

## Seismic Certification of IT Liquid Immersion Cooling Systems

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### White Paper

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In Collaboration with METaseismic, Hypertec and Submer



# Enabling Seismic Certification for Liquid Immersion Cooling in AI Data Centers

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## Introduction

The rapid advancement of Artificial Intelligence (AI) is fundamentally reshaping data center infrastructure, driving an urgent demand for increasingly high-performance and resilient information technology (IT) equipment.

Within this evolving landscape, liquid immersion cooling has emerged as a critical thermal management solution for achieving unprecedented computing densities and supporting high-performance workloads. However, a fundamental question persists regarding the operational resilience of these complex systems, specifically how submerged IT equipment and the coolant fluid maintain integrity and functionality when subjected to significant mechanical shock and persistent vibration.



Fig. 1 – Observed seismic damages in data centers [1]

Extreme seismic events can significantly disrupt data centers, leading to damage and power outages in server units, as documented in ref. [1] (Fig. 1). The global impact of seismic hazards is substantial, affecting approximately 30% of the world's population, with high-activity zones shown in Fig. 2 [2]. The consequences of seismic damage can also extend far beyond the epicenter, impacting widespread communities.

The seismic problem in the IT industry is well recognized, with numerous numerical and experimental studies conducted on air-cooled IT equipment. For server rack systems, a reinforced cabinet strongly anchored to the floor is the typical solution to high intensity seismic shaking.

The certification of such enclosure for different levels of seismic activity follows standardized testing. Among the currently used testing standards, the Telcordia GR-63 Standards define four seismic zones, with the “zone 4” representing areas with the highest seismicity, and for each of them establish shake table tests in three perpendicular directions, i.e. longitudinal, lateral and vertical, to verify the integrity of the seismic enclosure. According to these standards, the seismic enclosure must resist seismic inertia forces that can reach a 5 G-force level in each of the tested direction.

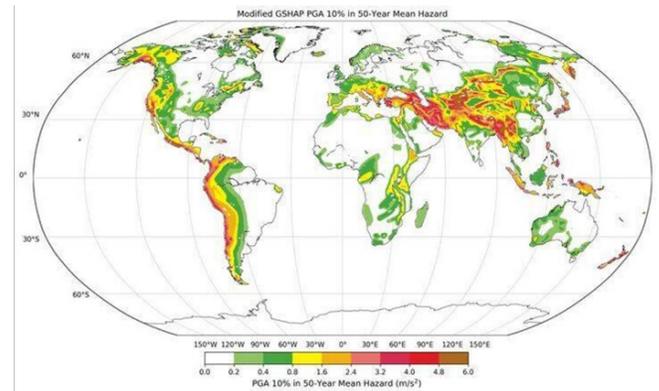


Fig. 2 – Seismic hazard maps in terms of peak ground acceleration with 50% probability of exceedance in 50 years [2]

The recent development of liquid immersion cooling systems necessitates assessing their seismic performance and identifying appropriate protective solutions. These systems present a unique challenge: the coolant fluid cannot be anchored. Consequently, its sloshing under violent ground shaking could result in high pressures on the internal electronics, mechanical systems, and structural components. Additionally, spillage of the coolant would reduce the system's thermal mass, potentially compromising its cooling capability.

As an alternative solution to reinforcing and anchoring, a MetaSeismic innovative protective base is proposed to absorb and dissipate most of the seismic vibration energy, with the aim of reducing spillage of coolant and prevent damages to the electro-mechanical and IT equipment.

This study presents results from seismic tests on a liquid immersion cooling system, specifically a 2500-liter Submer tank with powered Hypertec IT equipment, subjected to the highest level of shaking defined by the NEBS GR-63 Standards. Seismic testing of such systems presents a unique challenge deriving from the fluid-dynamics of the coolants subjected to the seismic excitation and the resulting complex Fluid-Structure-Interaction (FSI).

### Preliminary numerical analysis

Numerical analysis was conducted to preliminarily verify the system's behavior both with and without the MetaSeismic bases. Smoothed particle hydrodynamics (SPH) [3] was used to capture the dynamic behavior of the coolant fluid and its interaction with the tank's structure and the internal servers.

