Grounding & Bonding Standards Hierarchy:

From ANSI/BICSI 002 to the Field Requirement for Belleville Washers

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How ANSI/BICSI 002 → TIA-942 → ANSI/TIA-607 → NEC §110.3(B) → UL 467 → IEEE 837 → ANSI NEMA CC1 → Manufacturer Instructions create a legally enforceable chain requiring Belleville spring washers in data center grounding assemblies

Applicable Standards: ANSI/BICSI 002 | ANSI/TIA-607 | TIA-942 | NFPA 70 (NEC) §110.3(B) | UL 467 | IEEE 837 | ANSI NEMA CC1

Executive Summary

This white paper traces the complete regulatory and standards hierarchy that governs grounding and bonding hardware selection in data center environments, from the top-level planning document (ANSI/BICSI 002) down to the field-level requirement to use Belleville spring washers on aluminum busbars with steel or silicon-bronze fasteners.

The central legal mechanism is NEC §110.3(B), which makes manufacturer installation instructions code-enforceable once equipment carries a UL 467 listing. This single provision transforms what might otherwise be considered optional guidance, including washer type, washer preload, and torque values, into legally binding installation requirements that no inspector or installer may waive.

Key Conclusion
When a UL 467-listed grounding lug is installed on a busbar using hardware with a different coefficient of thermal expansion from the lug and/or busbar material, most commonly steel or silicon-bronze fasteners with aluminum, Belleville (spring-type) washers are not optional. They are required by ANSI NEMA CC1 2018 (R2023) Section 5.5 and by the manufacturer's installation instructions, which are code-enforceable under NEC §110.3(B). Industry practice and Solon Manufacturing's engineering guidance recommend preloading the washer to 60–100% of its flat load, with 80% flat as the ideal installation target.

1. The Standards Hierarchy

Grounding and bonding requirements in data centers flow through a layered hierarchy of standards. Each layer either mandates alignment with the layers below it or incorporates those lower-level requirements by reference. Understanding this hierarchy is essential for determining which requirements are advisory, which are enforceable, and which supersede others.

1.1 ANSI/BICSI 002 — Data Center Design & Implementation

ANSI/BICSI 002, Data Center Design and Implementation Best Practices, is the authoritative top-level planning and design document for data center infrastructure. It addresses site selection, architecture, power, cooling, cabling, and, critically, grounding and bonding systems.

Section 4 of BICSI 002 explicitly mandates that all grounding and bonding designs align with NEC (NFPA 70) and IEEE standards. This is not a reference for general background; it is a design requirement that pulls the entire lower portion of the standards hierarchy into scope for any BICSI 002-compliant facility.

1.2 TIA-942 — Data Center Infrastructure Standard

ANSI/TIA-942, Telecommunications Infrastructure Standard for Data Centers, governs telecommunications and data infrastructure within data centers. TIA-942 incorporates ANSI/TIA-607 for grounding and bonding, meaning all TIA-942-compliant installations are also bound by TIA-607 busbar and bonding conductor requirements.

1.3 ANSI/TIA-607 — Grounding and Bonding for Customer Premises

ANSI/TIA-607, Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises, is the primary telecommunications grounding standard. It specifies:

- Busbar minimum width
- NEMA hole spacing for two-hole lugs
- Material and dimensional requirements for busbars used in telecommunications bonding

These busbar geometry requirements directly govern the maximum outside diameter (OD) of washers used in lug assemblies, as explained in Section 4 of this paper.

1.4 NFPA 70 (NEC) §110.3(B) — The Legal Enforcement Mechanism

Section 110.3(B) of the National Electrical Code (NEC), published by the National Fire Protection Association (NFPA 70), is the pivotal provision that converts manufacturer documentation into legally enforceable code requirements:

> **NEC §110.3(B) — Listed or Labeled Equipment**
> "Listed or labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling."

The practical consequence is significant: once a component carries a UL listing, the manufacturer's published installation instructions, including torque values, washer type, washer preload, and bolt specifications, carry the same legal weight as the code text itself. An installer or inspector may not substitute lower torque values or different washer configurations than those specified.

