support Services Subcontractor; and design equipment foundations, utility ductbanks, and utility manholes.

C. In facility construction projects the constructor will furnish and install equipment foundations, ductbanks, and utility manholes. *Integrated equipment, such as secondary unit substations, will usually be part of the construction contract.*

2.0 CODES AND STANDARDS

2.1 General Requirements

A. Comply with the applicable portions of the latest edition of each code and standard listed below or referenced elsewhere in this Section, in effect at the time definitive design work commences, unless otherwise noted in Appendix G of the Management and Operating Contract for the Los Alamos National Laboratory.

B. If there is a conflict between Codes, Standards and requirements in this Section, contact the LANL ESM Electrical POC for assistance in resolving the conflict. A requirement in this Section that exceeds a minimum Code or Standard requirement, it is not considered a conflict, but a difference.

2.2 American Society of Civil Engineers

A. ASCE 7 – *Minimum Design Loads for Buildings and Other Structures*

B. ASCE 91 – *Design of Guyed Electrical Transmission Structures*

2.3 Edison Electric Institute

A. *Suggested Practices for Raptor Protection on Power Lines: The State of the Art in 1996*

2.4 Federal Regulations

A. 40 CFR 112 – *Oil Pollution Prevention for Non-Transportation Related Onshore and Offshore Facilities*

B. 16 USC 668-668d - *Bald Eagle Protection Act of 1940*

C. 16 USC 703-711 - *Migratory Bird Treaty Act of 1918*

D. 16 USC 1531 - *Endangered Species Act of 1973*

2.5 Institute of Electrical and Electronics Engineers (IEEE)

A. IEEE C2 – *National Electrical Safety Code* (NESC) (ANSI)

B. IEEE C37.20.2 – Standard for Metal-Clad and Station-Type Cubicle Switchgear

C. IEEE C37.20.3 – Standard for Metal-Enclosed Interrupter Switchgear (ANSI)

D. IEEE C37.24 – *Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear*

E. IEEE C37.73 – *Standard Requirements for Pad-Mounted Fused Switchgear*

F. IEEE C62.22 – *Guide for the Application of Metal-Oxide Surge Arresters for Alternating Current Systems* (ANSI)

G. IEEE Std 80 – *Guide for Safety in AC Substation Grounding*

H. IEEE Std 524 – *Guide to the Installation of Overhead Transmission Line Conductors* (ANSI)

I. IEEE Std 751 – *Trial-Use Design Guide for Wood Transmission Structures* (ANSI)

J. IEEE Std 835 – *Standard Power Cable Ampacity Tables*

K. IEEE Std 977 – *Guide to Installation of Foundations for Transmission Line Structures* (ANSI)

L. IEEE Std 998 – *Guide for Direct Lightning Stroke Shielding of Substations*

M. IEEE Std 1048 – *Guide for Protective Grounding of Power Lines*

N. IEEE Std 1119 – *Guide for Fence Safety Clearances in Electric-Supply Stations* (ANSI)

O. IEEE Std 1243 – *Guide for Improving the Lightning Performance of Transmission Lines*

P. IEEE Std 1410 – *Guide for Improving the Lightning Performance of Electric Power Overhead Distribution Lines*

2.6 Insulated Cable Engineers Association

A. ICEA S-93-639 – *5-46kV Shielded Power Cables for Use in the Transmission and Distribution of Electric Energy* (also NEMA WC74)

2.7 US Department of Agriculture

USDA publications listed are available at the Rural Utilities Service website: www.usda.gov/rus/electric/bulletins.htm.

A. RUS Bulletin 1724E-150 – *Unguyed Distribution Poles – Strength Requirements*

B. RUS Bulletin 1724E-151– *Mechanical Loading on Distribution Crossarms*

C. RUS Bulletin 1724E-152 – *The Mechanics of Overhead Distribution Line Conductors*

D. RUS Bulletin 1724E-153 – *Electric Distribution Line Guys and Anchors*

E. RUS Bulletin 1724E-154 – *Distribution Conductor Clearances and Span Limitations*

F. RUS Bulletin 1724E-200 – *Design Manual for High Voltage Transmission Lines*

G. RUS Bulletin 1724E-302 – *Design Guide, Oil Spill Prevention and Control at Substations*

H. RUS Bulletin 1728F-700 –*Specification for Wood Poles, Stubs and Anchor Logs*

I. RUS Bulletin 1728H-701 – *Specifications for Wood Crossarms, Transmission Members and Pole Keys*

J. RUS Bulletin 1728H-702 – *Specifications for Quality Control and Inspection of Timber Products*

K. RUS Bulletin 1728F-804 – Specifications and Drawings for 12.47/7.2 kV Line Construction

L. RUS Bulletin 1728F-806 – *Specifications and Drawings for Underground Electric Distribution*

3.0 DISTRIBUTION SYSTEM CHARACTERISTICS

3.1 System Operating Voltages

A. The LANL distribution system is served by 115-13.8Y/7.97 kV transformers.

B. System loads (principally transformers) are connected to operate at a nominal voltage of 13.2 kV. No line-to-ground loads are supported on the system. All single-phase loads are connected line-to-line.

3.2 Basic Impulse Level (BIL)

A. Equipment installed on the LANL distribution system must have a minimum basic impulse rating (BIL) of 95 kV (at sea level).[2]

3.3 System Grounding

A. The LANL distribution system is constructed as a multigrounded system. The neutrals of transformers that supply the 13.8 kV system are solidly grounded[3].

B. Overhead distribution lines carry an electrically-continuous shield wire. Shield wires are connected to the grounding electrode systems in the supply substations and are grounded at each distribution structure.

C. Underground cable systems carry a separate grounding conductor *(typically a 4/0 AWG bare copper conductor embedded in the concrete duct bank)*

3.4 Typical Distribution System Configurations

A. The distribution system in developed technical areas is typically underground and configured as one or more primary loop systems[4].

1. Each loop circuit is fed from two utility substation circuit breakers; some loops are fed from different substations.
2. Pad-mounted sectionalizing switchgear is used as the loop switches and as isolation switches for individual transformer loads.
3. System is operated as an open loop.

B. The distribution system in less developed areas is typically aerial and configured as a radial system[5].

1. New facilities typically have building transformers served with underground circuits originating at primary riser poles.
2. Older facilities and some small new facilities will be served from pole-mounted distribution transformers.

4.0 DESIGN DOCUMENTATION

4.1 Calculations

Provide calculations for the following.

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2 Although the BIL of equipment is understood to diminish with altitude, the LANL system has operated satisfactorily for many years with equipment rated at 95kV BIL (sea level). System flashover levels are controlled with the widespread application of surge arresters.

3 LANL practice is to serve only phase-to-phase loads on the 13.8kV system. No phase-to-ground loads are supported.

4 Refer to IEEE Std 141 §2.4.2.4.

5 Refer to IEEE Std 141 §2.4.2.1.

A. Unit Substations: Refer to Sections D5000 and D5010.

B. Overhead lines

1. Load analysis and conductor selection

2. Conductor sag and tension, according to conductor type and size.

   a. Perform calculations for phase and neutral (or "static wire") conductors

   b. Limit conductor tensions as required by NESC Rules 261H through M. *Note that the strength of insulators and other components may limit the tension of the conductor.*

3. Pole strength requirements.

   a. Base calculations on wood species, construction grade, and loading.

   b. Limit stresses in poles and crossarms in accordance with NESC Section 26.

4. Voltage drop calculation for overhead service, feeder, and branch circuits.

5. Grounding calculation for each pole based on measured[6] soil resistivity at pole location.

6. Alternative designs

   a. For pole structures other than those illustrated in the LANL Standard Details, provide complete engineering analysis as described in the applicable RUS Bulletin(s). Provide calculations to establish impedance characteristics of the alternative conductor arrangement.

C. Underground lines

1. Load analysis and cable selection

2. Cable ampacity

   a. Limit conductor temperatures to 90°C [7].

   b. Determine ampacity in accordance with IEEE 835[8].

3. Pulling tensions, sidewall pressure and jam ratio[9]

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6 Measurements are necessary because surveys have shown a 10:1 variation in soil resistivity within a distance of 1 mile at LANL.

7 Even though Type MV-105 cable is used, the conductor temperature is limited to 90 °C by Type EB and DB duct commonly used in duct banks.

8 Ampacity tables found in the National Electrical Code do not apply to these systems. See NEC 90.2(B)(5).

9 Cable pulling tension and sidewall pressures may be calculated manually. A variety of guidelines are available for this purpose. However, except for the simplest of cable runs, these calculations can be quite tedious. Computer programs are available (American Polywater Corporation's "Pull-Planner" and SKM's "CABLE" being two examples) to perform the calculations.

a. Limit pulling tension to 0.008 lb/cmil for copper conductors[10] pulled by pulling eyes or pulling bolts (pulling tension applied directly to the conductor).

b. Limit pulling tension to 1000 lb for jacketed cables pulled by cable grips[11].

c. Sidewall pressure (in pounds per foot) is the tension on the cable coming out of a bend (in pounds) divided by the inside radius of the bend (in feet). Limit sidewall pressure to the values given in Table G4010-1[12].

