# Noise Measurement Technique and Metrics for Fire Suppression Nozzles

*Sudarshan Koushik[1], Duane McCormick[1], Paul Johnson[2] & May Corn[1]*

United Technologies Research Center

East Hartford, Connecticut[1] | Kidde Fire Systems, Ashland, MA[2]

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United Technologies Research Center

Kidde Fire Systems

# Background

- Data-Centers are becoming ubiquitous and protection from fire is critical to data safety
- Inert Gas suppression systems have certain benefits
  - Does not affect electronics
  - Minimal environmental impact (zero ozone depletion/global warming potential)
  - Minimal post-discharge cleanup
- But discharge of agent can be loud
- In some cases Inert Gas (IG) discharge can be louder than 130 dB
  - As loud as a military aircraft engine on carrier deck !!!
- Noise due to Inert Gas discharge has been known to cause hard-drive damage in data centers

# Background (contd.)

- Current generation drives have ~ 340,000 data tracks per inch[1]
- Acceptable tolerance ~ 1/1,000,000 inch
- Example: ING Data center shutdown in 2016

- SSDs are not expected to replace the Hard Drives soon because of cost

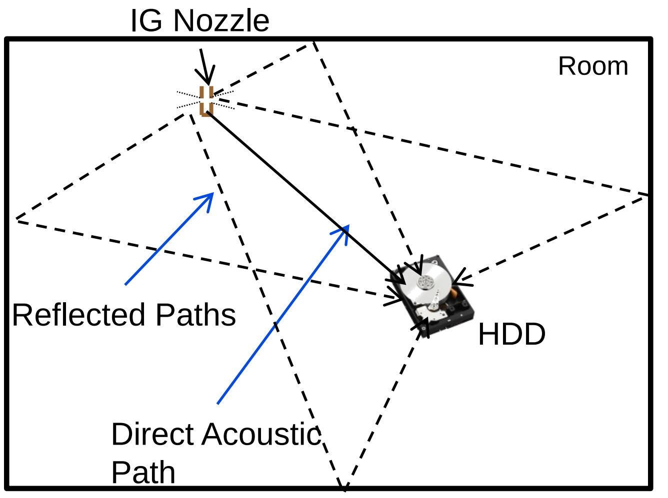
- Excessive vibration can result in permanent damage to drive
- Total loss of performance when SPL > 130 dB
- Studies have shown reduced read/write performance when subjected to noise in the 2 – 10 KHz frequency range for SPL > 110 dB[2]
  - More susceptible to tonal noise than broadband noise

1. "Exceeding Capacity, Speed and Performance Expectations", Seagate Technology , 2011
2. "Inert Gas Data Center Fire Protection and Hard Disk Drive Damage" Kent Green, Brian Rawson, Data Center Journal, 2012

# Objective

- Understand the Acoustic Characteristic of Inert Gas Nozzles
  - Physical mechanism
  - Acoustic directivity

  **Approach:**
  - Perform measurements in anechoic environment

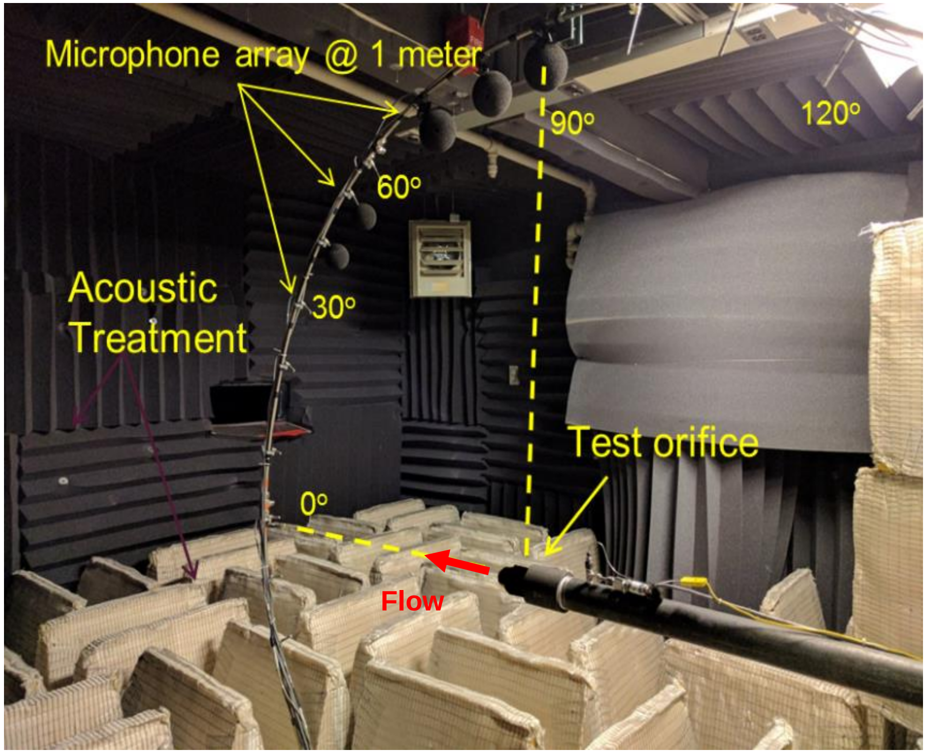



- How to evaluate Acoustic Impact of Inert Gas Nozzle in data center
  - Relevant Metrics