1.5 UL 467 — Listed Grounding and Bonding Equipment

UL 467, the standard for Grounding and Bonding Equipment, is the listing standard for busbars, lugs, clamps, and similar grounding hardware. Equipment bearing the UL 467 mark has been tested to UL's requirements for electrical performance, mechanical strength, and material compatibility.

The UL 467 listing is the trigger for NEC §110.3(B) enforcement. A lug or busbar that is UL 467 listed carries with it a mandatory obligation: it must be installed exactly as the manufacturer specifies.

1.6 IEEE 837 — Permanent Grounding Connections

IEEE 837, Standard for Qualifying Permanent Connections Used in Substation Grounding, establishes qualification test requirements for permanent grounding connections. It serves as a technical performance benchmark that informs the design requirements referenced by BICSI 002 Section 4 and is cross-referenced in IEEE grounding standards used in data center design.

1.7 ANSI NEMA CC1 — Nominal Torque Values

ANSI NEMA CC1, Electric Power Connections for Substations, provides standardized torque values that many grounding hardware manufacturers incorporate by reference in their installation instructions. Table 4-4 of ANSI NEMA CC1 provides nominal torque values for steel bolts. When a manufacturer's installation instructions state that torque shall conform to ANSI NEMA CC1 Table 4-4, those table values become NEC-enforceable requirements.

2. The Torque Requirement Chain

The following describes how torque requirements flow from the top of the standards hierarchy to a specific field installation.

2.1 How the Chain Operates

Step 1: ANSI/BICSI 002 Section 4 mandates alignment with NEC and IEEE. This brings NEC §110.3(B) into mandatory scope for the facility design.

Step 2: The installer selects a UL 467-listed lug (e.g., Burndy YAZ1C2N). Because it is UL 467 listed, NEC §110.3(B) immediately applies.

Step 3: The manufacturer's installation instruction specifies torque by bolt size and lug type, referencing ANSI NEMA CC1 Table 4-4 for steel bolt torque values.

Step 4: ANSI NEMA CC1 Table 4-4 provides the specific torque values. These values, now incorporated by reference through the manufacturer's instructions and enforced by NEC §110.3(B), are legally mandatory.

2.2 ANSI NEMA CC1 Table 4-4 — Steel Bolt Nominal Torque Values

The following torque values from ANSI NEMA CC1 Table 4-4 apply to steel bolts used in grounding lug assemblies. Where a manufacturer's installation instruction references this table, these values are NEC-enforceable:

Bolt Size	Torque (lb-ft)
1/4"	7
5/16"	15
3/8"	20
1/2"	40
5/8"	55
3/4"	87

Note: For silicon bronze (SB) hardware, 40 lb-ft at 1/2" bolt is the applicable value from this table.

Enforcement Note
The complete torque chain is governed by NEC §110.3(B). No inspector or installer may substitute a lower torque value than what the lug manufacturer specifies. Deviation constitutes a code violation.

3. When Are Belleville Washers Required?

The requirement for Belleville (spring-type) washers arises from the physics of dissimilar metal connections and aluminum's material behavior under mechanical load, and it is codified through the same NEC §110.3(B) enforcement chain described above.

3.1 The Technical Basis for Belleville Washers

Grounding assemblies in data centers typically join aluminum busbars to copper conductors using steel or silicon-bronze fasteners. This combination creates two problems that Belleville washers are specifically designed to address:

Differential Thermal Expansion: Aluminum expands and contracts at approximately twice the rate of steel with changes in temperature. Each thermal cycle loosens the joint, increasing resistance and reducing the effectiveness of the grounding path. A Belleville washer acts as a spring that maintains constant clamp load through these dimensional changes.

Aluminum Creep: Aluminum undergoes cold flow (creep) under sustained mechanical load. The material slowly deforms over time, reducing bolt preload. Without a compensating spring, the connection will loosen over years of service. A Belleville washer continuously compensates for this loss of material thickness.

These failure modes are well-documented in IEEE grounding literature and are the reason why ANSI NEMA CC1 2018 (R2023) Section 5.5 specifically requires Belleville washers when hardware materials have a different coefficient of thermal expansion from the lug and/or busbar material, of which steel or silicon-bronze fasteners with aluminum components is the most common data center example.