Table G4010-1 - Cable Sidewall Pressure Limits

Cable Type	Maximum Sidewall Pressure $\frac{\text{Cable Tension (lb)}}{\text{Bend Radius (ft)}}$
600V control cable 25kV and 35kV power cable Interlocked armored cable	300lb/ft (or less, if recommended by manufacturer)
600V power cable 5kV and 15kV power cable	500lb/ft (or less, if recommended by manufacturer)
Other	Per manufacturer's recommendations

d. *For conduit or duct runs of three conductors of equal diameter (or runs with three multi-conductor cables of the same size), calculate the jam ratio using the following formula[13]:*

Equation 1 - Three-Conductor Jam Ratio

$$J = 1.05 \times \frac{ID}{OD}$$

Where:

J = Jam Ratio

1.05 = A factor used to account for the slight flattening of the conduit at bends

ID = Inside diameter of conduit or duct

OD = Outside diameter of one conductor or cable

10 The pulling tension of 0.008 lb/cmil is commonly found in industry literature. Technical papers by Southwire ("Wire and Cable Pulling Tensions"), Kerite ("Pulling Tensions"), and Superior Essex ("Cable Pulling Guidelines") all cite this value. These publications all reference the Association of Edison Illuminating Companies (AEIC) Publication CG5-90, "Underground Extruded Power Cable Pulling Guide," May 1990.

11 The 1000 pound tension limit for cables pulled in by woven basket (e.g. a Kellems grip) is also commonly found in industry literature.

12 AEIC Publication CG5-90.

13 *"A Study of Tension and Jamming When Pulling Cable Around Bends,"* John M. Fee, Michael J. Fee, American Polywater Corp., March 2002

Avoid conduit runs with a jam ratio between 2.5 and 3.0. Note that jamming can occur at conduit fill levels that would be permissible by the National Electrical Code.

D. Switchgear

1. Load analysis and equipment selection
2. Short circuit calculations

E. Surge arrester coordination

F. Transformers

1. Load analysis and equipment selection
2. Short circuit calculations

4.2 Drawings

Provide drawings prepared in accordance with LANL Drafting Standards Manual for:

A. Unit Substations

1. One line diagram
2. *Three line diagram (These drawings may be left to the equipment vendor to provide as a shop drawing. This may be advantageous, since the three line diagram typically includes terminal details that are vendor-specific.)*
3. Plot plan, including topographic contours
4. Grading plan
5. Foundation plans and details
6. Equipment elevations and details
   a. Relay and control device panel layouts
7. Grounding and lightning protection plans and details
8. Fire protection systems, if used

B. Overhead Lines

1. Plan-and-profile drawings

a. Normally, prepare plan-and-profile drawings using a scale of 1”=200’ for the plan and 1”=20’ for the profile. *For lines with abrupt ground terrain changes, a scale of 1”=40’ in profile may be used.*[14]

b. Show aboveground and underground utilities in and adjacent to the right-of-way.

c. Show roads, road crossings, pipelines and buildings.

2. Section showing right-of-way clearing

3. Structure details: Use LANL ESM Standard Drawings ST-G4010-01 through ST-G4010-33 as templates for overhead line structure drawings.

C. Underground Lines

1. Plan-and-profile drawings

a. Normally, prepare plan drawings using a scale of 1”=100’ for the plan and 1”=10’ for the profile. *For lines in especially congested areas, the drawings may be prepared using plan scale of 1”=50’and profile scale of 1”=5’ may be used.*

b. Show end points of cables and ducts.

c. Indicate maximum allowable pulling tension and sidewall pressure for power cables.

d. Show potential interferences with any other below-grade installation in or adjacent to the right-of-way (foundations, piping and other utilities).

2. Details: Duct bank, manhole and pad-mount equipment

a. Show “exploded” or “unfolded” manhole plans; use LANL ESM Standard Drawings ST-G4010-34 through ST-G4010-37 as templates for manhole drawings.

b. Provide details of duct bank configurations; use LANL ESM Standard Drawing ST-G4010-32 as a template for ductbank drawings.

c. Provide details of manhole construction; use LANL ESM Standard Drawings ST-G4010-34 through ST-G4010-37 as templates for manhole drawings.

d. Provide details of foundations for pad-mount equipment; use LANL ESM Standard Drawing ST-G4010-38 as a template for equipment pad drawings.

e. Indicate clearances around pad-mount equipment; refer to Figure G4010-1.

f. Indicate line truck access to manholes and pad-mount equipment; refer to Figure G4020-2.

[14] RUS Bulletin 1724E-200, Chapter 10, Section 10.2

g. Detail padmount equipment protection from vehicle contact; use LANL ESM Standard Drawing ST-G4010-39 as a template for equipment protection details.

h. Detail any required oil spill containment; coordinate requirements with the LANL Water Quality Group.

5.0 OVERHEAD LINES

5.1 General

A. This section applies to both primary *(medium voltage, typically 13.8 kV)* and secondary (*low voltage, typically 480 and 208V)*[15].

B. *LANL standard details for overhead distribution lines are based upon crossarm construction. No details have been prepared for other designs, such as vertical construction. Use of alternate designs, while not prohibited, are not encouraged. For consistency in construction techniques, material stocking and maintenance, crossarm construction should be used unless there is an overriding technical requirement for another approach.*

C. *LANL standard details for overhead distribution and transmission lines utilize shielded construction for lightning protection.*

D. Consult with LANL Utilities and Infrastructure Group prior to commencement of design of overhead distribution systems using designs other than standard construction details. Provide complete engineering calculations and detail drawings for review and approval.

5.2 Clearances, General Requirements

A. Apply the requirements of NESC Section 23.

B. *Refer to RUS Bulletins 1724E-154 and 1724E-200 for an in-depth treatment of clearance and span rules. The NESC is the ruling document for LANL systems. Guidance provided in the RUS bulletins regarding clearances should be considered as explanatory material.*

5.3 Clearance Above Ground

A. Apply the requirements of NESC 232 and Table 232-1.

B. For circuits exceeding 22 kV phase-to-ground (38.1 kV phase-to-phase), apply the adjustment factors given in NESC Rule 232C1a for voltage and Rule 232C1b for LANL's elevation of 7500 feet.

5.4 Clearance Between Wires, Conductors and Cables Carried on Different Supporting Structures

A. Apply the requirements of NESC 233.

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15 NESC-2002 Rule 201

B. For circuits exceeding 22 kV phase-to-ground (38.1 kV phase-to-phase), apply the adjustment factors given in NESC Rule 233C2a for voltage and Rule 233C2b for LANL's elevation of 7500 feet.

5.5 Clearance of Wire, Conductors, Cables and Energized Equipment from Other Structures

A. Apply the requirements of NESC 234.

B. For circuits exceeding 22 kV phase-to-ground (38.1kV phase-to-phase), apply the adjustment factors given in NESC Rule 234G1 for voltage and Rule 234G2 for LANL's elevation of 7500 feet.

5.6 Grades of Construction

A. Apply the minimum construction grade requirements of NESC Table 241-1, except that the minimum allowable construction grade for LANL systems is Grade C[16].

5.7 Loading

A. NESC Loading

1. Use the NESC "Medium" loading zone[17] for combined wind and ice loading calculations required by NESC Rule 250B.

B. Combined Ice and Wind Loading[18]

1. Radial thickness of ice: 0.25 in

2. Horizontal wind pressure: 4 lb/ft^2

3. Temperature: +15ºF

C. Extreme Wind Loading

1. Applicability:

a. In any case where a structure and its supported facilities are 60 feet or more above the ground or water surface, extreme wind loading is to be applied to both the structure and its supported facilities[19].

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[16] Rules concerning grades of construction are covered in Section 24 of the NESC. A possibility of failure of a structure that supports overhead lines exists at any location. The degree of hazard that would exist, should a structure fail and a conductor fall, is related to the voltage of the conductor, the surface onto which the conductor might fall and the number of people who would be at risk of injury as the result of the fall. Increasing the strength of the line can reduce the probability of the conductor falling. The NESC recognizes three different degrees of hazard, together with three different grades of construction to alleviate the hazard. These grades are identified as B, C, and N. Grade N construction has essentially no strength requirements. For this reason, LANL overhead systems must be designed to meet or exceed the requirements of NESC Grade C construction. Grade N construction is not permitted.

[17] NESC-2002 Figure 250-1

[18] NESC-2002 Rule 250B

b. For metal, prestressed and reinforced concrete structures of any height, extreme wind loading is to be applied to the structure standing alone[20].

c. For wood structures of any height, extreme wind loading is to be applied to the structure standing alone[21]

2. Basic Wind Speed (3-second gust): 90 mi/h at 33ft above ground (assumes PC-1 and importance factor of 1.0; if PC-2 service, use 1.15)[22].

3. Horizontal wind pressure on surfaces is to be calculated in accordance with NESC 250.C, with air density adjusted for 7000 feet elevation[23].

4. Temperature: +60 ºF[24]

D. Seismic

1. No special consideration needs to given to seismic loading of overhead distribution or transmission line structures[25].

2. Design foundations and equipment anchoring in accordance with applicable seismic requirements.[26]

5.8 Slack Spans

A. LANL's Standard practice is to design distribution lines to be installed under tension with guyed deadend structures. *From time to time, space restrictions, or other constraints may make the use of slack spans necessary.* When slack spans are considered during design, submit details of the proposed installation to LANL's Utilities and Infrastructure Group for review and approval.

B. Provide calculations to verify the adequacy of conductor spacing based upon sag of the slack span. Refer to NESC Rule 235B1b and Table 235-3.

