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ZS 065

Material Specification

Wind, Ice, and Seismic Withstand

Substation & Civil Engineering

Date: 6 Dec 12

Project Issue Date: ___________

Company Project Information

Attachment to Exhibit _____, Section _____, Attachment no. _____

Project name: ____

Edited by: ____

Material Specification Contents

SECTION PAGE

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Wind, Ice, and Seismic Withstand

1 Scope

This material specification states the requirements for the wind, ice, and seismic withstand capability of substation equipment to be purchased by the company.

2 Applicable Documents

The following publications shall be used in conjunction with this material specification, and form a part of this material specification to the extent specified herein. When a referenced publication is superseded by an approved revision, the revision shall apply.

2.1 Industry Publications

Referenced industry publications are:

IEEE Std. 693, *Recommended Practices for Seismic Design of Substations*
ASCE 7-05, *Minimum Design Loads for Buildings and Other Structures*
AISC, *Steel Construction Manual* (ANSI/AISC 360)
AISI, American Iron and Steel Institute (Specification S100–07)
ACI 318, *Building Code Requirements for Structural Concrete*
IBC, *International Building Code*
ICC-ES, International Code Council Evaluation Services, Inc., (Evaluation Reports for post-installed anchors)
OSHA, Occupational Safety and Health Administration

3 General

3.1 Application Information

This material specification states the general requirements for the wind, ice, and seismic withstand capability of substation equipment. The equipment-specific requirements that vary depending on the particular equipment and application shall be stated in the purchase order. This material specification must accompany a company material specification for specific substation equipment identified in the purchase order.

3.2 Authorized Material Specification

This material specification is not considered valid until each page contains the approval signature (or initials) of the persons named in the title blocks.

4 General Wind, Ice, and Seismic Withstand Requirements

4.1 Codes and Standards

Except as required otherwise by this material specification, the general wind, ice, and seismic withstand requirements shall be in accordance with the latest applicable industry codes/standards, ANSI, AWS, IBC, ASTM, IEEE, ASCE, AISC, AISI, ACI, NEMA, OSHA, and company construction standards and material specifications in effect on the date of invitation to bid.

4.2 Wind and Ice Performance Criteria

Substation power equipment and supporting structures shall be designed for wind and ice loadings in accordance with the application of ASCE 7, Chapter 6, Wind Loads, and Chapter 10, Ice Loads—Atmospheric Icing. The basic wind speed (for a three-second gust) shall be 100 mph (as opposed to the values given in Figures 6–1, 6–1a, 6–1b and 6–1c of ASCE 7, Chapter 6). The nominal ice thickness and simultaneous wind speed shall be based on the values shown in ASCE 7, Chapter 10, Figures 10–2 through 10–5, except the nominal ice thickness shall not be less than 1/4″, and the nominal wind speed shall be no less than 40 mph. The “importance factor” shall be 1.15, and shall be in accordance with ASCE 7 for occupancy category IV.

4.3 Seismic Performance Criteria

Substation power equipment and supporting structures shall meet the requirements of IEEE Std. 693 seismic qualification level as checked (✓) below:

Low seismic qualification level . . . . ☐

Moderate seismic qualification level . . . . ☐

High seismic qualification level . . . . ☐

The seismic qualification and design of the equipment, with the exception of standby generators, shall be in accordance with the applicable provisions in IEEE Std. 693 and the supplementary requirements per Section 4.3.1. For equipment meeting the moderate or high seismic qualification, the nameplate shall indicate the seismic qualification level to which the equipment was designed and built. Standby generators identified to be qualified to the moderate or high seismic qualification level shall be qualified in accordance with the IBC, ASCE 7, and ICC–ES AC 156 as outlined in Appendix D.

