Modelling of noise reduction for Datacentre buildings fire protection with inert gas systems

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Abstract. Regarding INERGEN Clean gas Total Flood Fire Suppression System, these systems are specifically engineered for total flooding application in either unoccupied or occupied areas, but against its design, or their proved long term efficiency and global scale usage, since INERGEN agent is stored as a gas, it discharges as an invisible gas that can have a more destroying impact than the fire itself. Since 2008 up to now, there have been recorded on yearly basis several reports about INERGEN gas discharges conducting to faults in hard discs (HDD) operating in Data Centres protected by such a solution from fire due to the level of noise produced. The paper shows an analysis of this problem as hard disks damaging source detection and optimization by modelling of nozzle placement in the space choice as a technical solution to avoid these fire extinguisher side effects.

1 Introduction

Considering the fire protection of information and communications datacentre, the electronic equipment can be seriously damaged by the smoke and the results due to the burning process in a fire. Inergen gas systems are particularly valuable in extinguishing fires for buildings with electronic equipment as HDD where an electrically non-conductive medium is essential as the use of normally extinguishing solutions as foam, water or powder would be not suitable used because causing hard damage to the devices. The INERGEN gas is a mixture of three naturally occurring gases, not allowing combustion, so have no impact on the ozone layer, resulting no global warming potential. There have been recorded on yearly basis several reports as [1-4] about INERGEN gas discharges conducting to faults in hard discs (HDD) operating in Data Centres protected by such a solution from fire due to the level of noise produced. Several attempts to discuss and propose solutions for this problem were in [5-8]. However, the placement of the discharge nozzles is enumerated in [9] but no solution is proposed on how to optimise their position in order to reduce noise received by the HDD's. This is what this paper is proposing by Matlab modelling of nozzle placement in the space choice as a technical solution to avoid these fire extinguisher side effects.

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2 General principles of Inergen gas dry fire protection of Datacentres

The Inergen gas consists of three gases: Nitrogen, Argon and Carbon Dioxide and they are mixed in the following proportions (Table 1):

Table 1. INERGEN GAS composition

GAS\ Percentage	Proportion	Proportion range according to ISO14520-15
ARGON	40%	37.2% - 42.8%
CARBON DIOXIDE	8%	7.6% - 8.4%
NITROGEN	52%	48.8% - 55.2%

The INERGEN gas fire protection system for computer servers is designed to be total flooding and is made of a designed supply of gases connected to a piping system with nozzles to spreading into a Datacentre room (Fig. 1). Inergen gas extinguishes fires by lowering the oxygen content below the level that supports combustion (if the oxygen content of the room atmosphere is reduced to a level below 15%, most ordinary combustibles will not burn).

The INERGEN solution reduces the oxygen content from 20.9% to approximately 12.5% and increasing the carbon dioxide content from 0.03% to around 3.0%. The increase in carbon dioxide content increases an individual’s respiration rate and the body’s ability to absorb oxygen thus allowing the body to compensate for the lower oxygen content.

As well as INERGEN agent is stored as a gas, it discharges (Fig. 2) as an invisible gas, allowing people to safely exit from the protected space without the vision to be obscured.

Fig. 1. Datacentre room fire protection with INERGEN gas system.

Fig. 2. Two row standard container bank arrangement.

2.1 Discharge nozzles

The discharge nozzles are produced in a 180° and 360° forms and are designed to overall spreading of INERGEN throughout the fire area. Various kind of nozzles are especially drilled to fit all the needs of the fire protection system designer.

For the situations when the coverage of initially designed one nozzle is not enough for the entire area that area should be divided again into smaller parts and nozzle added for each part.

The discharge nozzles are made of a steel head containing an orifice plate. The orifice is exactly drilled to fit the INERGEN flow designed for each fire hazard area.

Fig. 3. Discharge nozzles a) draw of 360° nozzles, b) draw of 180° nozzles c) real picture with sample nozzles thread sizes available 3/8 in., 1/2 in., 3/4 in., 1 in., 1¼ in., 1½ in. and 2 in.

The Coverage area per nozzle is: 7 x 7 m (for 360°) and 7 x 7 m (for 180°) resulting in a Max Coverage Area Per Nozzle of 49 m². All these were included in standards as [10].

2.2 Acoustic nozzles

Data and Communications Centres and computer server rooms are enhancing their technologies for the purpose of high speed and higher data storage. This has contributed to increase the Hard Disk Drive (HDD) sensitivity to sound. Inergen gas fire suppression systems are used to protect datacentres, where HDD is the main hardware, but produce sound levels that may damage such noise sensitive equipment. The Acoustic Nozzle, designed for inert gas fire suppression systems, reduces the acoustic sound during a discharge. The Acoustic Nozzle discharges the Inergen gas into the hazard area but reduces the sound level produced by standard nozzles.

Fig. 4. Acoustic nozzle assembly.

Sound power means 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 produced during a discharge of the INERGEN Suppression System.