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19 NESC-2002 Rule 250C
20 NESC-2002 Rule 261A1c
21 NESC-2002 Rule 261A2f
22 Per NESC-2002 Figure 250-2(a), LANL is in a "Special Wind Region" and the basic wind speed (90 mi/hr) for the general New Mexico region does not apply. ASCE 7-2005, §6.5.4.1 permits the AHJ to "adjust the values given in Fig. 6-1…" (same as NESC-2002 Figure 250-2(a)) "…to account for higher local wind speeds." The basic wind speed of 90 mi/hr was chosen to be consistent with DOE-STD-1020-2002 Table 3-2 for PC-1 structures. Note that DOE-STD-1020 states that the basic wind load, V, for PC-2 SSCs at LANL is 96 mph, and the importance factor, I_w is 1.0. Nevertheless, the velocity pressure due to wind loads in ASCE 7 Eq. 6-15 is the same if V = 90 mph and I_w = 1.15 (IBC 2003 Table 1604.5 for Category IV) are used instead.
23 The elevation of 7000 feet is consistent with DOE-STD-1020-2002 Table 3-2.
24 NESC-2002 Table 250-1
25 NESC-2002 Rule 250A4 was added in 2002 to clarify that the strength requirements imposed by Section 25 (*Loadings for Grades B and C*) and Section 26 (*Strength Requirements*) made structures sufficiently strong to survive seismic events just by being strong enough to resist other loadings.
26 Typically Performance Category 1 for equipment associated with general use facilities, PC-2 for safety significant; PC-3 may apply to critical or safety-class systems or facilities. Consult Chapter 5.

5.9 Strength Requirements

A. Follow the strength considerations for overhead lines of NESC Section 26.

B. *Follow guidelines for stress calculations given in the following RUS Bulletins:*

1. *Distribution Poles*: RUS Bulletin 1724E-150
2. *Distribution Crossarms*: RUS Bulletin 1724E-151
3. *Overhead Distribution Line Conductors*: RUS Bulletin 1724E-152
4. *Distribution Line Guys and Anchors*: RUS Bulletin 1724E-153
5. *High Voltage Transmission Lines*: RUS Bulletin 1724E-200.

5.10 Pole Embedment Depth Requirements

A. Provide pole embedment as indicated in Table G4010-2.

Table G4010-2 - Pole Embedment Depth Requirements (RUS Bulletin 1728F-803)

Pole Length (ft)	Embedment Depth In Soil (ft)	Pole Top Height In Soil (ft)	Embedment Depth in Solid Rock (ft)	Pole Top Height In Solid Rock (ft)
30	5.5	24.5	3.5	26.5
35	6.0	29.0	4.0	31.0
40	6.0	34.0	4.0	36.0
45	6.5	38.5	4.5	40.5
50	7.0	43.0	4.5	45.5
55	7.5	47.5	5.0	50.0
60	8.0	52.0	5.0	55.0

Notes:

1. "Embedment depth in soil" depths must apply:
   a. Where the poles are to be set in soil
   b. Where there is a layer of soil more than 2 feet deep over solid rock
   c. Where the hole in solid rock is not substantially vertical or the diameter of the hole at the surface of the rock exceeds approximately twice the diameter of the pole at the same level
2. "Embedment depth in solid rock" depths may apply:
   a. Where the poles are to be set in solid rock and where the hole is substantially vertical, approximately uniform in diameter and large enough to permit the use of tamping bars the full depth of the hole. When there is a layer of soil 2 feet or less dept over solid rock, the depth of the hole must be the depth of the soil in addition to the "Embedment Depth in Solid Rock" value
3. On sloping ground, the depth of the hole must be measured from the low side of the hole.

5.11 Lightning Protection

A. Apply IEEE Std 1410 in the design and specification of overhead distribution lines.

B. Design distribution structures to obtain a critical impulse flashover voltage (CFO)[27] of not less than 250 kV to 300 kV[28] at an altitude of 7500 ft.

C. Design pole grounding system to obtain 40 ohms or less at each pole ground.[29]

[Existing distribution structure details appear to not meet the IEEE Std 1410 CFO recommendations; the weak point in the existing details appears to be the proximity of the shield wire grounding down-conductor to the center phase conductor. Possible changes include adding a horizontal pin insulator on the crosarm to hold the ground wire away from the center conductor.]

5.12 Overhead Secondary Lines (480V and below) Including Service Drops

A. Use 600 V insulated quadruplex (triplex for single-phase circuits) all-aluminum conductor (AAC) with aluminum conductor steel reinforced (ACSR) messenger wire.

B. Determine conductor ampacity based upon[30]:

1. 75 °C maximum conductor temperature
2. 40 °C ambient temperature
3. 2 ft/sec wind in sun

C. On primary structures with secondary underbuilds, design spacing between primary and secondary conductors in accordance with NESC Rule 235. Verify that conductor sag profiles maintain this spacing at all spans.

D. Design overhead service runs, feeders and branch circuits to provide voltage drop performance in accordance with LANL ESM Chapter 7, Section D5010. Provide calculations to verify conformance with those requirements.

E. *Sag-and-tension calculations for short runs of secondary lines can be simplified by using the parabolic equation for cable sag[31]:*

Equation 2 - Parabolic Sag Equation

$$\boxed{S = \frac{WL^2}{8T}}$$

Where:

S=conductor sag, in feet
W= weight of cable assembly, messenger any ice loading, pounds per foot

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27 Refer to IEEE Std 1410 §3.3.
28 Refer to IEEE Std 1410 §7.2.
29 Refer to IEEE Std 1410 §7.3.
30 Cable ampacity conditions from Southwire Quadruplex Service Drop Cable product sheet. Assumes polyethylene insulation.
31 *"Messenger-Supported Cables: How Tight Can I String It?"*, T&D Update, Southwire Company, March, 1996 (http://www.southwire.com/tech/pubs/tdu/96/tdu0396.htm)

L= length of span, in feet
T= conductor tension, pounds

Example: Assume a 4/0 AWG quadruplex service drop consisting of three 4/0 AWG insulated conductors and a bare 4/0 AWG 6/1 stranded ACSR messenger. It weighs 1.063 pounds per foot. The span length is 175 feet. Tension at the building anchor at one end of the span cannot exceed 1000 pounds. What is the cable sag?

Equation 3 - Example Sag Calculation

$$\boxed{S = \frac{(1.063)(175)^2}{(8)(1000)} = 4.07\ feet}$$

F. For overhead secondary conductors that terminate at an anchor installed on a building or at a weatherhead mast designed and installed by other parties, verify the capacity of the anchor point or mast. *Request that anchor points on buildings or masts be designed and installed to withstand cable tension of 1500 pounds.* Design secondary conductors that terminate at a building-installed anchor point or weatherhead mast to maintain tensions below the design strength of the anchor point or mast.

6.0 UNDERGROUND CONSTRUCTION

6.1 Cable

A. Shielded 15 kV Power Cable

1. Comply with NESC, AEIC CS6, and ICEA S-93-639/NEMA WC74 requirements for medium-voltage power cable and its installation. Use shielded power cable for 15 kV systems in raceways, duct banks, manholes, and vaults. Use shielded power cable for interconnections within switchgear and equipment where sufficient space exists for bending and terminating shielded cables. Use NRTL-listed Type MV90 or MV105 power cable selected using its 90 ºC ampacity[32], 4/0 AWG minimum. [33]

2. Terminate shielded 15 kV cables using cable terminations that meet Class 1A requirements of IEEE 48, *Test Procedures and Requirements for High Voltage Alternating Cable Terminations*.

3. Refer to LANL Master Specifications Section 26 0513 – *Medium Voltage Power Cable*, for material and installation requirements.

B. Non-shielded 15 kV Power Cable[34]

1. Specify non-shielded 15 kV power cables for jumpers used for raptor protection as shown in the standard detail drawings.

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[32] Operating temperature is limited to 90C because plastic power ducts are listed for 90C conductors.
[33] 4/0 AWG medium-voltage cable with 5 mil tape shield is the minimum size that can carry the expected 15% of 14000 amp ground fault that will appear on the cable shield for the 0.2 seconds before the SM-149 substation breaker trips on ground fault. Source *IEEE Transactions on Industry*, Vol. IA-22, No. 6, November/December 1986 paper entitled "Are Cable Shields Being Damaged During Ground Faults?" by Hamer and Wood.
[34] Design/installation requirements for 15 kV unshielded cable is corrective action #3 to Occurrence Report LANL-1994-0013.

2. Specify non-shielded 15kV power cables within switchgear or transformer enclosures where it is not feasible to install shielded cables due to inadequate space for bending or terminating shielded cables. Obtain approval from the LANL Electrical AHJ for each installation of non-shielded 15 kV cable.

3. Specify non-shielded 15 kV transformer cable with 220 mils of EPR insulation, chlorosulfonated polyethylene (Hypalon) jacket, and minimum 2 AWG copper conductor.

4. Support non-shielded cables in switchgear or transformer enclosures by full voltage rated, flame-resistant, non-tracking insulating materials[35] of sufficient strength, size, and placement to maintain adequate clearances. *The following are guideline minimum clearances:*

   a. 4.5 inches air separation between non-shielded cables.

   b. 4.5 inches air separation between non-shielded cables and grounded parts.

   c. 7 inches creepage distance between non-shielded cables.

   d. 7 inches creepage distance between non-shielded cables and grounded parts.

