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Riding the Rails - Cabinet Design Considerations to Meet AREMA & CENELEC Rail Standards

Railway continues to be a highly viable form of mass transit and freight transport, with major infrastructure updates and high speed lines targeted for development over the coming years. Already, enhancements to the existing railway systems now incorporate tremendous levels of offsite control, remote access and remote monitoring via electronic systems specifically designed for this industry.

But housing these electronics—both on the train and on the wayside of the tracks—requires an enclosure that can withstand the shock and, specifically on board the train, the unending levels of vibration of this rugged environment. (Figure 1).

FIGURE 1: *Today's railway racks need to optimize space as much as the electronic components themselves.*

The North American (AREMA) and European (CENELEC) rail specification standards for shock and vibration exist to ensure that electronics and enclosures can withstand the ongoing impact of a railway car barreling down the tracks. Both incorporate key test requirements for shock and vibration.

The AREMA test, based on lab experience, is the more difficult test to pass because of the vibration testing. Shock requirements are 10 g for a 11 ms pulse in the x, y and z-axis, three times in each direction. While moderately severe, this would not typically cause problems for a robustly designed rack.

But the vibration testing is done in the form of a sine sweep through a frequency range of 10 Hz to 200 Hz, with a peak acceleration of 1.5 g. Each sweep takes 12 minutes and must be completed 20 times for a total of four hours per axis (x, y, z). Using a sine sweep means that the rack will have to sit within the natural frequency band of the rack for a significant amount of time (approximately 30 seconds), which proves to be quite severe.

The shock portion of CENELEC test requires a shock input of 30 m/s^2 for 30 ms in the vertical direction as well as in the transverse direction and a shock input of 50 m/s^2 for 30 ms in the longitudinal direction. This translates to approximately 3 g, 3 g and 5 g, respectively.

The vibration testing is a little bit more difficult to define, and is intended to simulate random vibration. Conducted over a frequency range of 50 Hz to 150 Hz for 5 hours in each axis, this is an intense vibration test. The test inputs are defined as ratios of maximum and minimum accelerations to the frequency input.

When designing a rack to meet these rail specifications, it's important to consider the potential points of weakness during the 15 hours of endurance vibration testing across a full spectrum, which will most likely include the natural frequency of your enclosure.

The bolt-down points, weld locations and material types must be considered in addition to strengthening the shear support within the weakest axis of the enclosure. Even the type of hardware used to hold components together should be evaluated.

Both standards place especially high emphasis on vibration requirements with severe endurance tests, making vibration isolators a stable, yet highly cumbersome, attribute of many a rugged railway rack. But these workhorses of rugged design bring with them additional challenges, as systems grow in density without accommodation for added space within a mass transportation environment. As system complexity grows, available space does not, making it imperative for a designer to maximize every inch of an existing area.

No longer an isolated incident

In the past, it has been a difficult proposition to pass an enclosure through the AREMA and CENELEC test specifications without the use of resilient mounts or shock and vibration isolators. But recent design developments have enabled racks to meet the needed requirements of these industry standards.

Given the high density of systems being employed in modern railway systems, a rack that doesn't require vibration isolators will free up a tremendous amount of real estate, making way for the increasing electronics being placed in railway environments. Dimensionally, isolators can add anywhere from 2.5" to 6" to the height of the rack. This space can be critical during an install, specifically where there might be height restrictions due to existing equipment installed above the designated space.

There are other advantages to not using isolators, mainly cost reduction and a simplified design process. Long term, the cost of isolators can be crucial to saving money on a project, but also has impacts on the short term. An extra layer of design and specification is removed from the process when the isolators don't have to be included in the size specifications, especially at the assembly and installation levels.

With the isolator no longer a concern, they don't have to be accounted for the rack's bolting pattern or how it would work with the location where the frame will be installed.   This is especially true if there is a pre-determined footprint that must be met, as is often the case.

Shaking up Rack Design

The design team at Optima Stantron was recently tasked with developing a rail-based rack system to house control equipment on board trains intended for public transportation.