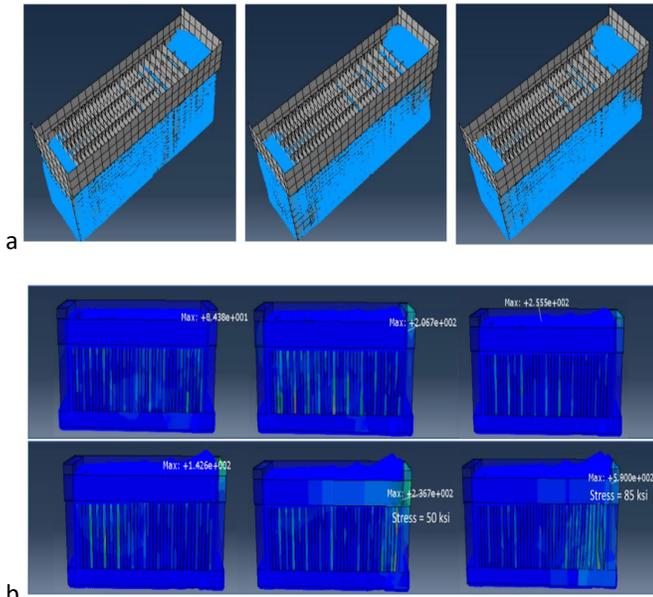


Fig. 3 – Effects of the fluid structure interaction analysis on liquid immersion cooling tank: a) coolant fluid sloshing; b) stresses on the servers

Analysis of the tank in an anchored condition (without the MetaSeismic protection) revealed significant sloshing of the fluid in the upper part, leading to predicted coolant spillage (Fig. 3a). Conversely, the lower part of the coolant fluid generated high pressures on the server installations, resulting in high stresses on the servers (Fig. 3b).

This analysis provided valuable data for designing the protective seismic base.

### The MetaSeismic base

The MetaSeismic base used to protect the system in the seismic test combines innovative technologies with AI algorithm to push the boundaries of performance and sustainability in this industry. The system filters out the shaking energy at the base to prevent that from reaching the tank (Fig. 4).



Fig. 4 – Liquid immersion cooling tank and METaseismic bases during installation: anti-sliding pads provide the only connection

### Testing setup

The tank, mounted on the MetaSeismic bases, was installed on an Anco R-6 Triaxial Shake Table for seismic testing. Accelerometers continuously monitored the system, recording the effect of the shaking at the top of the pod and midway to the top (Fig. 5).

Name	McBee #	mV/g	Calibration Due	Location
A1 SS	4433	66.13	11/17/2023	Control – Seismic Table
A2 FB	4437	66.61	11/17/2023	
A3 V	4429	66.30	11/17/2023	
A4 FB	4439	20.29	12/02/2023	UUT1 – Left Side, Top, Front Corner
A5 SS	4613	20.14	11/17/2023	
A6 V	4452	19.93	10/24/2023	UUT1 – Left Side, Center
A7 FB	4616	66.40	10/27/2023	
A8 SS	4174	66.27	10/27/2023	
A9 V	4176	66.95	10/27/2023	



Fig. 5 – Accelerometers installed on the system Cameras were positioned inside the pod to monitor the sloshing of the immersion fluid (Fig. 6).

This monitoring was crucial not only to prevent physical damage to the tank and servers or to verify system functionality during shaking, but also to confirm that no significant spillage occurred, which could otherwise affect post-earthquake cooling capability.



Fig. 6 – Camera view of the inside of the tank during testing

## Seismic input

MetaSeismic base was developed to resist the highest level of seismic excitation from NEBS GR 63 Telcordia Standards, equivalent approximately to a Magnitude 8.3 shaking and causes g forces up to 5 Gs on the tested equipment.

The seismic input, represented in terms of an acceleration vs frequency response spectrum is represented in Fig. 6. The excitation applied during the test shall be not lower than the response spectrum identified by the bold line for each of the tested directions. A sweep test over the frequency range 1-50 Hz shall also be performed at 0.2g acceleration in each direction to verify the transmissibility properties of the system.

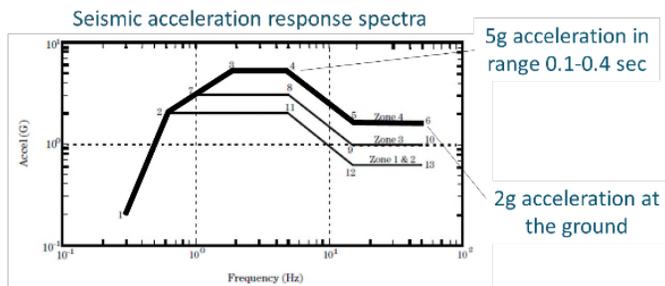


Fig. 6 – Target seismic acceleration response spectrum per Telcordia GR-63

## System dynamic performance

Power spectral density curves were extracted to verify that the shaking was above the Telcordia zone 4 target as shown also in the response spectrum curve below (Fig. 7).