6.2 Duct Banks

A. For new power duct bank installations, provide 30 percent spare ducts (rounding <u>all</u> fractions up to the next whole number), but not less than one spare duct.

B. Minimum duct size

   1. Low-voltage (0-1000 V): 2 inches

   2. Medium voltage (1001 V - 69 kV): 6 inches

C. For projects involving addition of cable(s) to an existing duct bank, if the installation will fill the only remaining open duct(s), provide a new duct run along the same route. Provide a minimum of two new spare ducts. *A fault in a duct bank frequently results in the faulted cable adhering to the walls of the duct, very difficult or impossible to remove.*

D. Design duct banks to provide a minimum cover of 24 inches from the ground surface to the top of the concrete.

E. Design duct banks and manhole systems to slope a minimum of 4 inches per 100 feet to a suitable sump area in a manhole.

F. Specify red-dyed concrete for medium-voltage duct bank embedment.

G. Perform calculations to determine pulling tensions and sidewall pressures for all duct or conduit runs of medium voltage power cable.

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35 Refer to IEEE C37.20-2001 for additional information about sheet, molded, or cast insulating materials.

H. Refer to LANL Master Specification Section 33 7119 – *Electrical Underground Ducts and Manholes* for ductbank material and installation requirements.

6.3 Manholes

A. Except as noted, design manholes in accordance with NESC Rule 323.

1. Dimensions as given in this Section. Interior height to be 7 feet, minimum.

B. Size manholes in accordance with Tables G4010-3 and G-4010-4.

Table G4010-3: 15 kV Power Manhole Sizes – No Switchgear On Manhole

Largest Cable	Straight Pull	Angle Pull						
		2 Ducts	3 Ducts	4 Ducts	5 Ducts	6 Ducts	7 Ducts	8 Ducts
4/0AWG	8' x 7'	8' x 7'	8' x 7'	8' x 7'	8' x 7'	8' x 7'	8' x 7'	8' x 7'
250kcmil	8' x 7'	8' x 7'	8' x 7'	8' x 7'	8' x 7'	8' x 7'	8' x 7'	8' x 7'
500kcmil	8' x 7'	8' x 7'	8' x 7'	8' x 7'	8' x 7'	10' x 10'	10' x 10'	10' x 10'
750kcmil	8' x 7'	8' x 7'	8' x 7'	10' x 10'	10' x 10'	10' x 10'	10' x 10'	10' x 10'
1000kcmil	12'-6" x 6'	10' x 10'	10' x 10'	10' x 10'	10' x 10'	10' x 10'	10' x 10'	10' x 10'

Number of ducts is the maximum number entering any one face of the manhole.

Table G4010-4: 15 kV Power Manhole Sizes – One 15kV Pad-Mount Switch On Manhole

Largest Cable	Straight Pull	Angle Pull						
		2 Ducts	3 Ducts	4 Ducts	5 Ducts	6 Ducts	7 Ducts	8 Ducts
4/0AWG	12'-6" x 6'	12'-6" x 6'	12'-6" x 6'	12'-6" x 6'	12'-6" x 6'	12'-6" x 6'	13' x 8'	13' x 8'
250kcmil	12'-6" x 6'	12'-6" x 6'	12'-6" x 6'	12'-6" x 6'	12'-6" x 6'	12'-6" x 6'	13' x 8'	13' x 8'
500kcmil	12'-6" x 6'	12'-6" x 6'	12'-6" x 6'	13' x 8'	13' x 8'	13' x 8'	13' x 8'	13' x 8'
750kcmil	12'-6" x 6'	13' x 8'	13' x 8'	13' x 8'	13' x 8'	13' x 10'	13' x 10'	13' x 10'
1000kcmil	12'-6" x 6'	13' x 8'	13' x 8'	13' x 10'	13' x 10'	13' x 10'	13' x 10'	13' x 10'

Number of ducts is the maximum number entering any one face of the manhole.

C. For manholes with two 15 kV pad-mount switches mounted on manhole, the minimum size is 18'-6"x6'.

D. Refer to LANL Master Specification Section 33 7119 – *Electrical Underground Ducts and Manholes* for manhole material and installation requirements.

E. Design manholes so that cable entry and exit is in the same horizontal plane, minimum of 1 foot above floor to bottom of lowest conduit.

F. Align conduits for straight through pulls in manholes. *Offset conduits create pulling problems.*

G. Design a means for drainage in the bottom of the manhole. *Means of drainage include a rock-filled sump under the floor of the manhole or installation of a sump pump. The sump pump has the disadvantage that it requires a source of low-voltage power for operation.*

H. Specify a grounding electrode *(ground rod)* accessible from within the manhole. Bond duct bank grounding conductors to the electrode. Where cables are spliced within manholes, bond cable shields and the duct bank grounding conductor to the electrode.

I. *Provide manholes spaced every 500 feet along duct runs. Alternate spacing may be considered based upon the results of pulling tension calculations. Base pulling calculations on circuit runs of three 1000kcmil conductors.*

J. *It is not always necessary for conduits to pass through manholes. Where cable-pulling calculations permit, bypass manholes with large radius bends to avoid double pulls.*

K. Mark manhole cover with manhole number.

6.4 Rodent-Proofing

A. Purchase and install outdoor medium-voltage equipment to be rodent proof with maximum 1/4-inch unprotected openings in enclosures.

B. When penetrating an exterior wall, roof, or floor for the passage of conduits, wireways, bus ducts, etc., seal opening and provide a metal collar securely fastened to the structure.

C. Seal all cable entries and plug unused conduits entering indoor or outdoor equipment from outdoors with material that rodents will not be able to gnaw through, squeeze through, or push aside. Examples of such material include:

1. 1/4-inch mesh welded, galvanized hardware cloth
2. 1/4-inch stainless steel hardware cloth
3. Galvanized plaster lath

6.5 Underground Secondary Lines (480V and below) Including Service Drops

A. Use 600V insulated Type XHHW-2 copper conductor installed in concrete-encased duct.

B. Determine conductor ampacity based upon IEEE 835 under the following conditions:

1. 75°C maximum conductor temperature
2. 20°C ambient soil temperature
3. Soil thermal resistivity (Rho) of 120
4. Load factor of 100%.

C. Design underground service runs, feeders and branch circuits to provide voltage drop performance in accordance with LANL ESM Chapter 7, Section D5010, 2.11 *(Conductors)*. Provide calculations to verify conformance with those requirements.

7.0 PADMOUNT SWITCHES

7.1 Description

A. For purposes of this Section, "padmount switches" are understood to consist of a single self-supporting enclosure containing interrupter switches.[36] A padmount switch may include power fuses and accessory compartments.

B. Padmount switches are restricted to outdoor use.

C. Padmount switches shall be manufactured in accordance with IEEE C37.73.

7.2 Application

A. Padmount switches are typically used for sectionalizing applications in the LANL power distribution system. *Within the limitations of their current-carrying capability, interrupting duty and available configurations, padmount switches typically offer the lowest-cost switching solution.*

B. For application of padmount switchgear, consult with the LANL Utilities and Infrastructure Group and the support services subcontractor.

C. Because of the relatively limited short-circuit capacity of padmount switchgear, available fault current at the proposed switch location must be carefully considered.

7.3 Installation

A. Specify padmount switches atop or immediately adjacent to manholes.

B. Route cables to padmount switches through manholes.

[36] These are the typical green boxes manufactured by Federal Pacific, S&C Electric, Cooper Power Systems and others. Their cabinets are nearly cubical, measuring 5 feet on each side.

C. Design foundation for pad-mounted switch; refer to LANL Master Specification Section 33 7711 – *Pad-Mounted Switch Rough-in* for material and installation requirements.

7.4 Clearances

A. Design installations of padmount switches to permit maintenance access. Design the installation of padmount switches to ensure 10 feet of clear working space in front of the switch enclosure doors for the full width of the enclosure[37]. *In areas where vehicle parking may be possible, bollards, curbs or other structures should be installed to keep vehicles out of the working space. The sides of switches without doors or auxiliary compartments containing electrical control or instrumentation devices do not need working space greater than 30 inches for personnel access. For switches with side-mounted accessories such as fuse storage compartments or crank-type switch operators, this access space is to be measured from the outer face of the accessory or the end of the crank handle.* Auxiliary compartments with electrical control or instrumentation devices must be provided with working space in conformance with NESC Rule 125.

8.0 METAL-ENCLOSED INTERRUPTER SWITCHGEAR

8.1 Description

A. For purposes of this Section, "metal-enclosed interrupter switchgear" is understood to be equipment consisting of interrupter switches housed in individual steel compartments[38]. Switching devices are fixed (not drawout). Buses are typically exposed when the compartment door is open. The switchgear may include fuses, sensing and metering devices and control equipment. Metal-enclosed switchgear is not available with power circuit breakers.

B. Metal-enclosed interrupter switchgear is available with enclosures suitable for indoor or outdoor installation.

C. Metal-enclosed interrupter switchgear shall be manufactured in accordance with IEEE C37.20.3.

8.2 Application

A. *Metal-enclosed interrupter switchgear differs from padmount switches in its higher continuous current and interrupting rating, and wider availability of custom features. Metal-enclosed interrupter switchgear is commonly used as the primary disconnecting means for unit substations.*

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[37] 10 feet of clearance in front of padmount switches is a long-standing LANL practice. It presumes the use of hot-sticks for operating switches and replacing fuses in the switch compartments.

