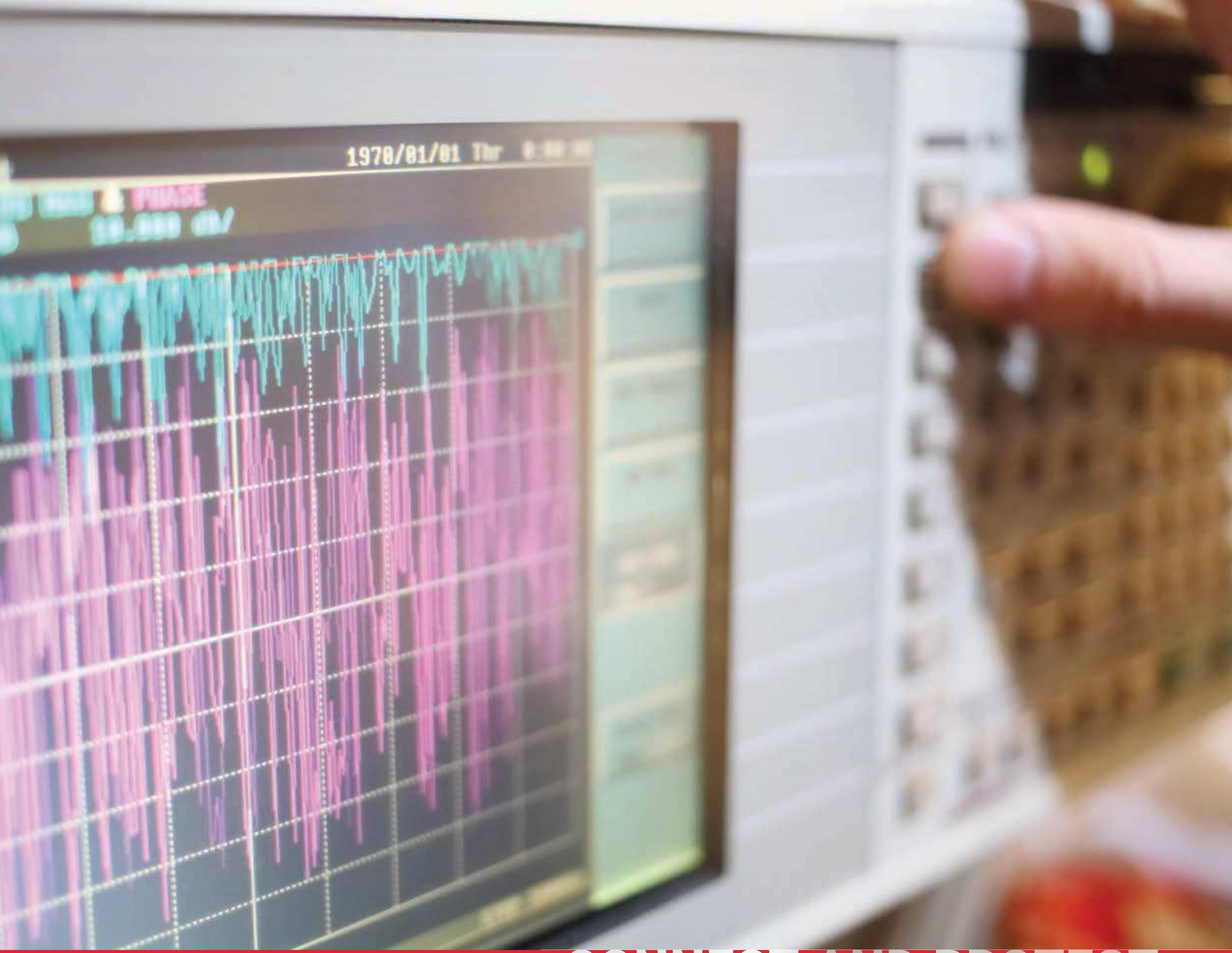

CONNECT AND PROTECT

nVent ERIFLEX Technical Note

Behavior of nVent ERIFLEX flexible conductors and earthing braids under vibrations as seen in electric mobility applications

nVent
ERIFLEX

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Key Words
e-mobility, vibrations, electric vehicle, earthing, bonding, grounding, battery, battery pack, fuel cell

EXECUTIVE SUMMARY

The purpose of this document is to review the performance of nVent ERIFLEX solutions for electric mobility namely, nVent ERIFLEX insulated power conductors and nVent ERIFLEX earthing and bonding conductors, under vibrations. Testing is carried out using the test schedule detailed in ISO 6469-1 for 12 hours in each direction and with a max acceleration of 2.64g for frequencies ranging from 5 to 200Hz. No damage on the nVent ERIFLEX tested products was visible therefore validating the use of nVent ERIFLEX solutions in the field of electric mobility.