  **Approach**
  - Measurement methods and standards

# Experimental Capability at UTRC

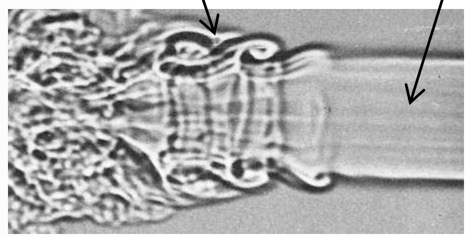
- Nozzle and orifice test rig
- Anechoic room with minimal reflections at frequencies > 800 Hz
- Vary upstream pressure and mass flow rate
- Pipe flow measurements of pressure, temperature and mass flow rates
- Semi-circular microphone array at every 10º for detailed directivity




- High-speed narrow-band acoustic measurements (up to 50 KHz resolution)
- Capability to measure jet velocities and perform shadowgraphs on high speed flow
- Test single orifice configurations as well as different nozzles

# Noise Generation in Single Orifice

- Coherent turbulent structures at all flow regimes
  - Most dominant noise source
  - Broadband in nature




- Supersonic for Pressure Ratios (PRs) > 1.9
- Normal shock when PR < 4
  - Feedback between shock and orifice lip leads to tonal noise
- Shock cells form at higher PRs
  - Turbulent structures in the flow convecting through the shock cells result in broadband shock associated noise

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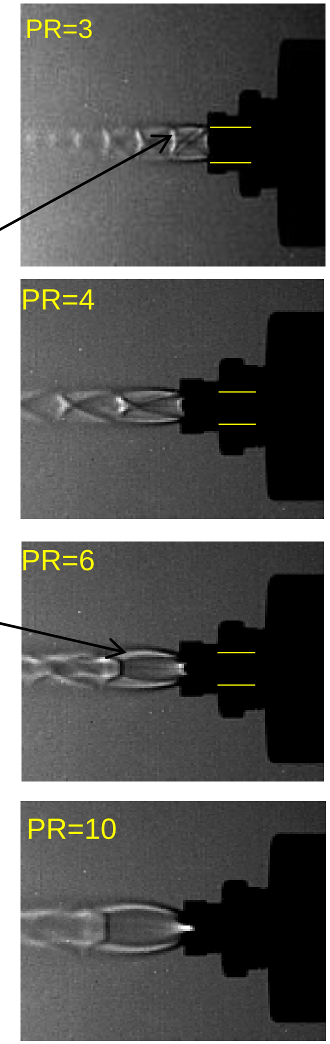
**For more details**