[38] These are the typical tall medium-voltage switches manufactured by Federal Pacific, S&C Electric, Cutler-Hammer and numerous others. For 15kV-class equipment, the cabinets are approximately 4 feet wide, 7 to 10 feet tall and 4 feet deep.

B. For application of metal-enclosed interrupter switchgear, consult with the LANL Utilities and Infrastructure Group and the support services subcontractor. *Consultation with the equipment vendors is also recommended.*

C. Manufacturers' ratings do not take into consideration the effect of solar radiation on metal-enclosed interrupter switchgear installed outdoors. Use IEEE Standard C37.24 to calculate the derating of the continuous current rating of switchgear exposed to the sun.

9.0 METAL-CLAD SWITCHGEAR

9.1 Description

A. For purposes of this Section, "metal-clad switchgear" is understood to be equipment consisting of individual steel compartments with drawout switching devices. Switching devices may be load-break interrupter switches or power circuit breakers. The switchgear may include fuses, sensing and metering devices and control equipment.

B. Metal-clad switchgear is available with enclosures suitable for indoor or outdoor installation.

C. Metal-clad switchgear shall be manufactured in accordance with IEEE C37.20.2.

9.2 Equipment

A. Specify General Electric Power/VAC vacuum metalclad circuit breaker elements for use on 15kV-class systems unless the LANL Utilities and Infrastructure Group and the LANL ESM Electrical POC has approved the use of other equipment[39].

B. *Note that the requirement for GE Power/VAC equipment is not intended to unreasonably limit the market for the supply of switchgear equipment. The limitation extends only to the interrupter devices (the vacuum bottles) and the removable circuit breaker mechanism (the breaker" truck"). The switchgear control systems, buswork and enclosures may be assembled by a qualified fabricator other than General Electric.*

9.3 Application

A. *Metal-clad offers the most flexible means of control and protection for power systems. Sophisticated protective relay schemes are readily applied to metal-clad switchgear. Of the three available types of switchgear, metal-clad is the most expensive.*

B. For application of metal-clad switchgear, consult with the LANL Utilities and Infrastructure Group and the support services subcontractor. *Consultation with the equipment vendors is also recommended.*

C. Specify outdoor installations of metal-clad switchgear with walk-in aisle-type enclosures.

[39] The selection of General Electrical circuit breaker elements has been made for reasons of interchangeability of equipment from one installation to another, commonality of repair parts and personnel training and safety.

D. Provide ventilation *(and air conditioning if required)* as necessary to ensure that interior temperatures do not exceed 95 °F[40].

E. Manufacturers' continuous current ratings do not take into consideration the effect of solar radiation on metal-clad switchgear installed outdoors. Use IEEE Standard C37.24 to calculate the derating of the continuous current rating of switchgear exposed to the sun.

10.0 MEDIUM-VOLTAGE TRANSFORMERS

10.1 General

A. This Section pertains to transformers with medium-voltage (13.2 kV) primary ("H") windings.

B. Specify transformers with primary basic impulse level (BIL) rating of 95 kV at an elevation of 7500 feet *(110 kV at sea level)* and a secondary BIL of 30 kV. De-rate all components and clearances affected by elevation for an elevation of 7500 feet.

10.2 Transformer Selection

A. Outdoors, use non-PCB liquid-insulated transformers.

1. Pad-mounted transformers

   a. Mineral oil insulated transformers. Less-flammable liquid-insulated transformers may be used with special permission from the LANL ESM Chapter 7 POC only in cases where a mineral-oil-filled transformer is not suitable. *Critical applications may warrant the purchase of a spare less-flammable liquid-filled transformer because such transformers are not stocked by the LANL SSS.*

   b. Copper windings

   c. 65 ºC average winding temperature rise over a 30 ºC average, 40 ºC maximum ambient temperature.

   d. ANSI C57.12.22 live-front radial-feed construction

   e. 15 kV distribution class metal-oxide surge arresters

   f. Tap changer for de-energized operation

   g. Oil-immersed load-break primary switch

   h. Current-limiting fuses in dry-well canisters.

40 LANL Engineering Standards Manual, Section D1030 GEN (*General Mechanical Requirements*), part 10.0.E.

2. Pole-type distribution transformers

    a. Mineral oil insulated transformers

    b. Single-phase

    c. Aluminum windings

    d. 65 ºC average winding temperature rise over a 30 ºC average, 40 ºC maximum ambient temperature

    e. Completely self-protected (CSP) type for single-phase installation, non-CSP for three-phase banks.

    f. 13.2 kV primary voltage, 125 kV BIL

    g. Universal taps at 14.4 kV 13.8 kV, 12.87 kV and 12.54 kV

3. Unit substations

    a. Less-flammable liquid-insulated transformers

    b. Copper windings

    c. 55/65 ºC average winding temperature rise over a 30 ºC average, 40 ºC maximum ambient temperature.

    d. 15 kV intermediate class metal-oxide surge arresters

    e. Tap changer for de-energized operation

B. Indoor installations,

1. Where liquid containment for transformer oil, structural fire rating and sprinkler system are available, use non-PCB less-flammable liquid-insulated transformers.

    a. Copper windings

    b. 55/65 ºC average winding temperature rise over a 30 ºC average, 40 ºC maximum ambient temperature.

    c. 15 kV intermediate class metal-oxide surge arresters

    d. Tap changer for de-energized operation

2. Where liquid containment, fire rating and sprinkler systems are not available, use vacuum cast-coil dry-type transformer.

   a. Copper windings

   b. 100 ºC average winding temperature rise over a 30 ºC average, 40 ºC maximum ambient temperature.

   c. 15 kV intermediate class metal-oxide surge arresters

   d. Four 2.5% full-capacity taps.

10.3 Transformer Capacity

A. Base transformer capacity on load calculations for facilities calculated in accordance with the National Electrical Code, this Chapter, and loading guidance in the following IEEE Standards as applicable:

   1. IEEE C57.91-1981 – *Guide for Loading Mineral-Oil-Immersed Overhead and Pad-Mounted Distribution Transformers Rated 500 kVA and Less with 65 ºC or 55 ºC Average Winding Rise*

   2. IEEE C57.92-1981 – *Guide for Loading Mineral-Oil-Immersed Power Transformers Up to and Including 100 MVA with 55 ºC or 65 ºC Average Winding Rise*

   3. IEEE C57.96 - *Guide for Loading Dry-Type Distribution and Power Transformers)*

B. Use the following loading factors to determine transformer capacity:

   1. Average 24-hour ambient temperature:

      a. 20.9 ºC[41] for outdoor installations at elevation of 7000 ft[42] or higher

      b. 22.3 ºC[43] for outdoor installations at elevation of less than 7000 ft.

   2. Elevation: Actual site elevation determined from USGS 1:25000 topographic map.

   3. *Transformers serving facilities having a significant daily load cycle may be operated with the peak load above the transformer nameplate rating so long as normal transformer life expectancy is maintained; refer to IEEE transformer loading guides.*

C. For single-ended services the calculated load (using NEC) plus future load growth shall not exceed the calculated transformer self-cooled peak loading capability. *(Example: For a facility with significant daily load cycle: 730 kVA calculated load (per NEC) plus 146 kVA future load growth (20%) = 876 kVA. Select a 500 kVA pad-mounted transformer with a 2-*

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41 Refer to Los Alamos Climatological Survey at http://wxmach.lanl.gov/climate/LANormals.html; Los Alamos highest 24-hour average temperature is 69.6 ºF (20.88 ºC) on June 28.

42 7000 ft elevation is arbitrarily chosen as the demarcation between the Los Alamos and White Rock climates.

43 Refer to Los Alamos Climatological Survey at http://wxmach.lanl.gov/climate/WRNormals.html; White Rock highest 24-hour average temperature is 72.1 ºF (22.27 ºC) on July 6.

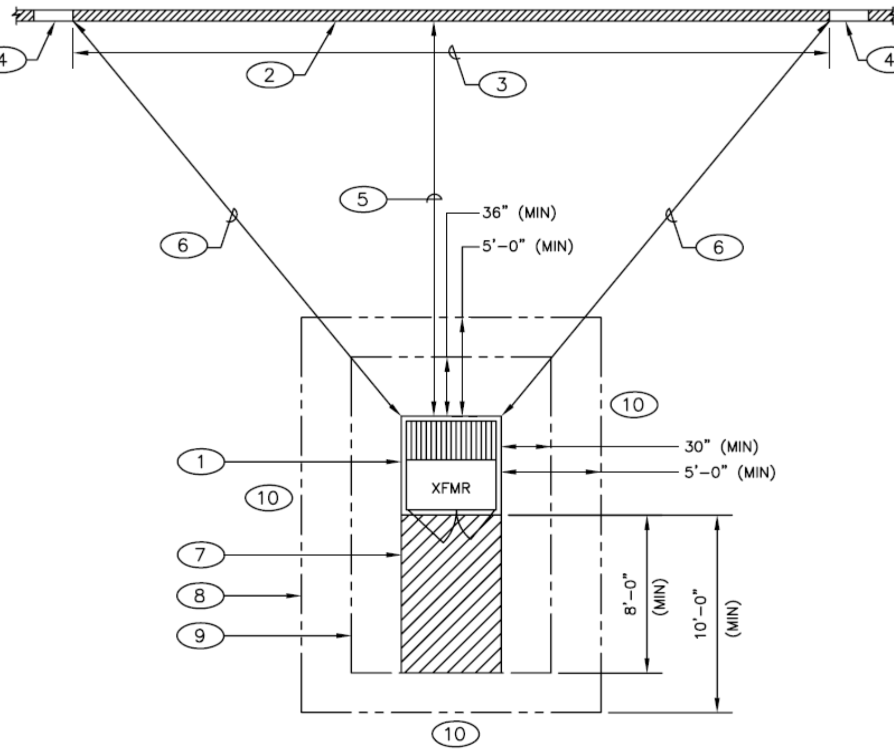
hour peak loading capability of about 900 kVA based on Table 6 in IEEE C57.91-1981). Note: Base the secondary service conductors on the 876 kVA calculated load.