Equipment Specifier Note: When selecting the seismic performance criteria for spare equipment, the following items shall be considered:

- The peak ground acceleration at potential locations of equipment installation
- The current stock of spare equipment and corresponding seismic qualification levels

- Justification for selecting a higher seismic qualification level equipment based on the cost difference of equipment qualified to different seismic qualification levels (equipment qualified to the high or moderate seismic qualification levels from some manufacturers may cost the same)
- The need for robust performance of mobile units may justify a higher seismic qualification level

4.3.1 Supplementary Seismic Qualification and Design Requirements

Supplementary seismic qualification and design requirements applicable to certain equipment identified to be qualified to the high or moderate qualification level are included in appendices as listed below:

- Appendix A – Special Anchorage Requirements
- Appendix B – Control House Equipment Panels and Racks
- Appendix C – Series Capacitor Bank Support Structures
- Appendix D – Standby Generators

4.4 Foundation Design

The foundation design engineer of record shall be fully responsible for the performance of the foundation system. The equipment manufacturer and anchor bolt designer shall not be held responsible for the performance of the foundation system provided the anchorage supplied is in compliance with these provisions. The foundation design engineer shall obtain equipment-specific loading conditions from the manufacturer to ensure that all load cases are considered. The foundation design engineer shall also review the foundation's design requirements or any constraints listed in the geotechnical engineering report.

4.5 Required Documentation

- Documentation for seismic qualification shall be prepared per IEEE Std. 693 Annex S and Annex T for analysis and test reports
- If the qualification is by analysis, the report shall be submitted on a mutually-agreed-upon date after the award of contract
- If the qualification is by testing, the test plan and test report shall be submitted on a mutually-agreed-upon date
- Documentation for the wind and ice calculations shall be submitted on the same date as the final seismic report
- Calculations for anchorage design shall be included
- Drawings shall indicate the maximum forces at each anchorage location (tension, shear, compression)

- Drawings shall indicate forces to be used for designing foundations (shear, overturning moments, axial forces)
- It shall be the responsibility of the equipment manufacturer to ensure that the calculations and other documents required to qualify equipment to 210–1 / ZS 065, *Wind, Ice, and Seismic Withstand* are prepared in strict accordance with the applicable standards, are complete, accurate, checked, stamped, and signed before submitting to the company for review
- For moderate and high seismic level qualifications, checked in Section 4.3, all calculations, test results, and drawings shall be checked, stamped, and signed by a professional engineer licensed in the United States
- Allow a minimum of four (4) weeks in the schedule for company review of the calculations and other documents submitted. The manufacturer shall assume all responsibility for any additional calculation and document review time that may result from errors and omissions in the submittals
- The company has in the past accepted equipment qualification calculations and other documents prepared by several consultants. The familiarity of these consultants with the company requirements for qualifying substation equipment could potentially result in shorter document preparation time for manufacturers and review times for the company. The company can provide this list of consultants to manufacturers who request this information. There is no requirement that a manufacturer use one of these consultants

4.6 Copies of Wind, Ice, and Seismic Analyses

The manufacturer shall furnish one hard copy and two PDF copies (on two CDs) of the analyses of wind and ice loading and seismic effect, including all calculations and drawings. Copies shall be sent with equipment approval drawings.

4.7 New Equipment Qualifying Requirements

IEEE Std. 693 requires some equipment to be seismically-qualified by time history shake-table testing. If equipment tested accordingly is currently not available, the company will not require the manufacturer to conduct shake-table testing. In such cases the equipment to be installed at the substation will be determined by the company project team. This determination will be based on available equipment options, the site specific ground accelerations, criticality of this substation, system redundancy, availability of spares, replacement/repair durations, and associated risks.

5 Issuing Department

The engineering standards and technical services department of PacifiCorp published this material specification. Questions regarding editing, revision history, and document output may be directed to the lead editor at (503) 813−5293. Technical questions and comments may be submitted to Steve Haacke, MidAmerican Energy Company substation engineering, (563) 333−8388 or Perumal Radhakrishnan, PacifiCorp substation standards engineering, (503) 813−5699.