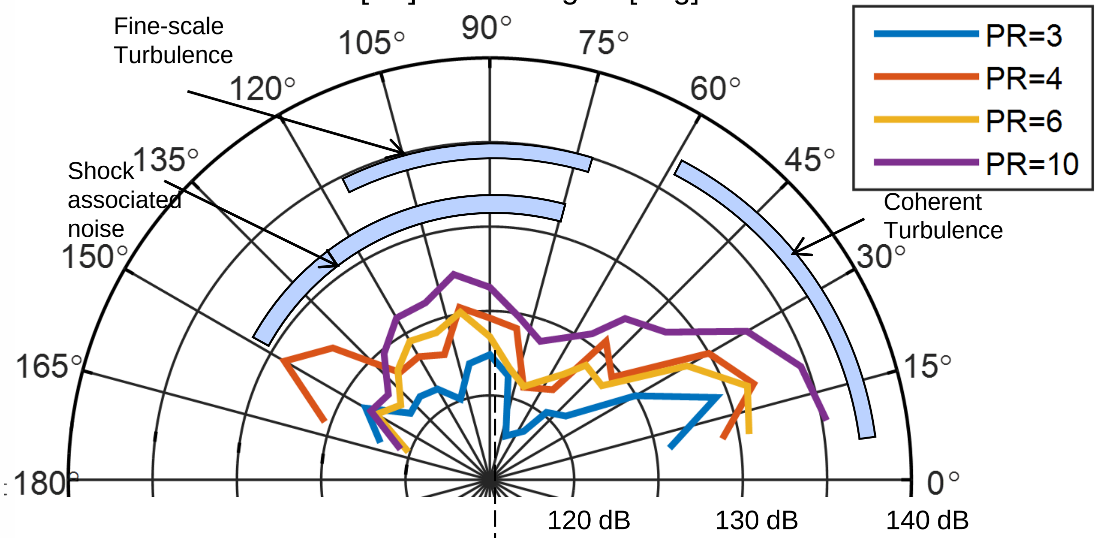


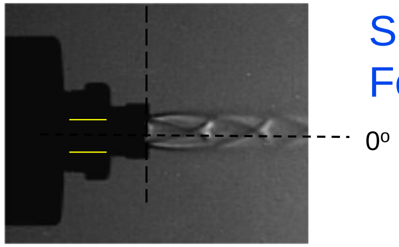

Shadowgraph

# Acoustic Directivity – Single Orifice

- Jet noise radiation has specific directivity pattern depending on dominant mechanism
- There can be quiet spots depending on flow parameters
  - Close to 0º in the jet, there is no acoustic radiation
  - Around 60º-75º where the dominant mechanism transitions between large-scale and fine-scale turbulence
- Developed scaling laws based on measurement

Dominant directivity of acoustic mechanisms
SPL [dB] vs Mic angles [deg]

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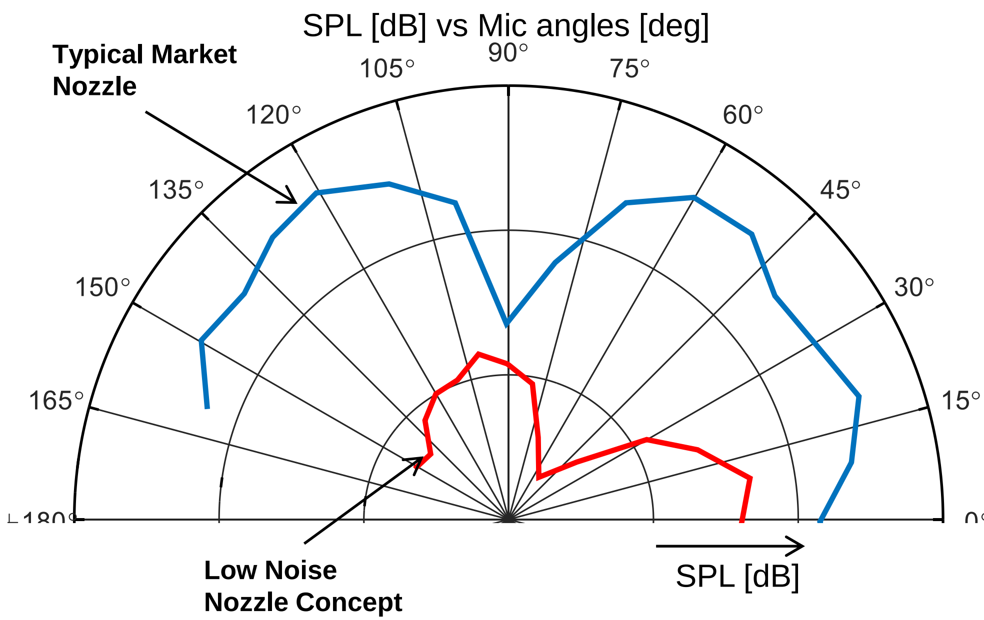
For more details

Overall noise radiation has a distinct directivity pattern with quiet spots

# Acoustic Directivity – Inert Gas Nozzle

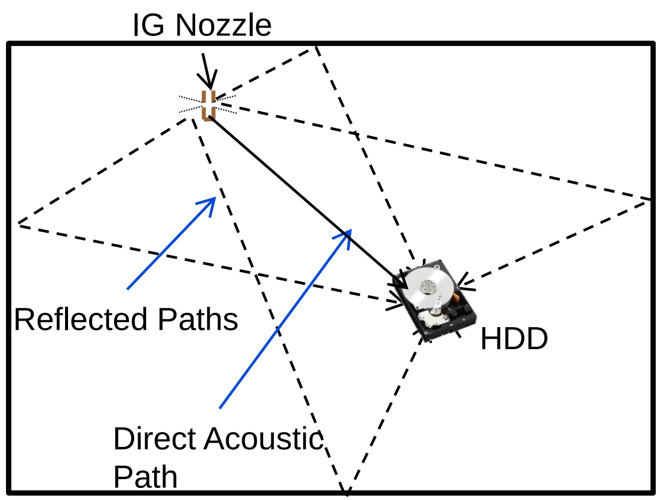
- Single-orifice scaling laws can be used to estimate nozzle noise
- Conceptual low noise nozzle acoustics based on single orifice jet studies
- Nozzle design can affect acoustic directivity
- Single microphone based measurement could easily overestimate (or underestimate) acoustic benefit