D. For double-ended services, the calculated closed-tie load (using NEC) plus future load growth shall not exceed the calculated forced-air cooled peak loading capability of either transformer. *(Example: For a hypothetical facility with significant daily load cycle: 2625 kVA calculated "closed-tie" load (per NEC) plus 525 kVA future load growth (20%) = 3150 kVA. Select 2000/2300kVA (OA/FA) outdoor unit substation transformers each with 2-hour peak loading capability of about 3300 kVA based on Table 3(f) in IEEE C57.92-1981).* Note: Base the secondary service conductors on the 3150 kVA calculated load.

10.4 Transformer Location

A. Locate outdoor liquid-insulated transformers with respect to structures, windows and ventilation openings according to the National Electrical Code, and FM Global Property Loss Prevention Data Sheet 5-4; refer to Table G4010-1 and Figure G4010-1.

Figure G4010-1 Transformer Clearances



TRANSFORMER PAD CLEARANCES
SCALE: NONE

KEYED NOTES:

1. PAD OR OIL CONTAINMENT STRUCTURE FOR TRANSFORMER.
2. ROOF OVERHANG OR BUILDING WALL WITH CONSTRUCTION AS INDICATED IN TABLE G4010-5.
3. WALL WITH NO DOORS, WINDOWS, VENTILATION LOUVERS, OR SIMILAR OPENINGS LESS THAN THE VERTICAL CLEARANCE ABOVE TOP OF TRANSFORMER INDICATED IN TABLE G4010-5
4. DOOR, WINDOW, ARCHITECTURAL GLASS, VENTILATION LOUVER, OR SIMILAR OPENING.
5. MINIMUM SEPARATION BETWEEN TRANSFORMER AND BUILDING; REFER TO TABLE G4010-5.
6. MINIMUM SEPARATION BETWEEN TRANSFORMER AND COMBUSTIBLE CONSTRUCTION; REFER TO TABLE G4010-5.
7. PROVIDE CONCRETE APRON, MINIMUM 4 INCHES REINFORCED CONCRETE; MAY BE INCORPORATED WITH SIDEWALK.
8. MINIMUM CLEARANCE TO EQUIPMENT, FENCE, OR SIMILAR CONSTRUCTION THAT PROJECTS ABOVE TOP OF TRANSFORMER PAD. LANDSCAPING MUST NOT RESTRICT ACCESS OR VENTILATION.
9. MINIMUM CLEARANCE TO CURBING, SIDEWALKS, OR BARRIER PIPES.
10. PROVIDE AND MAINTAIN AN 18 FT WIDE SPACE ON ONE SIDE OF PAD TO ALLOW A UTILITY LINE TRUCK TO DRIVE UP NEXT TO THE PAD FOR INSTALLATION AND MAINTENANCE OF THE TRANSFORMER. LANDSCAPING SHALL NOT RESTRICT THIS ACCESS.

Table G4010-5 Separation Distance Between Transformer and Structure

Liquid	FM Approved Transformer or	Liquid Volume (gallons)	Horizontal Distance (feet)			Vertical Distance (feet)
			Two Hour Fire	Non-combustible	Combustible Construction	

	Equivalent		Resistant Construction	Construction		
Less Flammable (FM Approved Fluid)	Yes	N/A	3	3	3	5
	No	≤10,000	5	5	25	25
		>10,000	15	15	50	50
Mineral Oil or Unapproved Fluid	N/A	<500	5	15	25	25
		500-5000	15	25	50	50
		>5000	25	50	100	100

B. Locate transformer to permit access for maintenance and for transformer replacement.

1. Provide space maintenance access on all sides of each transformer; refer to Figure G4010-1.
2. Provide all-weather access path so a utility digger derrick truck can drive up next to at least one side of each transformer; refer to Figure G4010-2.

C. Locate transformer so terrain other structures will protect it from accidental contact by vehicles, or provide suitable protective barriers; refer to Standard Drawing ST-G4010-39.

D. Locate transformer so drainage is away from the building or design a containment or diverter for the liquid.

E. Locate outdoor transformers where no piping or conduit, except that connected to the transformer, will be beneath the transformer pad.

F. Design foundation or pad for transformer; refer to Drawing ST-G4010-38 for typical transformer pad detail; refer to LANL Master Specification Section 33 7311 – *Pad-Mounted Transformer Rough-in* for material and installation requirements.

10.5 Overcurrent Protection

A. Install primary overcurrent devices to provide through-fault protection of transformer in accordance with IEEE Standard 242 *(Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems).*

11.0 UNIT SUBSTATIONS

11.1 Description

A. For purposes of this Section, “unit substations” are understood to mean assemblies of metal-enclosed, unitized electrical power substation equipment consisting of a medium-voltage interrupter switch section, a transformer section, and a secondary-voltage distribution section. The transformer associated with the substation may be either liquid filled or dry type.

B. *Unit substations are typically designed to receive power at voltages up to 34.5 kV, transform it to voltages of 5000 volts or less, and control its distribution to load areas.*

C. Underwriters Laboratory certifies unit substations with low-voltage ratings of 600V, maximum and transformer ratings as high as 3000kVA[44]. *Ratings to 10MVA are available.*

11.2 Equipment

A. *Unit substations may be configured in the following arrangements (in increasing order of reliability):*

1. *Simple radial primary feed. This is the simplest and least expensive arrangement. It consists of a single medium-voltage feeder, one transformer, and one low-voltage bus.*
2. *Primary selective. This arrangement also has one transformer and one low-voltage bus. It differs from the radial primary feed in that the primary switches can select one of two incoming feeders.*
3. *Loop feed primary. This is similar to the primary selective system. The difference is that the primary switches arranged to permit operation with both switches closed, making power from both feeders always available.*
4. *Secondary selective. This arrangement normally operates as two electrically independent unit substations with a normally open low-voltage bus circuit breaker. The system is designed so that approximately half the system load is on each bus. In case of a failure on either of the incoming primary circuits, only one bus is affected. Opening the main breaker on the dead bus and closing the bus tie circuit breaker can restore service - this operation can be automated. Either transformer can be removed from service for maintenance, with the entire load carried through the bus tie circuit breaker. Reliability can be further enhanced by making the incoming primary feeds selective or loop feed.*

B. For outdoor applications, use oil-insulated transformers. *Some installations adjacent to "navigable waterways" may justify the application of cast epoxy dry-type transformers.*

C. For outdoor applications, provide low-voltage switchgear section with walk-in type weatherproof enclosure.

D. For indoor applications, use dry-type transformers. *Refer to Section D5010 for additional requirements.*

E. *Refer to Section D5010 for the low-voltage components of unit substations.*

11.3 Application

A. Unit substations are especially suitable for use at large facilities that will require numerous high-current low-voltage feeders.

44 UL 1062 – *Unit Substation*

12.0 FUSING

12.1 General

A. Fusing is the principal means of overcurrent protection in the LANL distribution system. Consult with the LANL Support Services Subcontractor for fusing requirements. *Discussion of protective relay applications at LANL is beyond the scope of this document. Consult with LANL Utilities and Infrastructure Group for any contemplated protective relay schemes.*

13.0 LIGHTNING PROTECTION

13.1 Overhead Transmission Lines

A. LANL transmission lines universally employ two overhead ground wires (OHGWs) placed above the phase conductors to intercept lightning strokes.[45] The OHGWs are grounded at every structure. This practice is consistent with guidelines in IEEE 1243.

13.2 Overhead Distribution Lines

A. LANL overhead distribution lines universally employ a shield wire placed above the phase conductor to intercept lightning strokes. The shield wire is grounded at every pole. This practice is consistent with guidelines in IEEE 1410.

B. *Arresters are generally not used along distribution lines except at risers and at equipment taps (transformers, capacitors, metering equipment, etc.).*

13.3 Cable Risers and Pole-Mounted Equipment

A. Provide lightning arresters to protect underground cables and equipment insulation. For selection of arrester rating, refer to IEEE Standard C62.22 or arrester manufacturer's guidelines.[46, 47]

B. Bond arrester ground terminals to the static wire downlead.

C. Design the leads from line phase conductors to arresters to be as short as practicable[48].

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45 The two-pole H-frame structures typically used for LANL transmission lines necessitate the use of two shield wires.

46 *Metal-Oxide Surge Arrester Protection of Distribution Systems,* Hubbell Power Systems, Inc. Bulletin EU-1136-H

47 *Tranquell Surge Arresters – Product Selection and Application Guide,* General Electric Company, Bulletin FETA-100a, 8/99.