This material specification shall be used and duplicated only in support of MidAmerican Energy Company and/or PacifiCorp projects. This document is considered a valid publication when the signature block in the footer has been initialed by the authoring engineers and department managers.

Appendix A—Special Anchorage Requirements

A1 General

These provisions are applicable only to the following equipment identified as being qualified to the high or moderate seismic qualification level per Section 4.3:

- Transformers
- Oil-filled reactors
- Three-phase voltage regulators
- Phase shifters
- Power circuit breakers
- Shunt capacitor banks

The type of anchorage on company-supplied flat concrete slabs shall be in accordance with the voltage classifications in the sections below.

A1.1 Transformers / Reactors / Voltage Regulators / Phase Shifters Larger Than 138 kV (Nominal High-Side Voltage)

Equipment bases shall be designed to be anchored by welding to steel embedments in the concrete foundation, unless the cast-in-place bolted anchorage or post-installed bolted anchorage box is checked below:

In lieu of welded anchorage use cast-in-place bolted anchorage . . . . ❑

In lieu of welded anchorage use post-installed bolted anchorage . . . . ❑

Requirements for welded, cast-in-place bolted, and post-installed bolted anchorages are provided in sections A2.1, A2.2, and A2.3 respectively.

A1.2 Transformers / Reactors / Voltage Regulators / Phase Shifters 138 kV (Nominal High-Side Voltage) or Smaller

Equipment bases shall include tabs with holes ("anchor tabs") for anchoring the equipment to a concrete foundation using post-installed steel rods, bolts, special anchors, or welds.

Anchor tabs shall be designed such that they can be either bolted or welded to a foundation, depending on the particulars of an installation. If bolting anchorage is most suitable, the company will drill the foundation and install anchors through the holes provided in the equipment base. If welding is most suitable, the company will weld the anchor tabs directly to the steel embedments in the foundation. Locations of anchor tabs shall be coordinated with the embedded steel locations indicated in Figure A1. The company will choose the method of attachment after the transformer is delivered to the site.

Requirements for welded and post-installed bolted anchorages are provided in sections A2.1 and A2.3 respectively.

A1.3 Power Circuit Breakers of All Voltage Classes

Manufactured equipment bases for power circuit breakers of all voltage classes shall include holes for anchoring the equipment to a concrete foundation using post-installed steel rods, bolts, or special anchors per Section A2.3.

A1.4 Shunt Capacitor Banks of All Voltage Classes

Equipment bases for shunt capacitors of all voltage classes shall include holes for anchoring the equipment to a concrete foundation using post-installed steel rods, bolts, or special anchors per Section A2.3.

A2 Anchorages

A2.1 Welded Anchorage

All welding shall be performed according to AWS D1.1 by a certified welder and inspected by a certified welding inspector (CWI).

Selection of the size and length of prequalified field welds shall be included in the engineering analysis and calculations for qualification of the equipment. The welds shall be made to locations that are selected and designed to transfer forces. The heat caused by welding shall be considered. Welding to an embedment shall be completed in a manner not to produce sufficient heat to compromise the concrete substrate. When required, extended base plate tabs (may be the same plate as for the bolted options) shall be provided.

Company foundations will feature embedded steel, a minimum of 1/2″ thick, 6″ wide and spaced center-to-center at 2′–6″. Steel embeds will run parallel to each other and fit across the entire width of the foundation from the high- to low-voltage side. The manufacturer shall provide weld locations where the steel embeds cross. A typical foundation plan is provided for illustration of this concept (see Figure A1).