Need to be careful when comparing different nozzles

# Issue with Single Microphone Measurement

- The Sound Pressure Level (**SPL** or $L_P$) is a measure of the acoustic level at a **specific location**
- Reflections from walls and nearby surfaces affect the total SPL
- SPL at a microphone is NOT a true measure of the IG Nozzle characteristics



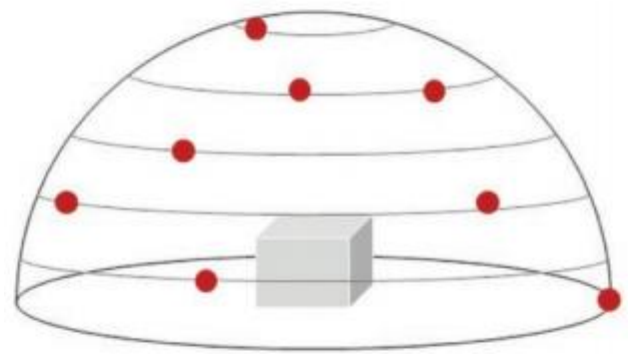

- Sound Power Level (**PWL** or $L_W$) is a measure of the rate at which acoustic energy radiates from the source
  - SPL due to direct path alone

$$L_P = L_W - 20\log_{10}(R) - 10.83$$

PWL of a source and room characteristics can be used to estimate SPL at a microphone

# PWL Measurement Methods – Precision Methods

- ISO 3745: Precision measurement in an anechoic room
  - Sound Pressure at multiple mics around the source is integrated to estimate PWL
  - Similar to the laboratory measurements performed on the Inert gas nozzle at UTRC
- Can provide insight into the acoustic directivity of the source



- ISO 3743-2: Precision Measurement in a qualified reverberation room
  - Quicker to setup than the ISO 3745
  - No directivity information

Both above approaches require specialized calibrated facility

# PWL Measurement Methods – Engineering Methods

- ISO 3747: In-situ measurement using a reference source
- ISO 3743-1: Engineering Method in a hard-walled room
  - A calibrated reference sound source (RSS) is first setup close to the IG Nozzle in the environment and SPL measured at multiple microphone locations
  - The nozzle noise is also measured at the same microphone locations
  - $L_{W(Noz)} = L_{W(RSS)} - \overline{L_{P(RSS)}} + \overline{L_{P(Noz)}}$

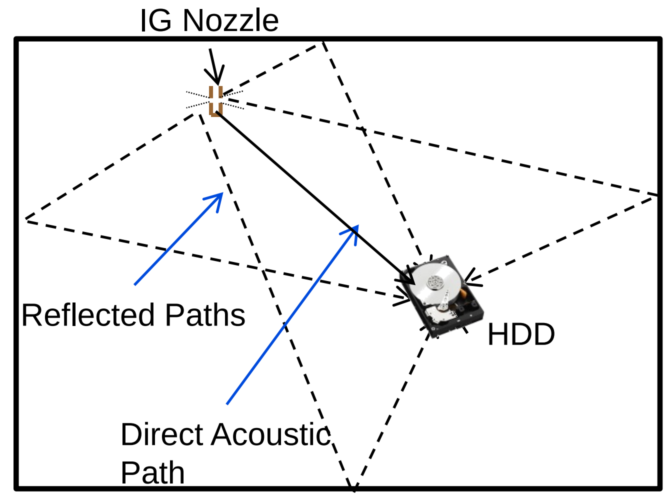
Example Calibrated Reference Sound source

- Reliability of measurement depends on meeting certain minimal room characteristics and choosing appropriate microphones locations (explained in the standard)

Efficient method to obtain nozzle Sound Power estimate

# Nozzle Acoustics in Data Center

- The final SPL at a microphone is a dependent on room acoustic characteristics
  - Room geometry
  - Acoustic absorption of wall
  - Door/Server Rack attenuation
  - etc.
- One can theoretically compute noise knowing all these
  - But inefficient and very error prone




- Or, reverse ISO-3747 In-situ method
- Measure SPL of the reference sound source at desired HDD location (within the server rack if desired)
  - $L_{P(Noz)} = L_{W(Noz)} - L_{W(RSS)} + L_{P(RSS)}$

Efficient method to obtain nozzle acoustic impact on HDD

# Summary

- Jet noise associated with agent discharge and the internal noise from within the nozzle are the dominant noise mechanisms
- Important to measure noise at multiple locations to correctly characterize the nozzle acoustics and directionality
- The Sound Pressure Level at a microphone is a function of the source characteristics as well the installed environment

**Recommendations**

- The Sound Power Level of the nozzle is the appropriate metric to define since it is independent of the final installation location
- ISO/ANSI Standards exist to measure PWL in standard environments
- The measured PWL can then be used to estimate the SPL at a desired location when the nozzle is installed in a data center

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