Sound pressure is the sound that is received at a location remote from the noise source. The remote location may include HDDs. So, the sound pressure is the critical sound energy that can have effects on the HDDs. The Acoustic Nozzle is one of the factors that helps in reducing the sound pressure to an acceptable level and therefore reduces the risk of HDD damage. The sound pressure level can be also improved by several other factors including the positioning of the nozzles, optimizing the room acoustics, use of sound absorbing room construction materials, and installation of sound absorption panels. The estimated nozzle peak acoustic sound power across 500 Hz to 10k Hz frequencies at different flow rates is shown in Fig. 5.

Fig. 5. Nozzle sound power in dB versus flow rate in cubic metres per minute.

3 Problems with Datacentre computer hard disks when INERGEN Gas fire extinguishing systems are discharged

3.1 The overpressure generated in the room by INERGEN Gas extinguishing

About possible effects on Hard Disk Drives it must be considered that if the room overpressure is finally controlled by the overpressure flaps, although the speed of pressure rise may cause problems.

According to [9], it is very unlikely that the overpressure created by a dry extinguishing system with overpressure flaps, or the pressure gradient in such a setup, has any negative effects on typical HDDs.

3.2 Noise generated by the alarms

Sounders and horns are activated to warn people before the agent is released, and the release itself is also a source of noise. According to standards and codes alarming devices for dry extinguishing systems must generate sound levels between 90 and 120 dB.

Electrical horns are typically on the lower end of the range, pneumatic horns are at the upper end. The proper choice of the electrical devices and their placement near the entrance of the datacentre or even outside are easy to apply solutions to avoid damage due to this kind of noise.

3.3. Noise generated by the discharge of INERGEN Gas via nozzles

When discharging an INERGEN gas extinguishing system also high noise levels are produced when the agent expands and flows through the nozzle(s) into the datacentre room. The sound level created depends on many different factors, but it can even go above 120 dB. Those noise levels created by the extinguishing process may have negative effects on HDDs used in datacentre, ranging from a possible reduction in performance to full damage.

Fig. 6. The performance of the HDD drops dramatically after reaching the 50% curve shown by the black curve with black diamond data points [11].

3.4. Solutions for the HDDs damaging sound power reduction

It is evident that a solution is needed to lower the sound power of suppression nozzles in order to prevent HDD degradation or faults.

The Acoustic Nozzle is a substantial advancement in nozzle technology for the data centres fire protection, being a solution that can reduce sound exposure to sensitive HDDs and requires significantly less nozzles and piping. However, the exposure at high speed Inergen Gas discharge (at 5000CMF flow rate), even those can go up to a sound of 111 dB value that is still in a damaging range of HDDs. This is a problem also with the Sinorix Silent Nozzle that operates on the principle of a two-stage gas flow expansion.

The safe shutdown of the HDDs in a computers room or datacentres before the INERGEN release seems only a theoretical proposal as due to the need for speed in reaction time of the fire extinguishing system this cannot be applied.

The varying sound path absorption from one data center to another will yield different sound pressure levels at HDDs, so specific room acoustic calculations must be performed. The calculations must provide an estimate of the sound pressure level experienced at a HDD within a protected area. The sound pressure level calculation method requires the use of advanced acoustic formulas to determine the sound absorption between the fire suppression system nozzles and the data center HDDs.

The system designer must gather inputs including the hazard area construction materials, location of HDDs, and the sound power level of the suppression nozzles. Once the calculations are performed, the estimated HDD sound pressure level can be compared to the HDD acoustic noise performance curve in Fig. 6, the data center noise specification or applicable HDD manufacture data.

3.5 Nozzles placement in the room

Established acoustic engineering equations require additional data to define the path characteristics of the room in order to predict a sound pressure level. This data includes the distance between the source and the receiver and the total acoustic absorption within the sound path. The results determined by using the acoustic equations can help a designer to select the appropriate nozzle and its placement, HDD placement within a room, and the room construction materials to achieve the desired sound pressure level at the HDDs. Data center owners and operators must consider the source-path-receiver paradigm and understand that sound is generated as sound power at a source and transformed through the room paths to generate the sound pressure at HDDs.

In the next chapter of the paper the Modelling and simulation of the nozzles positioning via Matlab software is presented as an alternative to various tests shown in the literature considering the destructive type of the real testing of the system.

4 Matlab simulation and results for Inergen discharge nozzles positioning in the datacentre room

4.1 Model implementation

The noise model included in the noise calculation module is based on sound propagation model described in eq. (1).

4.2 Assessment of a Single Discharge Nozzle as noise source

The noise level at a receiver (HDD from a rack) at 0 - 2m above room ground level is obtained using the following equation:

$$L_{HDD} = L_N - 10 \cdot \log_{10}(2 \cdot \pi \cdot r^2) - a \cdot r \quad (1)$$

where:

the source (nozzle) is broadcasting noise at L_N in dB(A);

L_{HDD} = the sound pressure level at r in dB(A);

r = the line of sight distance between source and receiver in metres.

a = the attenuation coefficient in dB/m.