48 *Arrester Lead Length – Definition and Importance in Surge Protection of Distribution Systems,* Hubbell Power Systems, Inc., *Tips & News,* Vol. 2, No. 1, January 1996

13.4 Exterior Distribution Equipment

A. Provide lightning arresters to protect exterior distribution equipment such as transformers, padmount switches and switchgear. Use intermediate-class arresters.

B. Install unit substations and switchgear to meet NFPA 780. Provide air terminals on enclosures and lightning grounding systems as required.

14.0 PRIMARY METERING

14.1 Applicability

A. *Primary metering may be employed to monitor load flow characteristics on LANL primary feeders or in cases where a large facility has a dedicated medium-voltage service*[49].

14.2 Metering Equipment

A. Provide metering equipment material and installation conforming to LANL Master Specifications Section 26 2713, *Electricity Metering*.

15.0 GROUNDING

15.1 Overhead Lines

A. Bond the static wire to pole grounds at each pole.[50]

B. Use driven rods[51], buried wire, buried strips, or buried plates as required to obtain a ground resistance of less than 25 ohms[52] at each pole where practical.

1. Where 25 ohms is not practical, add electrodes connected in parallel to obtain a ground resistance of less than 40 ohms.[53]

2. Butt plates and wire wrap are not to be used.[54]

3. Made electrodes shall be installed a minimum of two feet from the pole[55].

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49 An example of such a facility is the LANL Strategic Computing Complex that has a medium-voltage service with medium-voltage and low-voltage utilization equipment.

50 Refer to IEEE Std 1410, §7.3; for shield wire protection to be effective, shield wire must be grounded at every pole.

51 LANL Standard details show the pole ground as a driven rod, ¾ inch by 8 feet long; this will usually be a satisfactory electrode where soil resistivity is less than 10,000 ohm-cm.

52 Refer to NESC Rule 096B.

53 Refer to IEEE Std 1410, §7.3; for distribution structures with a critical flashover voltage (CFO) of 300-350 kV, a ground resistance of 40 ohms or less is required for effective shield wire performance. Structures with CFO less than 200 kV will require ground resistance of 10 ohms or less.

54 NESC Rule 094B4 permits the use of butt plates and wire wraps as made electrodes only in areas of "very low soil resistivity." Soils in and around LANL have been consistently shown to be very high resistivity.

55 RUS 1728F-803, Section H, *Construction Specifications for Grounding.*

C. Bond messenger wires and guy wires to the pole ground[56].

D. All pole-mounted equipment is to have at least two connections from the frame, case or tank to the system neutral conductor. The pole ground wire may be used for one or both of these connections.

15.2 Underground Lines

A. At each cable splice and termination point, specify bonding of the cable shield to ground.[57]

B. Design underground duct banks with a bare 4/0 AWG grounding conductor embedded in the concrete. Connect the grounding conductor to a grounding electrode in each manhole and to each equipment item served by the ductbank.

15.3 Services

A. For services supplied by pole-mounted transformers, specify grounding the transformer secondary neutral to a grounding electrode separate from the static wire grounding electrode. For the downlead, use 600 V Type RHW-2 insulated wire.

B. Separate the transformer grounding electrode and the static wire grounding electrode by at least 20 feet.

C. For services supplied by padmount transformers, specify a grounding electrode system at the transformer. As a minimum, use one 3/4-inch diameter, 8-foot long ground rod.[58] Bond the primary neutral and transformer secondary neutral to the transformer grounding electrode system.

16.0 RIGHTS-OF-WAY

16.1 Overhead 13.2 kV Distribution

A. Provide a right-of-way for 13.2 kV overhead distribution lines of 25 feet each side of the centerline, 50 feet total.

B. Provide 10 feet of right-of-way clearance around guy anchors. Measure from the guy anchor device *(i.e. the anchor plate, etc.)*, not the point at which the guy enters the ground.

C. Provide for the clearing of rights-of-way as necessary for the safe operation and maintenance of the line.

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56 NESC Rule 092C1 and 2

57 In LANL systems, the grounding conductor that accompanies underground circuits is a bare 4/0 AWG copper conductor embedded in the duct bank concrete. NESC Rule 094B6 permits the use of such a conductor as a grounding electrode. This constitutes a Ufer ground, which has been demonstrated to be a highly effective means of achieving low ground resistance in poor soils.

58 The NESC has no requirement for resistance to ground of individual grounding electrodes on a multi-grounded system. Note that the user's service entrance must have its own grounding electrode system, separate from the system at the utility transformer.

1. The area surrounding the base of each power pole defined by a 10-foot radius shall be cleared of all vegetation that is not characterized as a "grass."

2. The area defined by a path totaling 20 feet wide *(10 feet each side of the center line)* shall be cleared of any vegetation taller than 2 feet, not including grasses.

3. In the limits of the corridor from 10 feet to 25 feet either side of the center line, remove all piñon, juniper and other trees and shrubs. Plants such as chamisa and scrub oak may remain if they conform to the height criterion imposed by a 45-degree slope limit starting 10 feet outside the centerline of the corridor.

4. Outside the 50-foot right-of-way, remove "danger trees" that exceed the height criterion imposed by the 45-degree slope limit. *The 45-degree criterion represents a measure of the risk of an equivalent fall-radius for oversized trees falling into power lines.*

16.2 Overhead 115 kV Transmission

A. Provide a right-of-way for 115 kV overhead transmission lines of 100 feet total[59].

B. Provide 10 feet of right-of-way clearance around guy anchors. Measure from the guy anchor device *(i.e. anchor plate, etc.)*, not the point at which the guy enters the ground.

C. Provide for the clearing of rights-of-way as necessary for the safe operation and maintenance of the line.

   1. The area surrounding the base of each power pole defined by a 10-foot radius shall be cleared of all vegetation that is not characterized as a "grass."

   2. The are defined by a path totaling 40 feet wide *(20 feet each side of the center line)* shall be cleared of any vegetation taller than 2 feet, not including grasses.

   3. In the limits of the corridor from 20 feet to 50 feet either side of the center line, remove all piñon, juniper and such fuel-rich shrubs and trees. Plants such as chamisa and scrub oak may remain if they conform to the height criterion imposed by a 45-degree slope limit starting 10 feet outside the centerline of the corridor.

   4. Outside the 100-foot right-of-way, remove "danger trees" that exceed the height criterion imposed by the 45-degree slope limit. *The 45-degree criterion represents a measure of the risk of an equivalent fall-radius for oversized trees falling into power lines.*

16.3 Underground 13.2 kV Distribution

A. Along duct banks, provide an access corridor 25 feet wide. *(The access corridor does not need to be centered on the duct bank.)*

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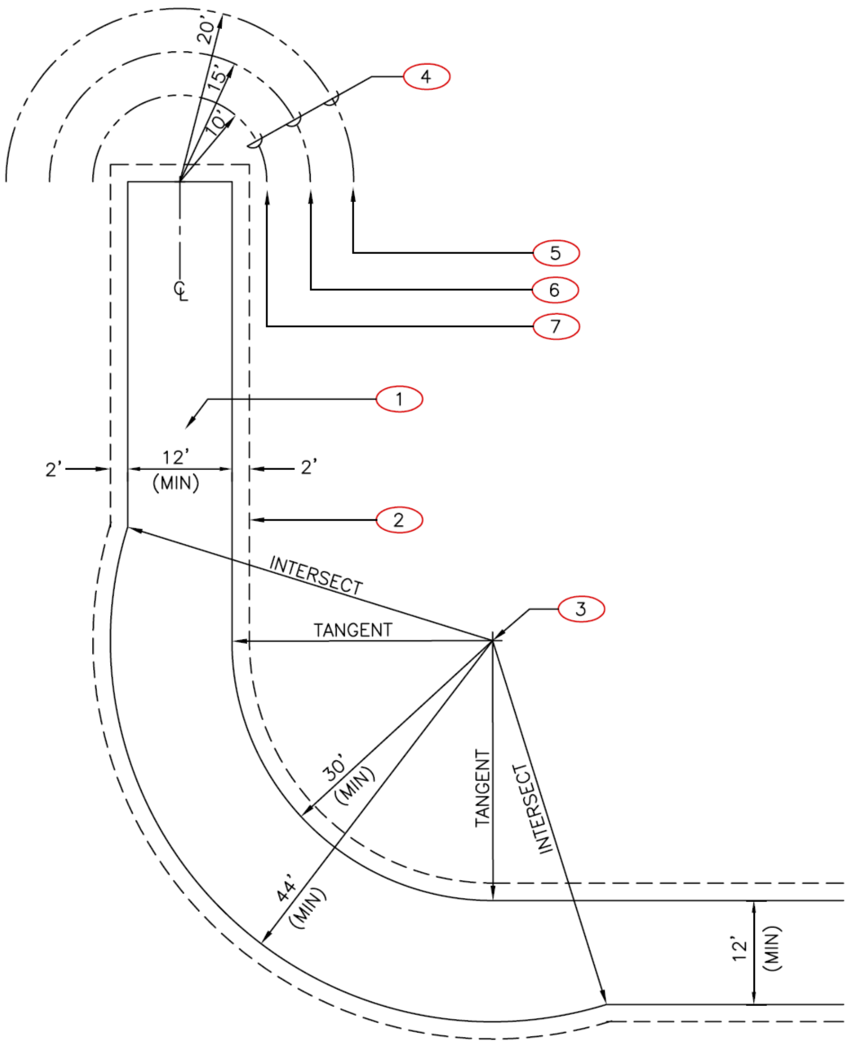
59 RUS Bulletin 1724E-200, Section 5.3

B. Around manholes and padmount equipment, provide sufficient access for maneuvering and parking line maintenance vehicles; refer to Figure G4010-2. Coordinate with the LANL Support Services Subcontractor for access requirements to manholes on a case-by-case basis.