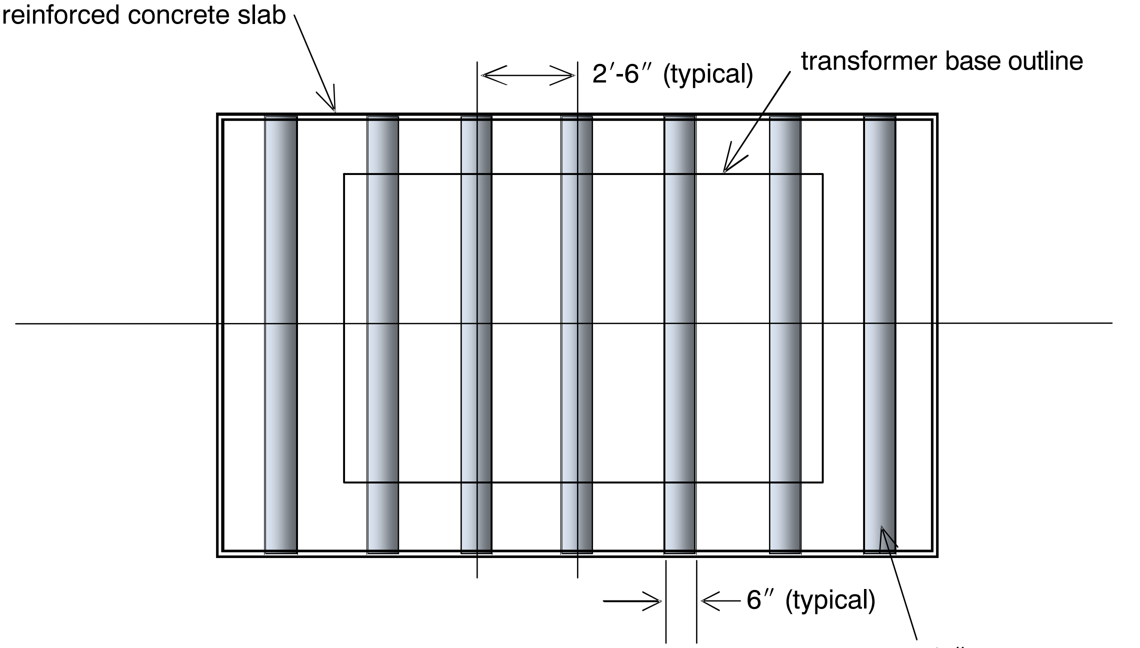

Figure A1—Foundation Plan with Embedded Steel

A2.2 Cast-in-Place Bolted Anchorages

The selection of the number, positions, and diameters of anchors shall be included in the engineering analysis and calculations for qualification of the equipment. Contrary to IEEE Std. 693, selection of anchor diameter shall be based on the design procedure in ACI 318, Appendix D, and not on the ASCE 113, *Substation Structure Design Guide*. The anchor demands shall be calculated using the load combinations specified in IEEE Std. 693. For anchor design purposes, the following criteria shall be used to determine the steel and concrete capacities per ACI 318, Appendix D:

- Anchor material shall be assumed to be steel meeting the requirements of ASTM F1554
- Supplemental reinforcement will be provided by the foundation designer such that concrete breakout failure mode can be ignored
- Adequate edge distance shall be provided by the foundation designer such that the side-face blowout failure mode can be ignored
- Minimum concrete compressive strength shall be 4000 psi (pounds per square inch)
- Minimum thickness of foundation is at least 25 times the diameter of an anchor
- Concrete is considered “cracked”
- Anchors will be installed in a high seismic region

In addition to calculations for steel failure modes, calculations for anchor pry-out and pullout failure modes shall be provided. Anchor spacing and effective embedment depth, in accordance with ACI 318, Appendix D, shall be considered.

Anchor rod/bolt hole size in the equipment base shall be at least 3/8″ in diameter larger than the diameter of the rod/bolt to facilitate installation.

Plate washers appropriately sized (but not less than 1/2″ thick) with holes no more than 1/16″ greater than the bolt diameter shall be provided with each bolt. These plate washers will be field-welded to the equipment base. Calculations and drawings shall indicate the washer and field weld details.

