Acoustic Nozzle Design for Fire Protection Application

Melissa A. Loureiro, Alan Elder, Arash Ahmadzadegan
Johnson Controls, Cranston, RI, USA

Abstract

Data centers are relied upon to store and distribute valuable information from customers across many industries, from the investment banking sector to the healthcare sector. This valuable information is primarily stored on Hard Disk Drives (HDDs). As the world becomes more data enabled and connected, the demand for reliable HDD technology is increasing. To keep up with these trends, HDD technology continues to evolve in terms of storage capacity and access speeds. One challenge that data centers are faced with is the ever increasing sensitivity of HDDs to noise.

Industry demands that data centers remain fully functional, with uninterrupted service year-round. Downtime, or more fatally, loss of data, can significantly damage the reputation of a data center and result in the loss of customers. To significantly help reduce the risk of downtime, data center owners install inert gas fire suppression systems. However, independent testing has shown that some fire suppression systems can discharge at high sound power (acoustic) levels, resulting in, at a minimum, a degradation of performance of some HDDs for a short period of time. These discharge sound power levels can also cause HDD failure in the worst cases.

To gain a greater understanding of the impact of acoustic energy on hard drives, Johnson Controls (JCI), conducted a comprehensive study of HDD performance with respect to acoustic energy and room acoustics to design a suppression system nozzle that would protect data centers from disturbances. This paper will provide an overview to the analytical method of designing this nozzle technology.

Keywords: Hard disk drive (HDD), sound, nozzle, inert gas system, suppression

Introduction

There has been considerable confusion in the marketplace about why some data center hard disk drives (HDDs) are damaged in the wake of a clean-agent fire suppression system discharge. When the issue first came to light, the fire suppression community was mystified as it searched for a cause. Was it the sudden increase in room pressure during clean-agent discharge? Was it the discharge gas itself? Or, was it some other part of the fire suppression process? Perhaps most puzzling, what caused the phenomenon to surface at that time? Clean-agent fire suppression systems had been discharged successfully in data centers for years without incident, so what had changed?

In investigating the possible causes of these HDD failures, it was determined that the generated noise was the root cause of these failures. Further confirmation was provided failures occurred after fire suppression warning alarms sounded without agent discharge. Early industry testing also indicated noise was to blame, leading to individuals in the fire protection community to take action.

Hard Disk Drive Capacity

The development of HDDs over the last 60 years has significantly changed. Designs were optimized from the size of two fridges down to 60 grams and an increase in capacity from 3.75 Megabytes in 1956 to 10 Terabytes today. This is a capacity increase of 2.7 million to one! Moore's law describes these technological developments and considers that through the history of computing, the number of transistors on a circuit board doubles every 2 years. As the industry increasingly squeezes more and more computing power into the same space and the sensitivity to certain external factors has increased, the fire suppression systems will have to continue to develop robust solutions to address these challenges.

HDDs are fairly robust pieces of equipment but they are sensitive to some external factors that can impair or irreparably damage their performance. A HDD allows gas to circulate within the casing but are designed to prevent particles from entering. They are not hugely sensitive to changes in humidity or to pressure change but they are sensitive to vibration due to the relative proximity of their moving parts. As the storage capacity grows at a substantial rate, estimated to be up to 40 % per year, the read/write arm fly heights have continued to decrease, therefore increasing this sensitivity to vibration.

Acoustic Disturbances in Fire Protection Systems

Noise levels:
When the gas is released from a pressurized container it moves through the piping network at very high velocities. During nozzle gas discharge in a data center, it generates a high-level of acoustic noise.

For conventional systems and nozzle technology, this has been measured to be in excess of 130 dB. This is close to the noise that is generated when jet plane is taking off (Figure 1). The noise reaches the HDDs where it causes vibration, which in turn causes slight variations in the position of the read/write element. The start of some performance degradation on a new HDD could occur at levels lower than 110 dB. As current generation HDDs increase the number of data tracks per square inch, the relative position of the read/write arm is critical. Slight disturbances to the read/write arm can cause disruptions to the read/write capability of the disc.