If L_N exists as a single, broadband sound power level, then $a = 0.005$ dB m/s.

Attenuation is generally proportional to the square of sound frequency. Quoted values of attenuation are often given for a single frequency, or an attenuation value averaged over many frequencies may be given. Also, the actual value of the attenuation coefficient for a given material is highly dependent on the way in which the material was manufactured. Thus, quoted values of attenuation only give a rough indication of the attenuation and should not be automatically trusted. Generally, a reliable value of attenuation can only be obtained by determining the attenuation experimentally for the material being used. Attenuation can be determined by evaluating the multiple backwall reflections seen in a typical scan. The number of decibels between two adjacent signals is measured and this value is divided by the time interval between them. This calculation produces an attenuation coefficient in decibels per unit time.

If L_N exists as octave band data, i.e. $L_N = \{L_N(i)\}$, where $i = 1 \dots n$, then:

$$L_p = 10 \cdot \log_{10} \left\{ \sum_{i=1}^n 10^{L_p(i) \cdot 10} \right\} \quad (2)$$

where:

$$L_p(i) = L_N(i) - 10 \cdot \log_{10}(2 \cdot \pi \cdot r^2) - a(i) \cdot r \quad (3)$$

and $a(i)$ is given in previous table.

Table 2. The overall characteristics.

Octave Band/ Hz	A-weighting/dB
63	-26.2
125	-16.1
250	-8.6
500	-3.2
1000	0.0
2000	1.2
4000	1.0
8000	-1.1

4.3 Assessment of Multiple Discharge Nozzles as noise source

Determine $L_p(j)$ for each nozzle, where $j = 1 \dots m$, using information on nozzle types (normal or noise reduced. The total sound pressure level resulting from all 'm' nozzles is then:

$$L_p = 10 \cdot \log_{10} \left\{ \sum_{j=1}^m 10^{L_p(j)/10} \right\} \quad (4)$$

Following the presented procedure, we have studied the results of software implementations of this model noise simulation of INERGEN discharge over Matlab simulation for different positions of the nozzles in the room, especially in surrounding to the two concrete blocks sustaining the building and centred in the half middle of the datacentre room.

The only literature based Matlab simulation regarding noise propagation is shown in [12] dealing only with impulsive sound around buildings although the open source software I-SIMPA proposed in [13] has capabilities on environmental noise and industrial noise but no suggestion on noise sources placement for a fixed surrounding.

This paper proposed Matlab simulation was detailed over the specific conditions and finally written as a function, considering the main parameters as nozzle height h , receiver distance r , each nozzle sound power level, propagation law described in (1) of this paper, and sound assessment of multiple noise sources. Within this simulation first the distance with HDD to noise source matrix was computed as the square root of each sum of quadratic heights and distance to nozzle placement and then the equation (4) was applied and mesh 3-D plotted over the position. Also, an independent pair of two INERGEN discharging nozzles from a system considering a close noise distance is presented as the case when the noise cumulates from the system of two.

For the simulation three situations were considered regarding the noise sources place near the concrete pillars of the datacentre. In Fig. 7 the two sources are considered to be placed as directly seeing each other but the direct sound path to the area where the HDD's racks is obstructed by the concrete pillars. In Fig. 8 one of the noise sources remains at the same position as in the previous figure but the other is considered to be moved on the next lateral face of the concrete pillar so the two sources cannot have direct view one to the other but the moved one has more direct path to the HDD's area. The last shown simulation in Fig. 9 considers the position of the two discussed noise sources as to be both placed on the lateral face of the concrete pillars a the direct path form each to the other is obstructed by the two weight pillars but them both have direct path to the HDD's area.

Fig. 7. Matlab simulation of Noise power level for each nozzle when the distance is less than 5 m between nozzle in 2D view and near front of the high attenuation of concrete blocks.

Fig. 8. Matlab simulation of Noise power level for each nozzle when the distance is less than 5 m between nozzle in 2D view and one (upper) obscured by the near front of the high attenuation of concrete blocks.

Fig. 9. Matlab simulation of Noise power level for each nozzle when the distance is less than 5 m between nozzle in 2D view and both obscured by the near front of the high attenuation of concrete blocks.

5 Conclusions

It is important to note that the sound power level for a nozzle, varies if its height is changed. The sound power level is also dependent on the humidity profile at the noise measurement site.

The discussed results showed similar performance due to the power, height and distance from the source analysed model.

It is then recommendable the placement of nozzles on the facets of the concrete sustaining bricks of the room as not to avoid direct view of the other many nozzles but to avoid direct view of the HDD racks as in figure 7.

We conclude that the proposed method shows a realistic estimation of the Discharging INERGEN noise over the discussed area and slight sophistications can occur to slightly tune the proposed model.

Further improvements can include the precise nozzle direction (180 or 360 degrees) and room percentage of filling with HDD racks impact on such described noise propagation.

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