A2.3 Post-Installed Bolted Anchorage

The selection of the number, positions, and diameters of post-installed anchors shall be included in the engineering analysis and calculations for the qualification of equipment. The design shall facilitate the installation of post-installed anchors, i.e. adhesive, expansion, or undercut anchors installed after placing equipment on the foundation. The minimum clearance space required to install this type of anchor in concrete is 9″ between the equipment face and the anchor, 15″ to either side of the anchor, and 84″ above the anchor (see Figure A2 below). The anchor demand shall be calculated using the load combinations specified in the IEEE Std. 693. For anchor design purposes, the following criteria shall be used to determine the steel and concrete capacities per ACI 318, Appendix D, and the International Code Council ICC–ES ESR report for the post-installed anchors:

- Anchors positioned in groups shall have a minimum center-to-center spacing of six times the diameter of an anchor
- Anchor material shall be assumed to be steel, meeting the requirements of ASTM F1554
- Supplemental reinforcement will be provided by the foundation designer such that concrete breakout failure mode can be ignored
- Adequate edge distance will be provided by the foundation designer such that the side-face blowout failure mode can be ignored
- Minimum concrete compressive strength shall be 4000 psi
- Minimum thickness of the foundation is at least 25 times the diameter of an anchor
- Concrete is considered “cracked”
- Anchors will be installed in high seismic regions

In addition to calculations for steel failure modes, calculations shall also consider:

- Anchor pry-out failure mode. Anchor spacing and effective embedment depth, in accordance with ACI 318, Appendix D, shall be considered
- Adhesive bond or pullout strength calculations required per the ICC–ES ESR report
- Anchor diameters may not exceed maximum allowed by ICC–ES ESR report

Finally, holes larger in diameter than the proposed anchors (by 1/4″ or more) are considered oversized. Oversized holes may result in shear forces distributed unevenly amongst the anchors. Oversized holes are permitted if plate washers are used, with holes no more than 1/16″ greater than the bolt diameter, field-welded to the equipment base.

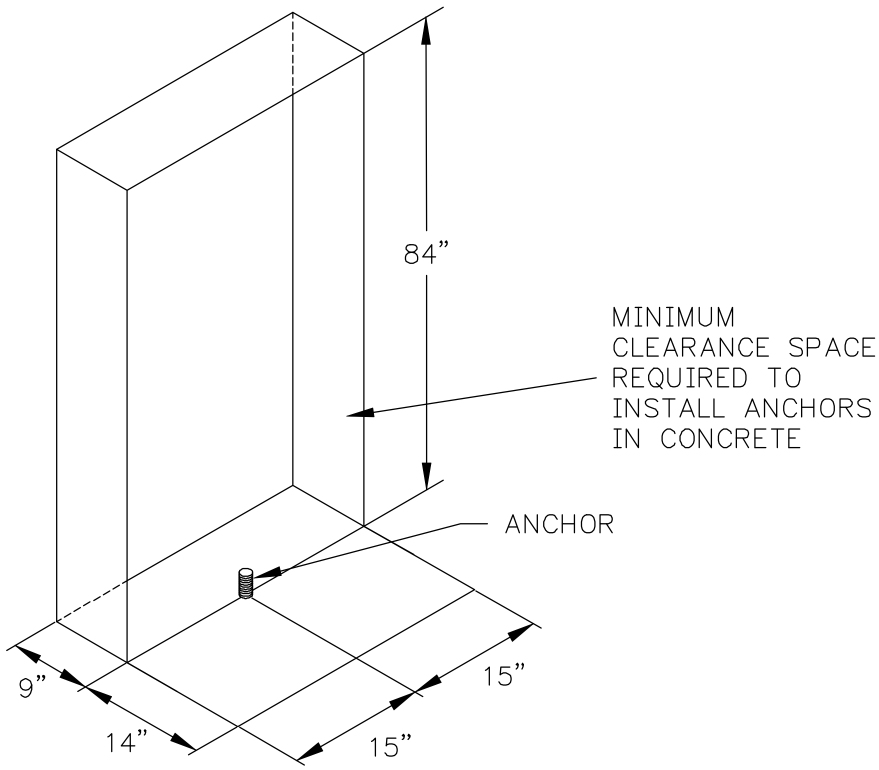

Figure A2—Anchor Clearance Zone for Post-Installed Anchors

Appendix B—Control House Equipment Panels and Racks

B1 General

These provisions are applicable only to the seismic evaluation of control house equipment panels and racks identified as qualified to the high or moderate seismic qualification level per Section 4.3.