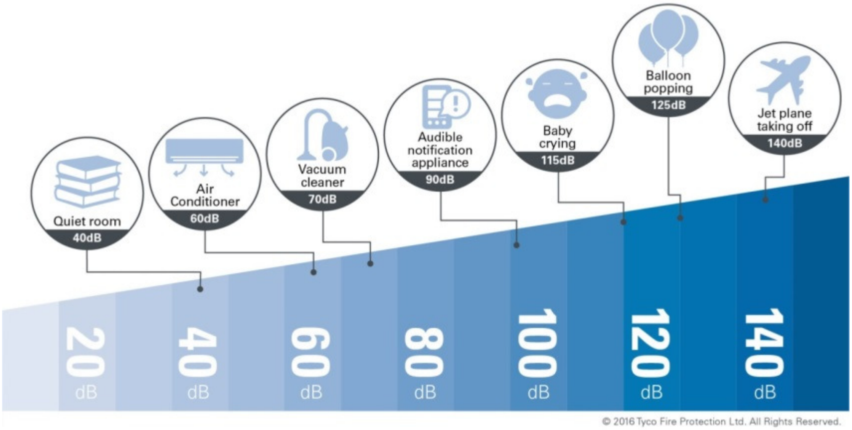

Figure 1. Decibel Level Comparison Chart.

The gas velocity exiting through a nozzle can be in excess of a Mach 1 (i.e. Supersonic). The temperature of the expanding gas reduces the temperature of the surrounding air. This extremely high velocity, greater than 760 MPH, is confined to the area close to the discharge outlet. The gas velocity then rapidly decreases as the gas expands and as it gets further away from the nozzle.

The risk of damage to HDDs is a combination of increased sensitivity of the HDDs and noise generated by external factors such as a fire suppression system. For an inert gas fire protection system, a nozzle could produce noise levels over 130 dB across a range of operating frequencies. In Figure 2, the data shown by the red trendline illustrates that noise levels cause up to a 50 % performance loss of the studied HDDs. The standard nozzle generated noise well above that performance limit, therefore creating the possibility for HDD performance degradation to occur. Performance interruptions to HDDs, such the ING Bank's main data center interruption in 2016, clearly have a potential to cause business interruptions through loss of valuable data and the consequential downtime.

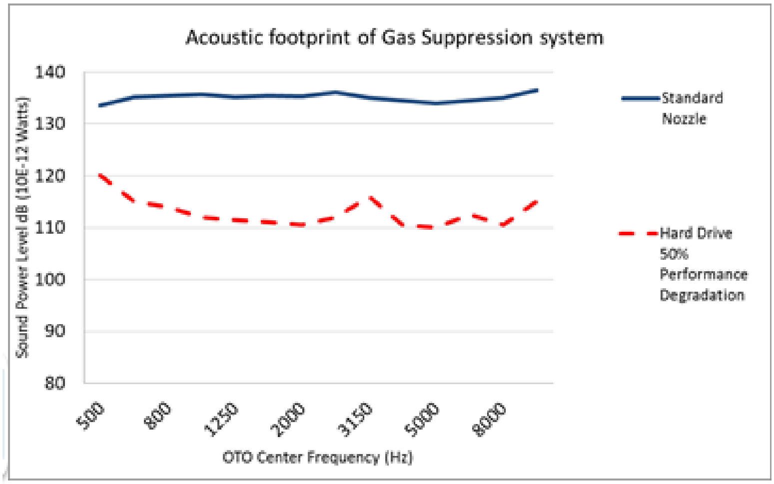

Figure 2. Inert gas fire protection system noise level comparison to HDD performance.

Sound Performance:
To further minimize the risk of equipment downtime, fire suppression systems should be installed into data centers with nozzles that do not induce HDD failures when discharged due to high noise levels. In designing a fire suppression nozzle to control the sound power level generated, the source-path-receiver paradigm must be considered to quantify sound amplitude and frequency. The source (i.e. the nozzle) is a system, sub-system, or component that is generating noise. The path (i.e. room materials and equipment spacing) is any combination of acoustic or structural paths the energy can take to travel from the source to the receiver. The receiver (i.e. the HDDs) is the person, instrument, or object that can be affected by the noise. In the case of the fire protection systems, discharge nozzles and detection alarms are sources of sound. Since there are various configurations of data centers, the sound power levels from the nozzle were minimized. The sound power level is independent of measurement distance and other path effects; it is the most accurate method of characterizing the sound performance of a nozzle.

Sound power is the amount of sound energy produced by a noise source like a fire suppression system discharge nozzle. The Acoustic Nozzle is designed to reduce the sound power level emitted during a discharge of the iFLOW Suppression System.

