RECOMMENDED PRACTICE FOR SEISMIC AND WIND CERTIFICATION FOR COMPLIANCE TO THE INTERNATIONAL BUILDING CODE (IBC) FOR ELECTRICAL GENERATING SYSTEMS AND VARIOUS CRITICAL COMPONENTS FOR BUILDING DESIGN CATEGORIES C, D, E OR F PER CHAPTER 13 OF ASCE 7, AND CHAPTERS 16 AND 17 OF THE IBC CODE

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1. INTENT

Electrical generating systems are comprised of a combination of products whose purpose is the supply of uninterruptible power, emergency power or primary power. The critical function of one system can adversely affect the operation of the entire system. The intent of this recommended practice is to define a set of acceptable criteria in the power generation industry for suitable methods of analysis and testing of electrical and mechanical equipment when IBC certification is required. Section 1708.5 of the IBC Code describes accepted methods for qualification and this document will further define those methods for the power generation industry. These requirements apply to designated seismic systems and critical components located outdoors where wind is a concern.

2. SCOPE

The provisions of this recommended practice shall apply to open generator sets, transfer switches and switchgear, pre-fabricated weather or sound enclosures, sub-base fuel tanks and day tanks, silencers and sound attenuating products, electric starting systems and radiators. External piping, electrical wiring and conduit are not included in this scope.

3. REFERENCE STANDARDS AND PRACTICES AS APPLICABLE:

IBC 2000, 2003, 2006	International Building Code
ASCE 7-98, 7-02, 7-05	American Society of Civil Engineers Document 7, Minimum Design Loads for Buildings and Other Structures
ICC-ES AC156	Acceptance Criteria for Seismic Qualification by Shake-Table Testing of Nonstructural Components and Systems
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association Seismic Restraint Manual Guidelines for Mechanical Systems.

4. DEFINITIONS

Approved Agency: An established and recognized agency regularly engaged in conducting tests or furnishing inspection services, when such agency has been approved.

Attachments: The means by which equipment is secured or restrained by the seismic force resisting system of the building structure. Such attachments and restraints may include anchor bolting, welded connections and mechanical fasteners.

Certificate of Compliance: A certificate stating that materials and products meet specified standards or that work was done in compliance with approved construction documents.

Designated Seismic System: Those architectural, electrical and mechanical systems and their components that require design in accordance with Chapter 13 of ASCE 7 and for which the component importance factor, Ip, is greater than 1 in accordance with Section 13.1.3 of ASCE 7.

Flexible Equipment: Component, including its attachments and force-resisting structural members, having a fundamental period greater than 0.06 second (less than 16.67 Hz).

Importance Factor (Ip): For seismic design, the importance factor is a numerical value given to a piece of equipment. The component importance factor, Ip, shall be taken as 1.5 if any of the following conditions apply:

1. The component is required to function for life-safety purposes after an earthquake, including fire protection sprinkler systems.
2. The component contains hazardous materials.
3. The component is in or attached to an Occupancy Category IV structure (IBC 2003/2006) or Category III structure (IBC 2000), and it is needed for continued operation of the facility or its failure could impair the continued operation of the facility.

All other components shall be assigned a component importance factor, Ip, equal to 1.0.

Label: An identification applied on a product by the manufacturer that contains the name of the manufacturer, the function and performance characteristics of the product or material, and the name and identification of an approved agency, and that indicates that the representative sample of the product or material has been tested and evaluated by an approved agency

Main Wind-Force-Resisting System: An assemblage of structural elements assigned to provide support and stability for the overall structure. The system generally receives wind loading from more than one surface.

Pre-fabricated Engine Generator Set Weather and Sound Enclosure: Fabricated enclosure that protects components from the enviroment in which it is installed. It can contain generator sets, transfer switches, switchgear, fuel tanks, silencers or anything else required for the application.

Rigid Equipment: A component, including its attachments and force-resisting structural members, having a fundamental period less than or equal to 0.06 second (greater than or equal to 16.67 Hz).

S_{DS}: Short period spectral acceleration.

Structural Modeling: The mathematical analysis of equipment and structures by applying prescribed design forces to computer generated models or through discrete analysis.