3.2 The Standards Trigger: When Belleville Washers Are Mandatory

Belleville washers are required when all of the following conditions are present:

- The fastener hardware has a different coefficient of thermal expansion (CTE) from the lug and/or busbar material. This is the fundamental trigger under ANSI NEMA CC1 2018 (R2023) Section 5.5
- The lug is UL 467 listed
- The manufacturer's installation instructions (rendered enforceable by NEC §110.3(B)) reference ANSI NEMA CC1 Section 5.5 or otherwise specify Belleville washers

> **Practical Note — CTE Mismatch as the Trigger**
> The requirement is not limited to aluminum busbars with steel hardware. Any combination where the fastener, lug, and busbar materials have meaningfully different coefficients of thermal expansion should be evaluated for Belleville washer use. Common examples include: steel bolts with aluminum busbars (most frequent in data center grounding); silicon-bronze hardware with aluminum; and stainless steel fasteners with copper busbars in some configurations. When in doubt, consult the manufacturer's installation instructions for the specific hardware combination, and refer to ANSI NEMA CC1 2018 (R2023) Section 5.5.

This encompasses the vast majority of data center grounding busbar assemblies. Manufacturers that reference ANSI NEMA CC1 in their installation instructions, and are therefore subject to its Section 5.5 requirements.

4. Belleville Washer Requirements

Where Belleville washers are required, the following specifications apply. The requirement to use Belleville washers derives from ANSI NEMA CC1 2018 (R2023) Section 5.5, incorporated by reference through manufacturer installation instructions and enforced under NEC §110.3(B).

4.1 Preload Specification

Industry practice and Solon Manufacturing's engineering guidance, widely adopted by grounding hardware manufacturers, recommend the following preload targets for Belleville washers used in grounding assemblies:

- Preload range: 60% to 100% of the washer's flat load
- Ideal installation preload: 80% of flat load

"Flat load" is the manufacturer-specified force at which the Belleville washer is fully flattened. Preloading to 80% of flat load provides the optimal balance between spring travel remaining (to compensate for future thermal cycling and creep) and initial clamp force. These figures represent Solon's published engineering recommendations and represent widely accepted industry best practice; they are not stated verbatim in ANSI NEMA CC1 Section 5.5. Always verify preload requirements against the specific washer manufacturer's published data and the lug manufacturer's installation instructions.

> **Practical Guidance**
> Preload is achieved through torque. The torque values in Section 2.2 are designed to achieve the specified preload range when Belleville washers are used with the corresponding bolt size. Do not substitute a lower torque value.

4.2 Belleville Washer and Flat Washer Selection by Bolt Size

The following table provides Solon Manufacturing part numbers for both Belleville washers and ideal flat washers corresponding to each bolt size, along with associated preload and torque values. These represent Solon's published hardware guidance consistent with manufacturer installation instructions for UL 467-listed lugs:

Nominal Size	Size (in)	Preload (lb)	Torque (lb-ft)	Solon Belleville
1/4"	0.25	1,440	6	4961
5/16"	0.313	2,112	11	51280
3/8"	0.375	3,200	20	61498
1/2"	0.5	4,800	40	815112
5/8"	0.625	5,760	60	10H131

Source: Solon Manufacturing hardware reference. Torque values consistent with ANSI NEMA CC1 Table 4-4 (Steel Bolts). Verify part numbers and preload figures against current Solon and lug manufacturer documentation.

4.3 Practical Note — When to Apply the Belleville Washer Requirement

Although the most common application in data center grounding is steel or silicon-bronze fasteners with aluminum busbars, the underlying engineering rationale, and the trigger under ANSI NEMA CC1 2018 (R2023) Section 5.5, is differential thermal expansion between dissimilar materials, not aluminum specifically. Designers and installers should evaluate the need for Belleville washers whenever the coefficient of thermal expansion (CTE) of the fastener hardware differs meaningfully from that of the lug and/or busbar material.