Sound pressure is the sound that is received at a location remote from the noise source. The remote location may include HDDs. It is sound pressure that is the critical sound energy relevant to the effects on the HDDs. The JCI Acoustic Nozzle is one of the components that reduces the sound pressure to an acceptable level and therefore reduces the risk of HDD damage. The sound pressure level can be further reduced by a number of other factors including the design of the system by reducing its flow rate, positioning of the nozzles, and optimizing the room acoustics through use of sound absorbing room construction materials and installation of sound absorption panels.

The sound output of fire suppression systems is dependent on many factors, including discharge duration, peak agent flow rate, and valve technology. The standard discharge control method in inert gas suppression technology for many years has been metering orifices. These systems have proven reliability and have a proven track record of suppressing fire events. One drawback of this orifice flow technology is high peak flow rates through nozzle orifices that generate high sound levels, some cases exceeding 145 dB at 3 feet away from the nozzle. Though regulating valve technology can reduce sound levels by more than 5 dB, a solution was needed to lower the sound power of suppression nozzles even further to prevent HDD degradation.

HDD Characterization

A series of tests were conducted to understand the correlation between sound pressure levels and HDD performance to develop the necessary limits for the Acoustic Nozzle solution. The test sample included 12 different HDDs of various styles and manufacturers. The HDDs were 3.5” type with drive capacities ranging from 320 gigabytes to 10 terabytes and with a drive speed of 7200 RPM and were manufactured between 2009 and 2016. Furthermore, the selection also included a mix of air-filled and helium-filled HDDs. These were chosen based on customer feedback on the typical HDDs that exist at our customer sites. Each HDD was tested across a frequency range of 500 Hz - 10,000 Hz.

In conclusion, it was shown that a sound pressure level (SPL) of approximately 110 dB (re 20 μPa) in any one-third octave (OTO) band is likely to cause reduced performance in HDDs (average 50% performance reduction curve), as shown in Figure 2. However, SPL values for some HDDs within the test sample experienced reduced read/write speeds while exposed to SPLs as low as 85 dB (re 20 μPa). The average of the 12 HDD sample set achieved 50% performance of drives between 110 and 120 dB across the 500 Hz -10 kHz range.

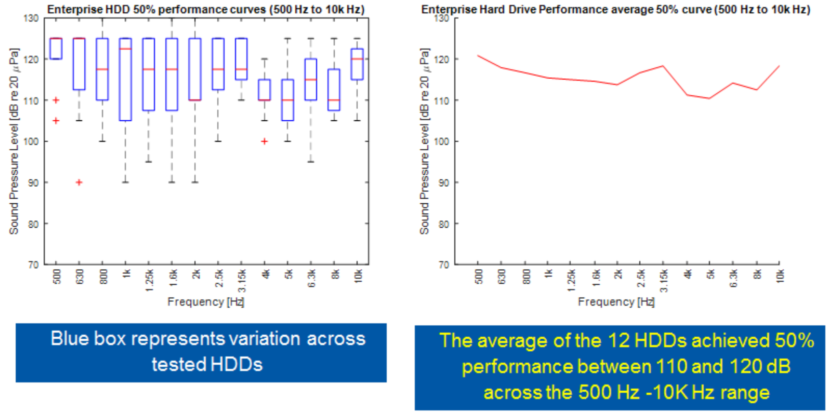

Figure 3. HDD performance characterization.

In Figure 3 summarizes the variations of sound pressure across the tested frequency range. The results of the average HDD performance illustrates that some drives achieve 50 % performance degradation at levels as low as 90 dB for some frequency bands.

Figure 4 summarizes the sound performance results of the two variations of HDDs tested, air-filled and helium-filled HDD. Degradation of both drives occurred at frequencies above approximately 4.

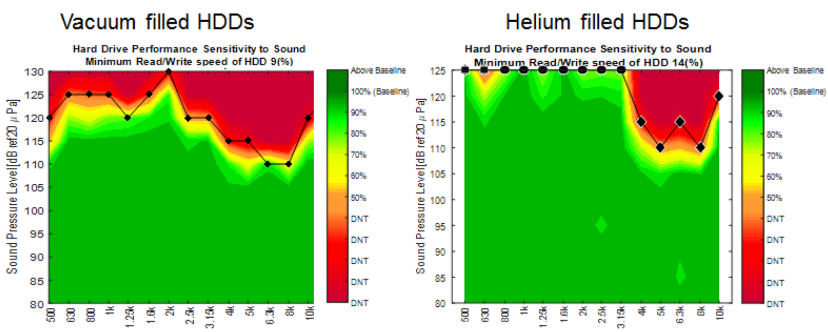

Figure 4. HDD sound characterization.