INTRODUCTION AND SCOPE

Electric mobility entails distributing electrical power between the various electrical components (battery pack, converter, controller, motor, on-board charger) of a vehicle. It also requires proper earthing and bonding of all metal parts in order to maintain equipotentiality. Power as well as earthing and bonding is typically done using either automotive grade flexible busbars or with cable and lug assemblies (wire harnessing). Durability of such components, and therefore, the reliability of a vehicle as a whole depends, among other factors, on the ability to withstand sustained vibrations without failure. Various electric-mobility related standards include test methods for the assessment of the vibration withstand capabilities of components.

STANDARDS REVIEW

One of the higher-level standard that can be looked at is UL2580 [1], a safety standard which covers the topic of Batteries for Use In Electric Vehicles. Referenced in this standard are two vibration related standards which are applicable to e-mobility. These are:

- SAE J2380: Vibration Testing of Electric Vehicle Batteries [2]
- ISO 6469-1: Electrically Propelled Road Vehicles – Safety Specifications – Part 1: On-Board Rechargeable Energy Storage System (RESS) [3]

Additionally, standards such as UN 38.3 Requirements for the transportation of Lithium Batteries [4], ISO 12405-4:2018: Electrically propelled road vehicles —Test specification for lithium-ion traction battery packs and systems — Part 4: Performance testing (formerly ISO 12405-1:2011) [5] or IEC 62660-2:2018: Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 2: Reliability and abuse testing [6] also directly or indirectly mention vibrations. Kjell et al. in 2013 [7], Ruiz et al. in 2017 [8] and Berg et al. in 2020 [9] have carried a thorough review of these standards. IEC 62660-2:2018 is applicable to secondary battery cells (rechargeable lithium cells) and is also referenced in UL2580 as a reference standard for the testing of Secondary lithium Cells. It does not deal with vibrations on the broader vehicle or battery pack as opposed to SAE J2380 or ISO 6469-1. ISO 12405-4:2018 points to ISO 6469-1 as follow: "A battery pack or system to be tested according to this document shall fulfil the following requirements: The electrical safety design and safety requirements shall comply with the requirements given in ISO 6469-1".

From a scope standpoint, UL 2580 states that "this document provides a test procedure for characterizing the effect of long-term, road-induced vibration and shock on the performance and service life of electric vehicle batteries. (...) this procedure correspond to approximately 100 000 miles of usage" (161 000 km). It provides both a standard test schedule and an alternative time compressed schedule. The scope of ISO 6469-1 states that "this document specifies safety requirements for rechargeable energy storage systems (RESS) of electrically propelled road vehicles for the protection of persons.". No equivalent miles of usage is mentioned.

A comparison of UL 2580 and ISO 6469-1 is shown in table 1. Both standards offer a similar test schedule with with ISO 6469-1 being more demanding in terms of maximum acceleration. It is therefore this standard that has been selected for vibration testing of nVent ERIFLEX flexible conductors and earthing braids

Standard	Total Duration (hours)	Frequency Range (Hz)	Acceleration (m/s2 @ RMS) for Z, X, Y dir.
UL 2580	38.11*	10-190	1.9, 1.5, 1.5*
ISO 6469-1	36	5-200	2.64, 2.34, 2.51

*maximum for alternative (time-compressed) schedule

Table 1 - Vibration Test Profiles according to UL 2580 and ISO 6469-1

NVENT ERIFLEX SOLUTIONS FOR ELECTRIC MOBILITY

Two types of nVent ERIFLEX insulated power conductors and two types nVent ERIFLEX earthing and bonding conductors can be used in electric mobility applications.

Electrical power can be distributed using:

- nVent ERIFLEX Flexibar Advanced
- nVent ERIFLEX IBSB Advanced

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The nVent ERIFLEX Flexibar Advanced is an insulated flexible busbar made of 1 mm thick tin plated copper laminates stacked together. The nVent ERIFLEX IBSB Advanced is a prefabricated insulated flexible braid composed of tin-plated wires. Both conductors feature nVent's halogen-free, low smoke, flame retardant insulation. This insulation is rated at 115°C and is considered a reinforced insulation per IEC and UL, therefore allowing for weight-saving and very compact assemblies. Both solutions comply to various IEC, UL or market specific (marine, rolling stock) standards. Figure 1 shows both nVent ERIFLEX Flexibar Advanced on the left and nVent ERIFLEX IBSB Advanced on the right.

Figure 1 – nVent ERIFLEX Flexibar and IBSB Advanced Power Conductors (left to right)

Regarding earthing and bonding, the following two type of braids can be utilized in electric mobility:

- nVent ERIFLEX MBJ
- nVent ERIFLEX CPI

The nVent ERIFLEX MBJ is a prefabricated earthing braid made of tin-coated copper strands and manufactured in a similar manner to the nVent ERIFLEX IBSB Advanced mentioned earlier (minus the insulation). The nVent ERIFLEX CPI is a prefabricated earthing braid made of 316L copper strands. Both solutions are certified to IEC, UL and market specific standards. Figure 2 shows both the nVent ERIFLEX CPI on the left and thenVent ERIFLEX MBJ on the right.