Practical Application Note
Belleville washers should be considered any time the bolt, lug, and busbar assembly incorporates materials with different coefficients of thermal expansion. This includes, but is not limited to: steel bolts with aluminum busbars (most common); silicon-bronze hardware with aluminum; stainless steel fasteners in copper busbar assemblies; and any mixed-metal assembly subject to significant thermal cycling. The manufacturer's installation instructions for the specific UL 467-listed lug are always the authoritative field reference.

5. Summary: The Complete Chain of Authority

The following summarizes how each standard in the hierarchy contributes to the field requirement for Belleville washers:

Standard/Code	Role in the Belleville Washer Requirement Chain
ANSI/BICSI 002 §4	Mandates alignment with NEC and IEEE; brings §110.3(B) into mandatory scope for data center designs
TIA-942	Incorporates TIA-607; governs telecommunications infrastructure and busbar geometry
ANSI/TIA-607	Specifies 4" minimum busbar width and 1-3/4" NEMA hole spacing; establishes busbar geometry constraints for hardware selection
NFPA 70 (NEC) §110.3(B)	The legal linchpin: makes manufacturer installation instructions code-enforceable for all UL-listed equipment
UL 467	The listing that triggers §110.3(B); any listed lug or busbar must be installed per manufacturer instructions
IEEE 837	Technical performance standard for permanent grounding connections; informs design requirements in BICSI 002 §4
ANSI NEMA CC1 §5.5	Requires Belleville washers when hardware has a different CTE from the lug and/or busbar; the fundamental standards trigger for Belleville washer use
ANSI NEMA CC1 Table 4-4	Provides NEC-enforceable torque values for steel bolts by size; incorporated by reference in manufacturer instructions
Solon Manufacturing Engineering Guidance	Source of the 60–100% flat load preload range (80% ideal); industry best practice widely adopted by grounding hardware manufacturers; not stated verbatim in ANSI NEMA CC1
Manufacturer Installation Instruction	The authoritative field reference; specifies exact torque, washer type, and hardware for the specific lug, enforceable as code via §110.3(B)

6. References

The following standards and documents govern the requirements described in this white paper. Consult the current published edition of each document; editions and amendment dates may differ from those cited in any given project specification.

[1] ANSI/BICSI 002, Data Center Design and Implementation Best Practices. Building Industry Consulting Service International (BICSI). See especially Section 4 (Grounding and Bonding).

[2] ANSI/TIA-942, Telecommunications Infrastructure Standard for Data Centers. Telecommunications Industry Association (TIA).

[3] ANSI/TIA-607, Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises. Telecommunications Industry Association (TIA).

[4] NFPA 70, National Electrical Code (NEC), Section 110.3(B): Listed or Labeled Equipment. National Fire Protection Association (NFPA).

[5] UL 467, Standard for Grounding and Bonding Equipment. UL LLC (Underwriters Laboratories).

[6] IEEE 837, Standard for Qualifying Permanent Connections Used in Substation Grounding. Institute of Electrical and Electronics Engineers (IEEE).

[7] ANSI NEMA CC1 2018 (R2023), Electric Power Connections for Substations. National Electrical Manufacturers Association (NEMA). See especially Section 5.5 (Belleville washers) and Table 4-4 (Steel Bolt Nominal Torque Values).

[8] Solon Manufacturing Company, Belleville Disc Spring Engineering Reference. Solon, Ohio. Engineering guidance on preload ranges (60–100% flat load; 80% flat ideal), spring selection, and hardware part numbers for grounding applications. Consult current Solon technical documentation for updated part numbers and specifications.

[9] Manufacturer Installation Instructions for UL 467-listed grounding lugs (e.g., Burndy YAZ1C2N, YA36A3, YA34A3). Consult the current published instruction sheet for the specific lug model and hardware combination being installed.

Disclaimer

This white paper is provided for technical guidance purposes only. It does not constitute legal, engineering, or code-compliance advice. Always consult the current published editions of all referenced standards, the manufacturer's installation instructions for the specific equipment being installed, and a qualified licensed engineer or inspector for project-specific compliance determinations. Standards are revised periodically; edition currency must be verified.

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