Triaxial Test: A dynamic test in which the test specimen is subjected to acceleration in two principal horizontal axes and the vertical axis simultaneously. The two horizontal and the vertical acceleration components are derived from three different input signals that are phase-incoherent.

Uniaxial Test: A dynamic test in which the test specimen is subjected to acceleration in one principal axis. The acceleration components are derived from a single input signal.

Unit Under Test (UUT): The equipment item to be qualification-tested.

5. EQUIPMENT TYPES AND STANDARDS FOR QUALIFICATION

5.1 Open Generator Sets

Open generator sets are primarily comprised of six (6) basic components: skid, radiator, engine, alternator, junction box, and electronic controls and devices. Due to the size and variations of open generator sets, it is not always practical to use shake table testing as the sole criteria for qualification. Therefore, acceptable methods for qualification of open generator sets include both shake table testing in accordance with ICC-ES AC156 (or other approved standard) or a combination of structural modeling and shake table testing. Flexible components on open generator sets cannot be modeled structurally so structural modeling alone is not a sufficient method for seismic qualification.

When qualifying by shake table testing, strict adherence to AC156 must be followed. Single axis, dual axis or triple axis shake table testing are all acceptable methods. During shake testing, the unit under test (UUT) must contain the required fluids that it would normally have under operating conditions.

When qualifying by a combination of structural modeling and shake table testing, the following typically applies: engines and alternators are considered rigid components and do not require shake table testing. Structural modeling of the coupler attachment between the alternator and engine is required. Where no data exists for this coupler mechanism, static strength testing of this component is required. Additionally, relative motion of the alternator stator shaft must be analyzed to ensure that the potential sliding action of the shaft during a seismic event will not adversely affect the shaft bearing resulting in premature failure. Radiators shall be analyzed using structural modeling or shake table testing. The radiator housing and attachment supports must be analyzed in accordance with ASCE 7. Pass criteria for the radiator housing when modeling shall be no yielding at the attachments or corners -- the premise being that the only way a radiator will fail is if the unit parallelograms. Junction boxes, electronic controls and other electronic devices must be shake table tested to prove on-line functionality. These devices are considered flexible and cannot be structurally modeled to prove survivability. They shall be tested in strict adherence to AC156. Additionally, the components shall be mounted on test fixtures that replicate the normal operating environment of the component. Vibration isolated electronic components must be tested on their isolation systems. Likewise, junction boxes shall be affixed to their respective test fixture with typical bolt down or vibration isolated attachments. For analysis, models shall be created to structurally model the skid and the effects of the combined masses and reactions of the radiator, engine, alternator, junction box and controls under seismic load conditions. The equations for these structural models must be based on those as found in ASCE 7. A physical review of generator sets must also be performed to ensure that cables are properly restrained from coming into contact with pinch points during a seismic event.

After a combination of successful structural modeling and shake table testing, an open generator set can achieve seismic certification. The equipment must carry product labeling that designates the IBC certification in accordance with Chapter 17 of the IBC Code.

5.2 Pre-Fabricated Engine Generator Set Weather and Sound Enclosures

When combining an IBC certified open generator set with a custom pre-fabricated weather or sound enclosure, or custom sub-base fuel tank, the enclosure and tank must also be IBC certified for seismic and/or wind in order for the entire system to remain IBC certified. The certification for these two components must be based on the maximum weight and physical size that will fit in the pre-fabricated enclosure or onto the sub base tank.

For wind design, pre-fabricated enclosures must be designed in accordance with ASCE 7, Main Wind Force Resisting System Method 2. In general, high wind forces have a greater impact on the structural integrity of a pre-fabricated enclosure than do seismic forces. Therefore, when designing for both wind and seismic, it must be determined which force will have the greater impact on the pre-fabricated enclosure, and then structural modeling can be done in accordance with the worst case. If designing only for seismic, the pre-fabricated enclosure must be designed in accordance with ASCE 7 Chapter 13 or shake table tested in accordance with AC156. For the purposes of seismic design, a pre-fabricated enclosure is considered a non-structural building component and shall be designed using Allowable Stress Design (ASD). The forces at the attachments to the generator set or to the sub-base fuel tank must be calculated and then used during the structural modeling of the generator set skid or fuel tank.