Figure 2 – nVent ERIFLEX CPI and MBJ Earthing Braids (left to right)

VIBRATION TESTING OF NVENT ERIFLEX SOLUTIONS

A third-party laboratory accredited to ISO/IEC 17025: TESTING AND CALIBRATION LABORATORIES was used to perform this testing. Here below are pictures of the various components installed on the test bench. The components are fastened to the vibration table using nVent ERIFLEX ISO-TP metric insulators. Figure 3 shows two pieces of nVent ERIFLEX CPI braids in the lower left corner, three pieces of nVent ERIFLEX MBJ braids in the lower right corner and a piece of nVent ERIFLEX Flexibar at the top.

Figure 3 – nVent ERIFLEX Flexibar Advanced, nVent ERIFLEX MBJ, nVent ERIFLEX CPI (clockwise from top)

Additionally, samples of nVent ERIFLEX MBJ (top) and nVent ERIFLEX CPI (bottom) were fastened between a fixed table and the vibration itself as show in figure 4.

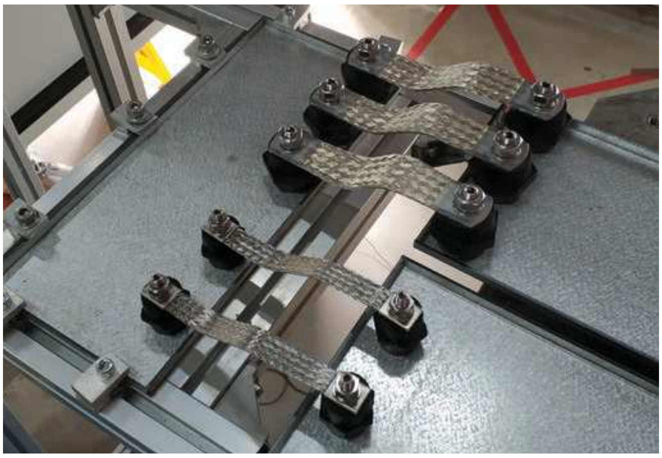

Figure 4 – nVent ERIFLEX MBJ (Top) and nVent ERIFLEX CPI (Bottom)

Vibration testing was carried out in the vertical direction Z, longitudinal direction X and transverse direction Y for a total duration of 36 hours as defined in ISO 6469-1.

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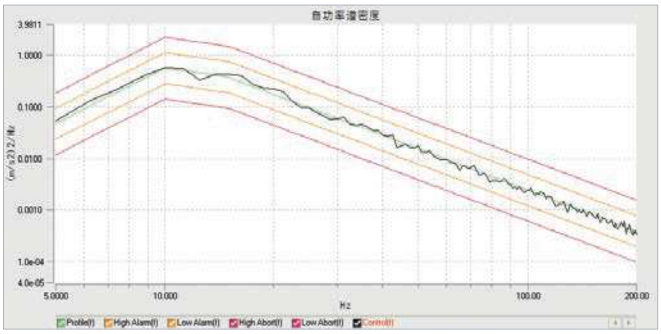

Figure 5 – Vibration Profile (Z-direction)

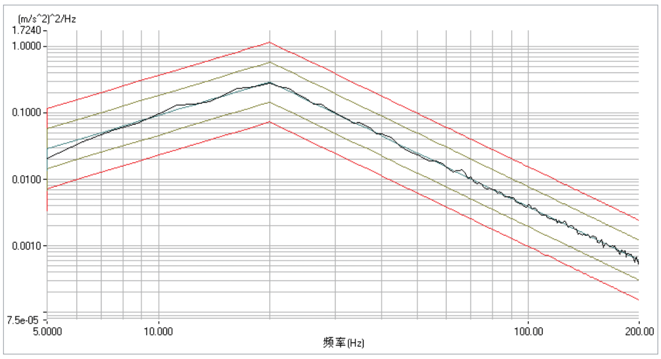

Figure 6 – Vibration Profile (X-direction)

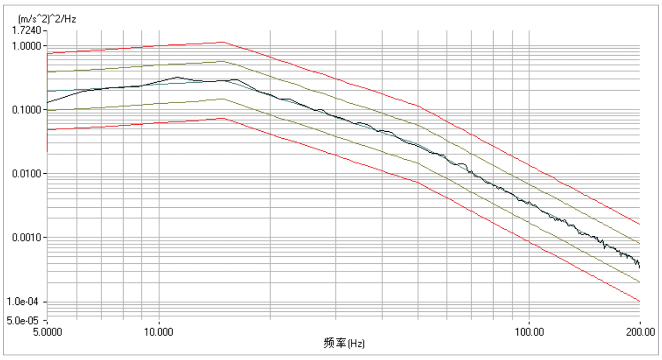

Figure 7 – Vibration Profile (Y-direction)

After these 36 hours the samples were removed and analyzed by the laboratory. The following photos show the samples after testing as well as close-up shots of the terminations for each of the samples. No visible damage was found on the strands (nVent ERIFLEX MBJ and CPI) or copper laminates and insulation (nVent ERIFLEX Flexibar Advanced).