The transmissibility curves show that the METaseismic base was able to reduce the transmission of seismic wave energy below 1 over the range of frequencies that contained most of the input energy.

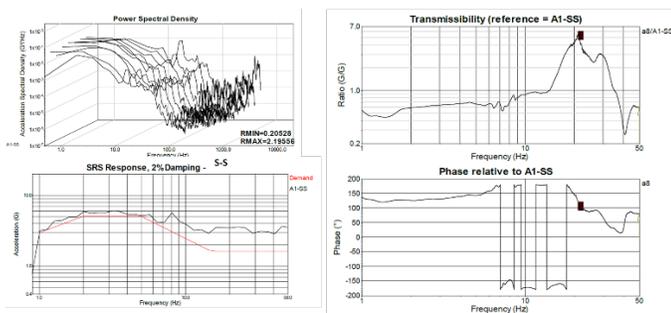


Fig. 7 – Acceleration response spectra and transmissibility curves from the test – longitudinal excitation

## Functional tests

The servers inside the tank were monitored through functionality tests running continuously before, during, and after the shaking tests. The results demonstrated no degradation in server performance and no alteration in temperature (Fig. 8).

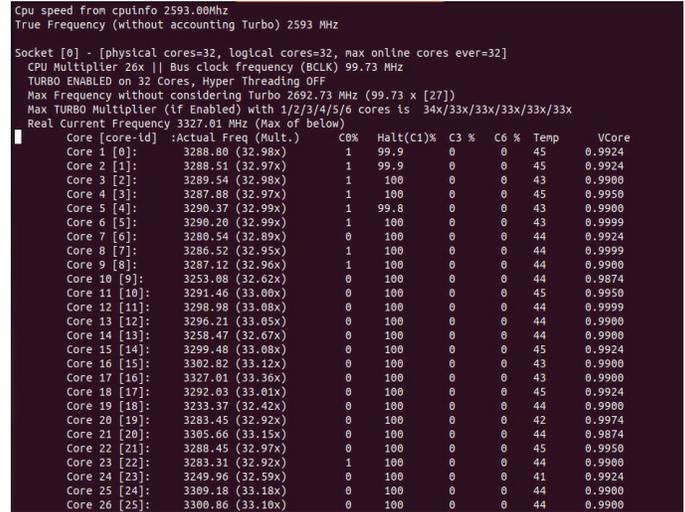


Fig. 8 – Functionality test results for the longitudinal test

Temperature readings for the sweep and lateral tests are presented in Figs. 9a and 9b, respectively. The average temperature of the servers was stable at 52.3 °C and 52.0 °C during these tests.

Additionally, coolant fluid spillage was monitored after each test and never exceeded 0.1% of the total volume. The coolant consistently covered the servers, and its thermal mass remained substantially unchanged.

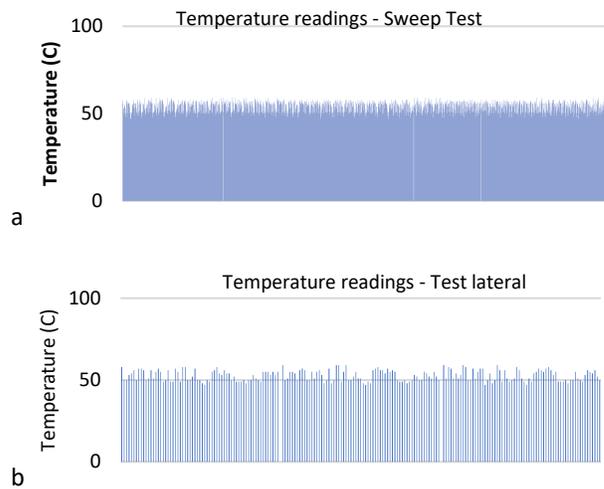


Fig. 9 – Temperature readings for the sweep (a) and lateral test (b)

## Conclusion

This study marks a significant advancement in ensuring the resilience of modern data infrastructure. We report the first successful seismic qualification of a functional liquid immersion cooling system, protected by a novel METaseismic base, under Telcordia GR-63 Zone 4 standards. Our rigorous testing confirmed the system's structural integrity, demonstrating no loss of server performance, stable thermal regulation, and minimal coolant spillage even under extreme seismic events. These findings establish a crucial precedent for

deploying high-density, liquid-cooled computing systems in seismically active regions, thereby enabling the reliable expansion of AI and other data-intensive applications globally.

## References

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