HDD characterization conclusions:

- Observed performance variation across all HDD models.
- Target peak sound pressure level at HDDs is 110 dBZ from 500 Hz-10 kHz to minimize performance reductions over 50 %.
- Data centers should make acoustic provisions to reduce the risk of HDD performance reduction in the event of loud noise.

Acoustic Nozzle Solution

As a result of the HDD issues studied, the Acoustic Nozzle solution was designed to minimize the impact performance issues within the data centers caused by noise vibrations emanating from the discharge of inert gas fire extinguishing systems. The JCI Acoustic Nozzle design significantly reduces the emitted sound power level during discharge, as compared to a standard Inert gas nozzle.

The JCI Acoustic Nozzle is available in a 360 degree pattern and comprises of an aluminum body and damping materials, which are responsible for absorbing sound. It is also able to achieve a significant coverage area of 9.8 x 9.8 meters (32 x 32 ft) and a maximum protected height of 6.1 meters (20 ft), in accordance with UL 2127 test standards.

Through extensive research, CFD simulation of the inert gas agent flow, and experimental study, it was confirmed that there were acoustic shock waves in the standard inert gas nozzle, shown in Figure 5. These shock waves were the source of the high sound levels during discharge. With the root cause identified through simulation and experimental tools, utilizing novel materials, an inert gas suppression nozzle with a low sound power was designed.

The Acoustic Nozzle was designed to minimize pressure drop across the interior geometry and is configured such that the gas exiting the outlet holes is as balanced as possible for flowrate and pressure. In order to enhance the sound reduction capabilities, the nozzle also incorporates sound absorbing materials in optimum locations. The nozzle is designed to emit low sound levels, while allowing the gas to uniformly reduce the oxygen concentration throughout the enclosure.

Figure 5. Standard Inert Gas Nozzle.

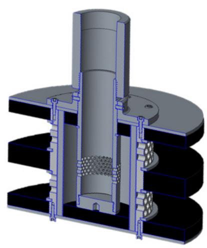

Figure 6. Acoustic Nozzle X-Section.

Total Solution

Calculations can be performed to predict the sound pressure experienced by a HDD. This can help customers determine if the sound generated will cause a reduction of HDD performance. To provide a complete solution to the customer, JCI has developed an acoustic room calculator to ensure that the HDDs are not impacted during fire protection system discharge. The basics of this calculation include the following parameters:

- Sound travels from the source through various paths. The sound at the HDD will change based on room configuration.
- Fire protection system layout and nozzle selection type are inputs to the room calculation
- Results include a sound pressure at the frequency range.

Conclusion

Inert gas suppression systems are designed to protect data center HDDs when a fire hazard is present. It is understood that due to the sensitivity of the HDDs, sometimes there are reductions in their performance when these systems discharge. By understanding HDD design limitations through experimental characterization and by determining the root cause of the main contributor during system discharge, the acoustic nozzle now is optimally designed to truly reduce the potential for data centers to suffer from downtime or from data loss. Using contemporary CFD simulations and visualization techniques, the sound level was reduced from over 145 dB to below 115 dB. With the new JCI Acoustic Nozzle solution and the Acoustic Room Calculation tool, customers now have a total solution to protect their HDD.

References

[1] Rawson, B. P., & Green, K. C. (2007). *"Inert Gas Data Center Fire Protection and Hard Disc Drive Damage." Datacenter Jou*rnal, http://www.datacenterjournal.com/inert-gas-data-center-fire-protection-and-hard-disk-drive-damage/.

[2] Nickerson, M. L., Green, K., & Pai, N. (2013). "*Tonal noise sensitivity in hard drives."* Journal of the Acoustic Society of America 134.5, 4222.

[3] Sandahl, D., Elder, A., & Barnard, A. (2016). "*The impact of sound on computer hard disk drives and risk mitigation measures.*"

[4] Elder, A., & Nichols, T. R. (2015). Protection of Data Centre: "*Economic and Environmental Consideration of the Alternative Technologies Available.*"

[5] Rawson, B. P., & Green, K. G. "*Inert Gas Data Center Fire Protection And Hard Disk Drive Damage*.", Data Center Journal. 27 August 2012. www.datacenterjournal.com/inert-gas-data-center-fire-protection-and-hard-disk-drive-damage/.