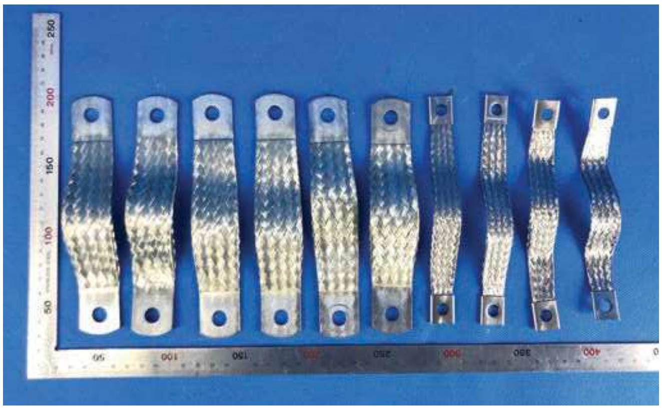

Figure 8 – nVent ERIFLEX MBJ and CPI braids after testing

Figure 9 – nVent ERIFLEX Flexibar Advanced after testing

Figure 10 – Close-up shot of the nVent ERIFLEX MBJ termination after vibration testing.

Figure 11 – Close-up shot of the nVent ERIFLEX CPI termination after vibration testing.

Figure 12 – Close-up shot of the nVent ERIFLEX Flexibar Advanced termination after vibration testing.

CONCLUSION AND COMPARISON WITH OTHER STANDS

As shown in the previous section, no damage was found to be visible on the nVent ERIFLEX tested products which leads to nVent ERIFLEX solutions being compatible for use in electric mobility systems designed against ISO 6469-1 or UL 2580 by extension.

Table 2 hereafter compares the requirements of ISO6469-1 with that of other standards in other vertical markets namely:

- IEC 61373:2010: Railway applications – Rolling stock equipment – Shock and vibration tests (Section 8 - functional random vibration tests) (Section 9 - simulated long-life testing at increased random vibration levels) [9]
- BV Marine Rules (Part C, Chapter 3, Section 6) [10]

Standard	Total Duration (hours)	Frequency Range (Hz)	Acceleration (m/s2 @ RMS) for Z, X, Y dir.
ISO 6469-1	36	5-200	2.64, 2.34, 2.51
IEC 61373 Section 8 – Class 1A	0.5 minimum	5-150*	0.75, 0.5, 0.37
IEC 61373 Section 9 – Class 1A	15	5-150*	4.25, 2.83, 2.09
BV Rules	1.5 minimum	2-100Hz	0.7

*for mass <500kg

Table 2 - Vibration Test Profiles for Various Applications

REFERENCES

[1] UL2580. ANSI/CAN/UL/ULC Standard for Batteries for Use In Electric Vehicles (2020)

[2] ISO 6469-1. Electrically propelled road vehicles — Safety specifications — Part 1: Rechargeable energy storage system (RESS) (2019)

[3] SAE J2380. Vibration Testing of Electric Vehicle Batteries (2013)

[4] UN 38.3, UN Transportation Testing for Lithium Cells and Batteries

[5] ISO 12405-4. Electrically propelled road vehicles —Test specification for lithium-ion traction battery packs and systems — Part 4: Performance testing (2018)

[6] IEC 62660-2. Secondary Lithium-Ion Cells For The Propulsion Of Electric Road Vehicles - Part 2: Reliability And Abuse Testing (2018)

[7] Kjell, G. and Jenny Lang. “Comparing different vibration tests proposed for li-ion batteries with vibration measurement in an electric vehicle.” 2013 World Electric Vehicle Symposium and Exhibition (EVS27) (2013): 1-11.

[8] Ruíz, V. et al. “A review of international abuse testing standards and regulations for lithium ion batteries in electric and hybrid electric vehicles.” Renewable & Sustainable Energy Reviews 81 (2018): 1427-1452.

[9] Berg, P. et al. “Durability of lithium-ion 18650 cells under random vibration load with respect to the inner cell design.” Journal of energy storage 31 (2020): 101499.

[10] IEC 61373. Railway applications - Rolling stock equipment - Shock and vibration tests (2010)

[11] Bureau Veritas Rules for the Classification of Steel Ships, PART C – Machinery, Electricity, Automation and Fire Protection (2018)

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