

Fundamentals of Architectural Acoustics

A Practical Handbook for Contractors and Architects

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A special thanks to Rachel Lodato, Marc Cordes, and John Bishop, for helping to make this handbook as accurate, thorough, and helpful to the reader as possible.

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Table of Contents

Preface 1

About the Author 4

Chapter 1: Basic Theory - Simplified 5

Chapter 2: ABC² – Acoustic Approaches & Solutions 13

Chapter 3: Soundproofing 19

 Soundproofing Walls.....19

 Target STCs27

 STC Ratings.....28

 Soundproofing Floors33

 Target IICs35

 IIC Ratings35

 Soundproofing Equipment and Machinery.....39

 10 Most Common & Serious Soundproofing Mistakes - Summary.....41

Chapter 4: Sound Absorption 42

 Target Reverb Times44

 NRC Ratings.....46

 Acoustic Panel Placement Guidelines50

 Noise Reduction by Absorption52

Chapter 5: Sound Masking 53

 Speech Privacy55

 Dynamic Range56

 Sound Masking System Design57

 Installing Sound Masking Systems60

Chapter 6: Acoustic Consulting..... 63

 Design for NC Criteria65

 Composite Noise Calculations66

 Exterior Noise Propagation.....66

 Vibration Paths67

Chapter 7: Special Occupancy Types..... 71

Appendix A: Glossary of Terms – In Layman’s Terms 72

Appendix B: A Guide to Field Testing..... 74

Appendix C: Case Studies 76

 Tall Pines – Construction Administration Issues for Multi-Family76

 Forum Architects – Design Changes for Multi-Family.....83

 Valrico Church – Room Acoustics92

 Yacht & Country Club – Exterior Wedding Noise.....100

 Elevated Fitness Center Adjacent to Spa102

 Hospital Acoustics – Improving Sleep for Better HCAHPS Scores107

Appendix D: Acoustic Testing ChecklistError! Bookmark not defined.

Appendix E: General Design Considerations:112

Appendix F: Specialty Products115

Appendix G: Relevant Standards & Specifications119

References & Citations.....120

Preface

Fundamentals of Architectural Acoustics is designed to provide Architects and Contractors with the tools they need to design and build acoustically-comfortable and code-compliant spaces.

This Handbook contains core soundproofing & acoustical principles that every building professional should know, derived from a dozen years of engineering analyses, field tests, and assessments. Most of the principles don't require any cost increases, and in fact, many of them will actually result in cost-savings if properly implemented.

From gym soundproofing in Seattle to 50-story high-rise multi-family developments in New England, and luxury cinemas from coast to coast, the same principles apply to give the end client a cost-effective design or remediation to noise issues. Our firm has engaged with the architectural industry, completing nearly 100 AIA Lunch & Learns over the past several years, in addition to countless other speaking engagements, to understand the most common and complex issues faced by Designers and Builders.

Q1: What You Don't Need to Know (or Care) About

Noise issues are a commonplace concern – one with which most readers can easily identify. Whether it was noisy neighbors in college, loud roommates, annoying clicking of your refrigerator, or constant chatter from an office next door. Why then, are significant sums of money spent on high-end appliances and other amenities, while acoustic systems are left to be figured out by future tenants and property managers?

For years, the field of Architectural Acoustics has been shrouded in mystery. This is due to several factors, including the implicit

- **Complexity of Acoustics:** although the science of acoustics can be rather complex, it can also be over-complicated by those with extensive knowledge in the field. Acoustic Consultants have a tendency of providing detailed analysis, although sometimes more rudimentary assessments will provide adequate design insight, especially for basic wall assemblies or typical reverberation environments.
- **Manufacturer's Data:** Further, many manufacturers use misleading lab test data and marketing materials which skew the conversation, making apples-to-apples comparisons between products difficult.
- **Formal Education:** There is very little formal schooling in this field, where architects often take one undergraduate level course and are expected to design acoustically-acceptable and compliant environments, regardless of the anticipated use. Unlike thermal and structural engineering, there is little regulatory oversight. For instance, in the International Building Code, there are 17 codes that outline bathroom urinal placement, but only 2 that address sound attenuation between units.