Utilizing Elma's standard M1 series welded aluminum platform, the engineers set out to develop a rack that would pass the CENELEC and AREMA standard's testing without the assistance of the shock and vibration damping typically needed for this type of application. Aluminum extrusions, when constructed together properly, can form quite robust structures that have an excellent strength-to-weight ratio. (Figure 2)

Option 1

Option 2

FIGURE 2: Rigorous testing of railway racks ensure adherence to CENELEC & AREMA specification.

Initially, welded aluminum gussets were added in each of the bottom four corners of the frame, parallel to the floor. Additional gussets were then added perpendicular to the floor due to discoveries made during testing about the amount of movement and stress occurring in the front-to-rear direction. The issue with this axis was the depth of the rack. It was only around 18” deep which resulted in a significant reaction to the vibration testing.

Not all improvements require dynamic engineering abilities. Sometimes, the KISS (keep it simple, silly!) principle works just as well, as in the case of the hardware issues from this design process. The nuts and bolts were vibrating loose without the use of a thread locker like Loc-tite. But by simply riveting all of the parts together, from the cross braces and distribution plate to the front-to-rear stiffeners and vertical mounting rails, all loosening of the hardware across the rack was eliminated. Problem solved.

Once reinforced, the outer portion of the frame saw some additional bowing at the bottom and whipping at the top, due to the initial location of the bolt down points a few inches inboard. To solve this problem, a distribution plate was employed that dispersed the force around the entire bottom edge of the frame from the four bolt-down points.

Touted as one of the more important discoveries during the design and test process, this plate gave the frame the final stability needed to endure the severe vibration requirements to come from the CENELEC and AREMA test specifications, sans vibration isolators.

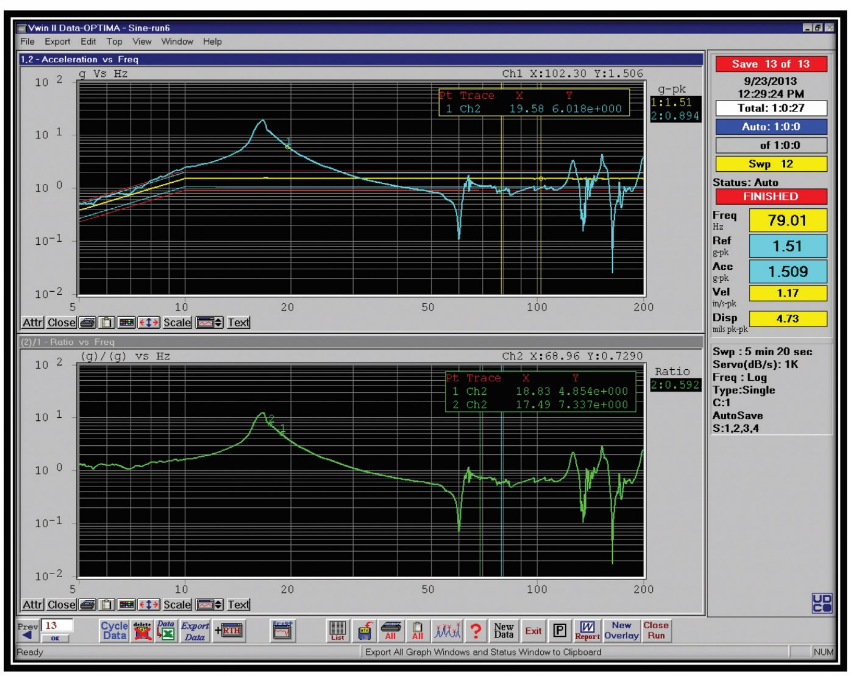

Figure 3 – *AREMA profile, sinusoidal vibration, transverse direction (actual passing test results).*

Starting with a rack that meets the railway industry standards, gives system engineers a leg up in designing a system to withstand severe shock and vibration. Knowing the rack will endure allows them to focus on the electronics being placed within the unit to ensure transmitted forces will not cause damage. For example, there might be a case where the top of the rack sees a significant force during a vibration incident, so the equipment installed would need to be able to handle that, just as the rack is able.

With considerable design and methodology experience, a thorough understanding of the project's requirements, and a lot of trials and testing, it is possible to successfully design isolator-free racks for electronic equipment that must meet the rigorous design specifications defined for the rail industry by AREMA and CENELEC.