BELLEVILLE WASHERS IMPROVE RELIABILITY FOR MISSION-CRITICAL GROUNDING & BONDING

DATA CENTERS | TELECOMMUNICATIONS ROOMS | SUBSTATIONS

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The Department of Energy (DOE) forecasts that demand for electricity will increase 15 to 20 percent over the next decade. Much of this growth will be driven by construction and deployment of data centers. Artificial Intelligence (AI) uses significantly more power than traditional computing and this will account for nine percent of total burden as compared to four percent today.

As businesses become reliant on AI, the requirement for reliability also increases. The increase in power raises safety concerns as well. Grounding and bonding of equipment is core to the infrastructure of these critical systems. Each element must comply with multiple standards and best practices to optimize performance. Compliance with all the standards is that joint resistance is kept below a maximum threshold. Put another way, if joint resistance is higher than acceptable value, then the joint has failed. It is well established that joint resistance is correlated to surface stress and hence, bolt preload. There are multiple factors where using Solon Belleville washers combat the loss of preload:

1. Differential Thermal Expansion (DTE) is prevalent in grounding and bonding lugs because the joint materials (aluminum or copper) have a thermal expansion coefficient that is much greater than the coefficient for the fasteners (steel or stainless). When the joint experiences a variation in temperature, the load on the fastener changes. This is why the NECA/BICSI 607 Standard states, "Where fastening hardware is subject to thermal cycling, the lock washer should be substituted with flat washers and a cupped spring washer (Belleville washer)…" Even small thermal cycles can lead to large fluctuations I preload. For example, for a common bolted ground lug, the bolt stretch might be .0005 in but the DTE could be .0002 in. with a 50F temperature fluctuation. This would result in a 40% preload variation. For high voltage connections, the DTE could be much greater. Addition of a Belleville washer might change the effective stretch by a factor of 10X to 20X.

Bellevilles installed on busbar and terminal lug

2. Embedment relaxation occurs because microscopic high spots on the threads and joint surfaces tend to relax over time due to highly concentrated stresses. This is actually desirable for electrical connections because yielding reduces joint resistance and this is one reason ductile materials are used in bonding and grounding. However, this will also lead to loss of preload. Adding Bellevilles nearly eliminates this loss of load.

3. Belleville washers distribute load more evenly than cases where the stresses are concentrated at the bolt holes. This leads to improved reliability and performance.

Bellevilles installed on bolted terminals

4. Vibration causes self-loosening in fasteners. Standard TR-NWT-001075 requires that joints pass numerous vibration and earthquake tests. *Solon Belleville washers prevent self-loosening due to vibration* by reducing the change in load during each cycle.

5. Catastrophic failure of fastening system components led to the enactment of the Fastener Quality Act. The Congressional Subcommittee on Oversight and Investigations found adherence to standards to be intermittent, particularly with overseas suppliers. While Belleville washers are not specifically covered in the FQA, the justification for the act applies. The stresses in Belleville washers can be substantially higher than those components covered by FQA. This makes it even more critical to *use Bellevilles manufactured in the USA*, using domestic steels.

Choosing the correct Belleville is critical. Solon's *product-selection calculator* optimizes bolted electrical connections.

Resources

Aluminum Company of America. 1957. *Alcoa Aluminum Bus Conductor Handbook*.

Bickford, John. *An Introduction to the Design and Behavior of Bolted Joints, Revised and Expanded*. Routledge, 11 May 2018.

Braunovic, M. Effect of Connection Design on the Contact Resistance of High Power Overlapping Bolted Joints. *IEEE Transactions on Components and Packaging Technologies*, vol. 25, no. 4, Dec. 2002, pp. 642–650, https://doi.org/10.1109/tcapt.2003.809108. Accessed 27 July 2022.

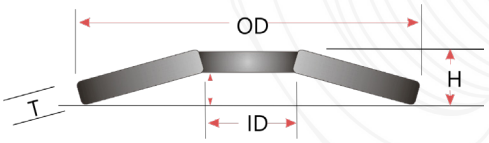
Compliance FAQs: Fastener Quality Act (FQA) | NIST. (2024, May 2). NIST. https://www.nist.gov/standardsgov/compliance-faqs-fastener-quality-act-fqa

Davet, George. How to Maintain Bolt Preload on Electrical Connections. Solonmfg.com, 2024, www.solonmfg.com/maintain-bolt-preload-on-electrical-connections. Accessed 22 Nov. 2024.

Lehnhoff, T. F., et al. Member Stiffness and Contact Pressure Distribution of Bolted Joints. *Journal of Mechanical Design*, vol. 116, no. 2, 1 June 1994, pp. 550–557, https://doi.org/10.1115/1.2919413. Accessed 8 Dec. 2021.

At Solon Manufacturing Co., an industrial bolting solutions provider, we make bolting better® through engineering and manufacturing Belleville springs and washer products that have solved bolting application challenges for OEMs and distributors in over sixty countries.

Our knowledgeable engineering team is available to provide application support and product recommendations. We offer a variety of application-specific Belleville spring washer selection tools that can assist designers in selecting the proper Belleville spring for their requirements. Learn more about the use of our products in the electrical industry:



Typical Belleville Diagram

- ***Product Selection Tool:*** *Bolted Electrical Connections Calculator*
- ***Case study:*** *Solon Belleville Springs Maintain Bolt Preload on Electrical Connections*
- ***Case study:*** *Solon Flange Washers Solve Gasketed Joint Leaks in Nuclear Power Station Heat Exchangers*
- ***Technical White Paper:*** *Maintain Bolt Preload on Electrical Connections Using Belleville Springs*

For additional resources and information, visit www.solonmfg.com.

ABOUT THE AUTHOR

George P. Davet, BSME, MBA is President, Chief Engineer and Owner at Solon Manufacturing Company and has written and published numerous articles on the use and application of Belleville spring washers. To learn more about Bellevilles and Solon Manufacturing, visit www.solonmfg.com, for technical resources such as case studies, white papers, product selection tools and videos.

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