B2 Seismic Qualification and Design

IEEE Std. 693 requires certain panels and racks to be seismically qualified by shake-table testing. As an alternate to this testing requirement, the company will accept seismic qualification calculations and design performed to the high seismic qualification level loading per IEEE Std. 693, Annex L.4.2 (Static analysis per A.1.3.1 at 1.5g in each horizontal direction and 1.2g in the vertical direction). Finite element models (FEMs) of the panels and racks should be developed using STAAD software. If some other software is used (please specify), then electronic files of the FEMs that include information of model geometry, loading, etc., that can be imported into STAAD shall be provided (ex. CIS/2 format). Forces shall be combined by the SRSS method or 100/40/40 combination.

Allowable stresses, which account for local buckling effects of the sheet metal panels, racks and components, shall be evaluated per AISI S100–07, *North American Specification for the Design of Cold-Formed Steel Structural Members*. Typically, panels and racks are fabricated with ASTM A1011 Grade SS (structural steel grade). However, ASTM A1011 Grade CS (commercial grade) steel will be acceptable provided coupon tests are performed to prove that the minimum yield strength is 30 ksi (kips per square inch). A plate bending radius of 1xt (thickness) may be assumed for 90 degree bends for shapes. Design shall include reinforcements required at panel cutouts for instruments, and anchorage of the panels.

Appendix C—Series Capacitor Bank Support Structures

C1 General

These provisions are applicable only to the seismic evaluation of series capacitor bank support structures identified as qualified to the high or moderate seismic qualification level per Section 4.3.

C2 Seismic Qualification and Design

The fixed series capacitor bank platform and support structure shall be qualified in accordance with IEEE Std. 693, Annex O, and the provisions contained herein. All capacitor bank platform structures shall utilize columns and diagonal bracing systems built with insulators between the platform and foundation for lateral force resistance. Bracing systems can utilize either tension-only or tension-compression members.

For structures with tension-only diagonal bracing systems, structural analysis shall be performed utilizing either site-specific developed time response histories, or IEEE Std. 693 developed time response history record. The seismic response history procedures in the latest version of ASCE 7 shall be used. Time histories shall be scaled to envelope the IEEE Std. 693 performance level response spectrum for 2% damping. For tension-only bracing systems, the loss of pre-tensioning during response history analysis shall be explicitly modeled. All connections and components of the bracing system shall be modeled.

For diagonal bracing members consisting of materials other than structural steel, structural capacity shall be established by means of testing and shall include all connection components that comprise the bracing assembly (i.e. shackles, pins, clevises, etc.). Testing shall include the development of load-deflection curves (loading and unloading) required for the structural analysis model. Results of test data shall be included in the final seismic qualification report. All bracing member capacities shall have a tested minimum factor of safety of 1.2 at the IEEE Std. 693 performance level demands. Further, for tension-only bracing, the minimum factor of safety shall be 1.5. Shackles, pins, clevises and other hardware shall be provided with a minimum 2.0 factor of safety at the IEEE Std. 693 performance level demands.

The use of supplemental damping or response modification devices shall be acceptable provided the demonstrated system response meets the IEEE Std. 693 performance level requirements. All nonlinear components of the lateral force resisting system shall be explicitly modeled to capture behavior and effect on the support structure system. The performance characteristics of all supplemental damping or response modification devices, both linear and nonlinear, shall be established by component testing and shall demonstrate adequacy for entire range of expected forces and displacements. The performance characteristics shall be explicitly used in the computer model.

