WHAT IS THE OPTIMUM CLIMATE FOR THE HIGHEST QUALITY OF SOUND IN LIVE MUSIC?

Ehlana Godfrey BSc (Hons) Live Sound Technology
Supervisor: Neil Brooming
School of Media, Arts and Technology Solent University

Abstract

The report explores the question 'What Is The Optimum Climate For The Highest Quality Of Sound In Live Music?'
The background information looks at the definition of sound, temperature, density and humidity, all key factors in the investigation. How the real world contributes to each of the climate factors is then discussed. Secondary data is presented and analysed relating to temperature, humidity and sound. Conclusively, it was found that temperature greatly impacts the behaviour of sound, by changing the speed of sound and the direction.

Definitions

Climate is defined as 'the usual condition of the temperature, humidity, atmospheric pressure, wind, rainfall, and other meteorological elements.' (Climate, 2020) These factors vary slightly depending on the location of the venue.

Temperature is 'the measured amount of heat in a place or in the body', measured in Kelvin, Celcius or Farenheit. (TEMPERATURE, 2020) Heat is a form of transferring energy from one medium to another. (What is Heat?, 2020)

Density is the relationship between the mass of a substance and it's volume, giving the SI Unit of g-1m3 (DENSITY, n.d.)

Humidity is the amount of water vapour held in the air. (Humidity, 2011)

What is the optimum climate?

The ideal temperature throughout the venue, across both horizontal and vertical planes, would be **Room Temperature (20°C - 22°C).** It is cool enough for performers and engineers to be comfortable, but warm enough that positive refraction is prominent. This temperature is also what microphones and instruments will have been built and tested at, so they will be the most responsive.
The temperature can be controlled indoors with well-placed air conditioning. If outdoors, engineers and riggers should ensure that equipment such as amplifiers and lighting are well spaced and kept as far away from the stage as possible.
Humidity is difficult to control both indoors and outdoors. While higher humidity does mean less absorption, so is acoustically more beneficial, it does mean audience and stage members will feel more uncomfortable. A **target humidity of 45%** would mean it is comfortable for people and only moderately increases the attenuation coefficient.
If air conditioning is to be used indoors, the air flow should be the same direction that the sound is propagating, to avoid refracting the sound. This will also help carry the higher frequencies further back in the room.

Testing

Below is a method for the frequency reponse tests planned to show the effect of different temperatures on audio and equipment. The test would have been carried out on a selection of speakers, microphones and instruments in a hemi-anechoic chamber - to reduce the interference from reflections.
1. Set-up the NTI FX100 unit with control software
2. Beginning with response of speakers: Set-up the calibrated measurement microphone one metre away from the front of the speaker, along the centre axis, at a height of 1.5 metre to simulate average human height.
3. Using a sine sweep generator at a set output decibel level and measure the frequency response as control data
4. Decide on temperature intervals. Measure at the front of the speaker using a digital thermometer. Make sure the chamber is evenly heated/cooled. Run sine sweep at each temperature interval, recording data in a spreadsheet (BS 60268-5:2003, 2011)
5. Allow the chamber to return to room temperature. Repeat the test with the microphones under test - do not test condenser microphones. Place the main thermometer next to the microphone

In a large chamber, microphones can be placed at varying heights. The dBSPL and temperature can be measured at each microphone to find the effects of temperature on refraction. As heat rises, it would be expected that the sound refracts up.

Temperature & Velocity

Temperature is positively proportional to the velocity of sound. This is shown using the 'speed of sound in gas' equation and the Ideal Gas equation:

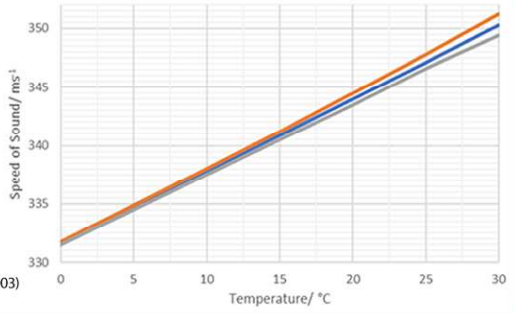
$$v = \sqrt{\frac{\gamma P}{\rho}} \qquad PV = nRT$$

Substituing 1 into 2, shows the relationship:

$$v \propto \sqrt{T}$$

As shown in the graph, the velocity increases with temperature. The rate of increase is marginally greater with the increase in humidity.

How temperature affects the speed of sound at a given humidity.



Graph drawn using data from (Velocity of Sound in Air, 2003)

Factors of Climate

The prominent factor is temperature, as it dictates the maximum humidty and wind speed.
A significant source of both temperature and humidity is humans - as part of the chemical respiration process, we radiate heat and produce sweat. The only way this can be controlled is through venue capacity and air flow.
HVAC systems can greatly increase the noise floor, but make venues more comfortable. HVAC can induce temperature gradients causing sound to refract.
Absorption is significant for frequencies around 2000Hz and is only effective over larger distances. (Everest and Pohlmann, 2015) . The air absorption coefficient is dependent on humidity. Some data demonstrating the changing coefficients can be read in figure six of the report.

	Sources of each factor	
	Indoor Venue	Outdoor Venue
Temperature	- Audience & Crew - Electronic Equipment - HVAC (Heating, Ventilation and Air Conditioning) - Direct light from rig on to stage	- Direct sunlight - Audience & Crew - Electronic Equipment - Portable heaters - Generators
Rainfall/Humidity/ Air Density	- Haze/smoke - Human bodies	- Rain - Human bodies
Wind/Air Flow	- HVAC - Open Stage Doors	- Wind

Dictionary.cambridge.org. 2020. TEMPERATURE. [online] Available at: <https://dictionary.cambridge.org/dictionary/english/temperature> [Accessed 11 April 2020].

Dictionary.cambridge.org. n.d. DENSITY. [online] Available at: <https://dictionary.cambridge.org/dictionary/english/density> [Accessed 17 May 2020].

Engineeringtoolbox.com. 2003. Velocity Of Sound In Air. [online] Available at: <https://www.engineeringtoolbox.com/air-speed-sound-d_603.html> [Accessed 25 May 2020].

Everest, F. and Pohlmann, K., 2015. Master Handbook Of Acoustics. 6th ed. McGraw Hill Education, pp.160, 183.

National Geographic Society. 2011. Humidity. [online] Available at: <https://www.nationalgeographic.org/encyclopedia/humidity/> [Accessed 23 May 2020].

Wikipedia. 2020. Climate. [online] Available at: <https://simple.wikipedia.org/wiki/Climate> [Accessed 18 May 2020].

BS 60268-5:2003. [ebook] British Standards. Available at: <https://bsol.bsigroup.com/Bibliographic/BibliographicInfoData/000000000030249748> [Accessed 5 May 2020].

Project Aims

By the end of the project, an ideal climate for the best possible sound from any given public address system will be presented. The following questions have been derived from the title question, which must be answered to conclude.

Aim One: What is a climate in regard to sound?
For the purpose of the project, it is defined in Section 2.2 of the report. The factors listed as contributors to the climate can be sorted into two categories: Thermal environment and atmospheric environment. The former encompasses all factors relating to thermal energy, while the latter describes anything that alters the air. All of this must be considered to answer the project question.

Aim Two: How is the highest quality of sound defined?
The 'best sound' will be defined differently by each person as it is mostly personal preference. A necessity is that all members of the audience can hear all parts of the performance across the whole frequency range. Every syllable pronounced should be clearly audible, with no muffling or ringing sounds. The background noise should be inaudible.