Figure G4010-2 Pad-Mounted Equipment Access Path



PAD MOUNTED EQUIPMENT ACCESS PATH
SCALE: NONE

KEYED NOTES:

1. ALL–WEATHER ACCESS PATH SURFACE FOR UTILITY LINE TRUCK: 8 INCHES OF COMPACTED BASE COURSE OR 4 INCHES OF ASPHALTIC CONCRETE; MAXIMUM 8 PERCENT GRADE.
2. CLEAR ZONE CONTAINING NO OBJECTS HIGHER THAN 18 INCHES ABOVE THE ACCESS PATH SURFACE. GEOMETRY AND SPECIFICATIONS BASED ON LANL ESM SECTION G2010 AND AASHTO "GEOMETRIC DESIGN OF HIGHWAYS AND STREETS."
3. CENTER OF TURNING RADII.
4. LIFTING CENTERS OF EQUIPMENT. MAXIMUM EQUIPMENT WEIGHTS AND DISTANCES BASED ON USING A DIGGER DERRICK TYPE UTILITY LINE TRUCK RATED FOR 12000 LB AT 10 FT. HEAVIER EQUIPMENT OR GREATER DISTANCES WILL REQUIRE A CRANE AND A WIDER ACCESS PATH.
5. UP TO 6000 LB (300 KVA TRANSFORMER OR 4–COMPARTMENT SECTIONALIZING SWITCHGEAR).
6. UP TO 8000 LB (750 KVA TRANSFORMER).
7. UP TO 12000 LB (1500 KVA TRANSFORMER).

C. Provide separation from other underground utilities as indicated in Table G4010-6.

Table G4010-6 - Separation of Underground Lines from Other Underground Utilities

	13.2 kV Electrical	Water	Sanitary Sewer (4-inch service)	Sanitary Mains and/pr Lines >8' Deep	Force Main	Storm Drain	Natural Gas	Steam or Hot Water	Open Telecommunications	Secure Telecommunications
MINIMUM SEPARATION AT VERTICAL CROSSINGS (inches)										
13.2 kV Electrical	12[2]	18	18	18	18	18	18	24	12[1]	24[1]
MINIMUM SEPARATION FOR PARALLEL UTILITY LINES (inches)										
13.2 kV Electrical	12[2]	36	36	60	36	36	60	60	12[2]	12[2]

Notes:
1. Separation may be decreased to 6 inches if the electrical lines are encased in concrete.
2. Separation may be decreased to 3 inches if the electrical lines are encased in concrete.

17.0 JOINT USE

17.1 Application

A. *From a standpoint of safety and reliability, the ideal arrangement is for communication and power lines to be separately supported with a separation adequate to avoid conflict[60]. However, there may be many instances where it is impractical to provide adequate separation. In these cases, joint use of pole line structures may be considered.*

17.2 Joint Use Agreement

A. Undertake joint use of pole line structures only where there is a mutual and reciprocal agreement between LANL's Utilities and Infrastructure Group and another user group.

17.3 Considerations

A. Before an agreement is executed to share space on utility poles, a number of factors must be considered[61]. These include:

1. Added weight of conductors or other equipment

2. Available pole space

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60 NESC-2002 Handbook, Section 222.
61 NESC-2002, Section 222

3. Clearance to ground and to structures

4. Any change of the grade of construction that may be caused by the addition of other conductors or equipment. For example, NESC Table 241-1 requires that Grade B construction be used when communication conductors (or fiber optic lines) are installed beneath open 13.2kV conductors. In cases where an overhead line was originally built to Grade C standards, the strength reserves in a structure may not be enough to be re-classified as Grade B[62].

5. The susceptibility of communication circuits to induced voltages of fundamental (60Hz) and harmonic frequencies of the power circuits. Because of their immunity from induced noise, the use of fiber optic cables should be encouraged over copper cables.

18.0 ENVIRONMENTAL PROTECTION

18.1 EPA Regulations and SPCCs

A. Environmental Protection Agency (EPA) regulations (40 CFR 112) for the prevention of water pollution due to oil spills became effective in 1974. The regulations require that an engineering assessment be made of each power facility to determine the potential for oil discharge and the resulting impact.

B. Originally designed to prevent and control the discharge of oil from facilities directly involved in producing and handling oil for heating, cooling and manufacturing, the EPA has also included under the "storage" portions of the regulations electrical apparatus which contain oil for electrical insulating purposes (i.e. transformers)[63].

C. Electrical faults in transformers can produce arcing and excessive temperatures that can vaporize insulating oil, creating excessive pressure that may rupture the transformer tank. In addition, operator error, sabotage or faulty equipment may also be responsible for oil release that may enter waterways[64].

18.2 Scope of an SPCC Plan

A. Refer to 40 CFR 112 and RUS Bulletin 1724E-302 for guidelines on development of an Oil Spill Prevention Control and Countermeasure (SPCC) plan.

18.3 Facilities Affected by EPA Regulations

A. Consider 40 CFR 112, the EPA regulations related to oil pollution. .

B. EPA regulations apply **only** if the facility meets the following conditions:

1. Facilities with above-ground storage capacities greater than 660 gallons in a single container or 1320 gallons in aggregate storage, <u>or</u>

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62 NESC-2002 Table 253-1 provides overload factors for Grade B and Grade C construction.
63 RUS Bulletin 1724E-302, §3.0
64 RUS Bulletin 1724E-302, §3.0

2. Facilities with a total storage capacity greater than 42,000 gallons of buried storage, or

3. Facilities which, due to their location, could reasonably be expected to discharge oil into or upon the navigable waters of the United States or its adjoining shorelines.

   a. *LANL's Water Quality & Hydrology Group has the responsibility for determining whether each facility could "reasonably be expected" to discharge oil into navigable waters. The Water Quality & Hydrology Group's main telephone number is 665-0453.*

C. In order to determine which size and type of electrical facilities require an SPCC plan and containment facilities, it is necessary to know the oil capacities of each piece of electrical equipment.

D. First, consider whether the quantities of oil contained at the facility exceed the quantities of oil specified in the regulations. If it does, consult LANL's Water Quality & Hydrology group to determine if an oil spill at the site could be reasonably expected to discharge oil into navigable waters. If the second condition is met, develop an SPCC plan.

E. In addition to preparing an SPCC plan, containment facilities or systems must be in place. The containment facilities work in combination with the SPCC plan.

18.4 Oil Containment

A. Design oil containment facilities based upon RUS Bulletin 1724E-302, Section 7.9 *(Oil Containment Pits)* and Figures 7-23 and 7-24[65]. *These guidelines illustrate a concrete equipment pit or "moat" under and around the transformer.* Use of other containment strategies must have advance approval of LANL Water Quality and Hydrology Group.

19.0 WILDLIFE PROTECTION[66] [67]

19.1 Mitigation Techniques

A. Mitigate the dangers to birds and wildlife in consultation with the LANL Ecology Group (group office telephone number: 665-8961). Contact the LANL Ecology Group during the design phase of all new line construction.

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[65] Available on-line at http://www.usda.gov/rus/electric/bulletins.htm

[66] Wildlife protection measures benefit LANL utility system performance by reducing the number of outages caused by animals.

[67] Specific legal protection to wildlife is provided by:

- The *Migratory Bird Treaty Act of 1918* (MBTA) (16 USC 703-711) makes it illegal to kill, injure…any migratory bird. This law covers all migratory birds along with their nests and eggs (http://migratorybirds.fws.gov/intrnltr/treatlaw.html#mbta)
- The *Bald Eagle Protection Act of 1940* (BEPA) (16 U.S.C. 668-668) protects bald eagles by making it illegal to take bald eagles (http://laws.fws.gov/lawsdigest/baldegl.html)
- The *Endangered Species Act* (ESA) of 1973 makes it a crime to take any endangered species (http://laws.fws.gov/lawsdigest/esact.html)
- US Fish & Wildlife Service enforcement actions have used the MBTA and BEPA to impose fines on utilities and require retrofit of distribution and transmission structures that present a danger to migratory birds.

1. Use mitigation techniques illustrated in LANL Standard Drawings.
2. Raptor and migratory bird mitigation – required only for new three-phase construction:
   a. Install perch deterrents where 60-inch line spacing is not available
   b. Install insulated link out for center phase at deadends
   c. Install insulated jumpers on all transformers, reclosers and three-phase risers
   d. Install insulated jumpers on all crossarm-mounted double deadends and angle structures
3. Raptor and migratory bird mitigation – required for areas where raptor fatality occurs or study determines need:
   a. Install elevated perches or perch deterrents where 60-inch line spacing is not available
   b. Install insulated link out for center phase at deadends
   c. Retrofit with insulated jumpers
4. For locations where active nests of raptors or migratory birds are in the right-of-way
   a. Modify route to avoid nest, if possible
   b. Move nest. Coordinate with the LANL Ecology Group (665-8961).
      - Move nest to adjacent tree
      - Construct platform for relocating nest