Components attached inside pre-fabricated enclosures must also be addressed. The weights of suspended piping and sound attenuated equipment, lighting fixtures and wall mounted equipment must be factored in to the structural modeling of pre-fabricated enclosures. Additionally, these components must be properly attached to the pre-fabricated enclosure for resistance to the same seismic design force to which the pre-fabricated enclosure is being certified. Where required, the use of seismic control devices such as aircraft cabling or bracing must be used with suspended equipment. Additionally, fasteners used to attach equipment to the pre-fabricated enclosure's structure must be properly analyzed for seismic forces.

When required by code, pre-fabricated enclosures analyzed in accordance with ASCE 7 must carry labeling in accordance with Chapter 17 of the IBC Code.

5.3 Sub-Base Fuel Tanks and Day Tanks

Sub-base fuel tanks and day tanks may be certified through shake table testing or through structural modeling. Sub-base fuel tanks shall be considered non-structural building components and structurally modeled or tested in accordance with Chapter 13 of ASCE 7.

When shake table testing a sub-base fuel tank, the tank should be filled with a fluid such as water in order to replicate the sloshing effect during a seismic event. Shake table testing should be done in accordance with AC156. When a sub-base tank is tested without the associated generator skid and pre-fabricated enclosure attached (if applicable), then a structural model is also required to ensure the tank is capable of handling the additional seismic effects these components will have on the tank. When certifying a tank using structural modeling, special care must be given to the weight and sloshing effects of the fuel. The tank should be certified for a worst-case scenario of a full fuel tank. When certifying a tank that will carry the loads of a generator set and a pre-fabricated enclosure, the structural model must include the forces of these components on the tank.

For the purposes of this recommended practice, a day tank is *any* tank that maintains a supply of fuel through the use of a locally mounted pump, motor, internal float switches and electronic controls module. Because a day tank incorporates components considered flexible, the recommended practice for certification is through shake table testing in accordance with AC156. In lieu of full shake table testing of a day tank, a combination of shake testing the pump, motor and electronic controls module and structural modeling of the tank is an acceptable approach.

5.4 Electronic Controls and Electronic Components

Electronic controls and components are considered flexible apparatus. When required to function after a seismic event in order to not cause the failure of another portion of the system, certification is required through shake table testing in accordance with AC156. If the failure of an electronic component is not critical or will not hinder the overall performance of a generator set system after a seismic event, then only proper seismic attachment to the equipment must be followed. When testing an electronic controller or component in accordance with AC156, the test fixture must replicate the actual attachment of the electronic controller or component to the equipment. Apparatus that are mounted with vibration isolators must be tested on their respective isolation system.

5.5 Electric Starting Systems

An electric starting system for generator engines consists of battery charger, battery, and if the engine has multiple starters, a best battery selector (BBS). Often, the BBS is referred to as a diode coupler in engineering specifications.

Batteries themselves are considered rigid and do not require testing or analysis; however, battery racks, chargers and BBS equipment do require testing or analysis since they are all considered flexible components.

Per ASCE 7-05 13.6.4, batteries on racks shall have wrap-around restraints to ensure that the batteries will not fall from the rack. Spacers shall be used between restraints and cells to prevent damage to cases. Racks shall be evaluated for sufficient lateral load capacity. Battery racks can be certified either through structural modeling or shake table testing. In lieu of using charged batteries during shake table testing, it is acceptable to use dummy masses to replicate the weight of the batteries.

Battery chargers and BBS devices are considered flexible components and therefore require certification through shake table testing in accordance with AC156.

5.6 Transfer Switch and Switchgear

Unless otherwise demonstrated by testing and/or structural analysis transfer switches and switchgear componentry are considered flexible and must be certified by shake table testing in accordance with AC156. Certification can be achieved through complete shake table testing of the cabinetry and the components or through a combination of structural analysis of the cabinetry and shake table testing of components. When shake testing individual components, test fixtures must replicate the method of attachment to the cabinet.