The top of the capacitor bank platform shall not deflect in any horizontal or vertical direction more than H/50 when subject to IEEE Std. 693 performance level demands, where "H" is equal to the height of the capacitor bank/support structure platform interface as measured from the top of the foundation.

The company recommends the support structure columns and diagonal braces be connected to and supported by steel pedestals embedded in the concrete foundation, rather than directly connected to concrete pedestals. The use of cast-in-place anchor rods or post-installed anchors is discouraged due to difficulty in satisfying requirements of ACI 318, Appendix D provisions. However, if either cast-in-place or post-installed anchors are provided, the ACI 318, Appendix D provisions shall be used and all concrete shall be assumed to be cracked for purpose of analysis.

Calculations shall be submitted to demonstrate the performance of the capacitor bank system as specified above. The submittal shall include a *Seismic Qualification Report* prepared in accordance with IEEE Std. 693, Annex S. The Report shall contain a comprehensive narrative that clearly explains all analysis & design assumptions along with final conclusions and recommendations. In addition, electronic file copies of input and output used for the structural analyses shall be provided on CDs or DVDs such that the company can review the computer file in STAAD. If software other than STAAD is used for analyses, then electronic versions of files importable into STAAD (ex. CIS/2 format) shall also be included (in addition to original files). Computer files will be used as part of technical review and validation of proper modeling methodology and analysis results.

Appendix D—Standby Generators

D1 General

These provisions are applicable only to the seismic evaluation of standby generators identified as qualified to the high or moderate seismic qualification level per Section 4.3.

Generator configuration shall meet the project specific requirements which may include one of the following:

- Generator mounted directly on a concrete foundation with a separate fuel tank
- Generator mounted on a sub-base fuel tank that is supported by a concrete foundation, where the top of the fuel tank is used as a working/walking platform
- Generator mounted on a sub-base fuel tank that is supported by a concrete foundation, with a separate grated platform used as a working/walking platform

Seismic qualification of the generator, sub-base fuel tanks and platforms shall be in accordance with the applicable provisions in IBC, ASCE 7, ICC–ES AC 156 and Section D.2.

All working/walking platform surfaces and approach steps shall be OSHA compliant, free of slip/trip hazards and be equipped with fall protection when applicable. Platforms and approach steps shall be designed for a minimum snow load of 30 pounds per square foot (psf), uniform live load of 50 psf and concentrated live load of 500 pounds.

Steel design shall be in accordance with the applicable provisions in AISC and AISI, with due consideration to effects of buckling and pryout at bolted connections.

Post-installed anchors (adhesive or mechanical anchors) shall be used to anchor the generator, fuel tank, and platform support steel to concrete foundations. Adequate clearance shall be provided to enable the installation of the anchors after the equipment is set in place on the concrete foundation.

D2 Seismic Qualification Methods

1. The generator set should be qualified by shake-table testing that meet or exceed the parameters below:

   a. Building code/referenced standards, IBC 2009/ASCE 7

   b. Test criteria, ICC–ES AC 156

   c. S_{DS} (g) = 1.67

   d. z/h = 1.0

   e. A_{FLX-H} (g) = 2.67

   f. A_{FLX-V} (g) = 1.12

   An I_p = 1.5 shall be assumed for evaluating functional requirements after testing (Ref ICC –ES AC156 Section 6.8.2).

For generators supported on top of sub base fuel tanks additional calculations shall be provided to verify that the support system is dynamically better (will transmit lower accelerations to the generator) than the support used for the shake-table test.

2. The enclosure, fuel tank, other components, connections and anchorages that are not shake table tested must be analyzed and designed to the following ultimate (LRFD) seismic forces:

   a. F_{p-hori} = 3.76 W_p

   b. Fp_{-vert} = 1.12 W_p

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