5.7 Engine Combustion Exhaust Silencers and Emission Control Equipment

Silencers and sound attenuating equipment are considered rigid components and do not require special analysis through structural modeling or shake table testing to prove online functionality after a seismic event. However, their attachment to the building structure or pre-fabricated enclosure must be analyzed for the prescribed seismic design forces to ensure the equipment remains moored and does not become a projectile during a seismic event. When necessary, this equipment must be seismically braced. Installation calculations must be reviewed and accepted by a professional engineer.

5.8 Sound Attenuation Products for Cooling and Combustion Air Handling Equipment

Aero-acoustic attenuators shall be analyzed using structural modeling or shake table testing. When structurally modeling, the attenuator housing and attachment supports must be analyzed in accordance with ASCE 7. Pass criteria for the attenuator when modeling shall be no yielding at the attachments or corners and no yielding at the attachment point of the acoustic airfoils within the attenuator case or combining frame. When certifying by shake table testing, the equipment must be in accordance with AC156.

5.9 Vibration and Seismic Control Devices

Seismically designed vibration isolators must be constructed to handle the shear, compression and tension loads imparted by the overturning moments resulting from applying the seismic design force to the center of gravity of the equipment to which they are attached. The manufacturer must prove through analysis or testing that the vibration isolator and its attachment fasteners are capable of withstanding these forces. Additionally, the vibration isolation manufacturer must provide evidence through a seismic calculation package that the isolator and equipment will remain fixed to the building structure in accordance with ASCE 7. These calculations must be supplied by the manufacturer of the isolation system and be reviewed and accepted by a licensed professional engineer. The design of the vibration isolation system must incorporate snubbing devices to limit horizontal direction to .25” or less. The system must also incorporate viscoelastic material between the snubbing device and components to minimize metal to metal impact.

5.10 Load Banks

Although not typically a critical component to the continuing operation of the electrical generating system, load banks may be required by the building owner or engineer of record to remain operational after a seismic event. Load banks can be divided into three categories: remote mounted, radiator core mounted and mounted in the radiator exhaust ductwork.

For each category, shake table testing or a combination of structural modeling and shake table testing is required. When a complete unit is not shake table tested, the core can be structurally modeled to verify its ability to withstand the affects of an earthquake. However, it is necessary to shake table test the electronic controls in accordance with AC-156 in order to verify its functionality after a seismic event.

When attaching a load bank to the radiator core, certification from the radiator manufacturer is required to ensure the extra weight on the radiator core does not affect the seismic qualification of the radiator. In the event the attachment of the load bank to the radiator does not void the certification of the radiator, the attachment method to the radiator must be analyzed to guarantee the load bank is positively fastened and can withstand the forces of the seismic event.

For remote floor mounted installations of a certified load bank, the attachment to the concrete slab or steel base needs to be verified to prove the equipment will not dislodge due to the seismic event.

When mounting a certified load bank in the radiator exhaust ductwork, the installation shall be done in accordance with SMACNA (Sheet Metal and Air Conditioning Contractors' National Association) Seismic Restraint Manual Guidelines for Mechanical Systems.

6. EQUIPMENT LABELING AND CERTIFICATES OF COMPLIANCE

Seismic and/or wind certificates of compliance must be supplied in accordance with the requirements of Chapter 17 of the IBC code. When required, labels must also be affixed to the equipment in accordance with Chapter 17 of the IBC Code.

The certificates of compliance and labels shall include any limitations to the application of the equipment and clearly state the level of certification achieved. For wind loading, these documents shall denote the level of certification through the listing of the wind speed, exposure category and building height for which the equipment was analyzed. For seismic certification, the certification "g-level" should be denoted on the label and certificate of compliance by listing the S_{DS} to which the equipment is capable of withstanding; and any limitations to the overall height in the building for where the equipment can be installed.

7. INSTALLATION DATA

Equipment manufacturers must address basic installation details for seismic and wind installation in their installation manuals and drawings. However, due the vast amount of varying site conditions for projects throughout the United States, the engineer of record or installing contractor should employ the services of an authorized agency to recommend and structurally certify the site specific recommendations for equipment installation.

Per 1707.8 of the IBC 2006, periodic special inspection is required during the anchorage of electrical equipment for emergency or standby power systems in structures assigned to Seismic Design Category C, D, E or F. The special inspector shall be employed by the building owner or the registered design professional in responsible charge acting as the owner's agent per 1704.1 of the IBC.