Unlike weatherproofing, which is easily identified when it is ineffective (i.e. water stains), sound leaks are more difficult to pinpoint and quantify. However, that does NOT mean it cannot be done – acoustic consulting is part art and part science, but it can always be measured objectively.

There are 17 codes in the International Building Code that outline urinal placement, but only 2 for sound attenuation

The intent of this book is to unveil the critical principles and approaches used by acoustic consultants when analyzing unique noise problems. We will show you the key mistakes many end users make when considering noise issues, and prioritize solutions on a cost-effective basis.

We'll also point you to supporting scientific and technical data that supports our approaches so that you may judge for yourself the efficacy of our methods.

Maybe most importantly is what we will not cover explicitly in this book. Our intent is not to instruct abstractly the basic scientific principles of sound transfer and wave theory. While this may be quite interesting to our readers, we would instead suggest they read *Architectural Acoustics*¹ by David M Egan or *Architectural Acoustics Illustrated*² by Ermann.

We won't spend time reviewing complex concepts like Initial Time Delay Gap, or overly-unique issues such as Flutter Echo and/or Creep Echo (common in domed cathedrals). Knowing the speed of sound through water and air won't help you design the best building you can on a shoe-string budget.

We've broken the Handbook down into Basic Theory, followed by each of the core treatment methods – Absorption, Blocking, Cover, and Consulting – something we collectively refer to as ABC². We've also included Critical Questions (many of which we've received, others we created) as well as Key Takeaways – the #1 thing to remember from each section if you forget everything else! Case Studies are littered throughout the handbook, and detailed in the Appendix.

What we mean by “Practical” Handbook:

Important	“Couldn't Care Less”
Effective ways to save cost and schedule on a project while improving the sound ratings	Wave Theory. Speed of Sound thru air and water
Prevent Commons Mistakes (marking wall/floor assemblies with incorrect ratings)	Opera House Acoustics
NRC & Reverb Time	Resonant frequencies or harmonics
dBA Readings	We don't care about other weighting systems that are rarely used
Improve Client Satisfaction – understand target sound ratings, and early detection of major issues	1/3 rd Octave Band Analysis for absorption coefficients
Cost-effective product categories	Brand-specific sales pitches
IIC	The 10 measurements that lead up to the IIC
STC	TL (Transmission Loss), Absorption Normalized Impact Sound Level (ANISPL), NIC, ASTC, STC, NNIC, NR
Basic Reverberation Calculator to tell you how much Carpet, Ceiling Tile, or Acoustic Panel/Cloud/Baffle square footage is needed	Sabins vs Eyring Equations.

Table 1: Critical Acoustic Fundamentals vs. Academic Concepts

Importance of Acoustic Design

Acoustics are often under-represented in the design criteria of a building, perhaps because they are not visible. Unlike a water stain, which would be immediately prioritized in a building, acoustic issues may be much more quickly dismissed. However, they can be equally damaging to workplace function and customer satisfaction.

While acoustics may often be regarded as a luxury, consider that acoustic complaints are the #1 criticism in a number of industries:

1. Restaurants: Too Noisy to hear or have conversations^{3,4}
2. Hospitals: Worst HCAHPS rating is Quality of Sleep due to Noise at Night^{5,6}

3. Hotels: Too Noisy to Sleep⁷
4. Apartments: Noisy Neighbors⁸
5. Office: #1 Privacy, #3 Distractions⁹

By addressing acoustics during construction and treating it as a core building function rather than as a luxury, you can create an acoustically-comfortable space without requiring additional expertise or driving significant cost changes.



About the Author

Walker Peek, born in Jacksonville, FL, studied Structural Engineering at the University of Florida with a minor in Business, and went on to study Industrial Engineering at Columbia University. Over the next 5 years, he spent time as a contractor at NASA, performing engineering studies on the launch infrastructure and commercial crew programs. After finalizing his ASQ Black Belt certification, he oversaw aerospace manufacturing operations at the nearby Space Shuttle Logistics Depot.

Walker founded Commercial Acoustics in 2013, while finishing his tenure at Kennedy Space Center. While looking for a new challenge and discussing ideas with a friend, his wife noted how loudly they were talking. While searching for a problem to solve, one presented itself right in front of them! Better still - It's the same problem that millions of people face across the world every day – unwanted noise interrupting their daily routines or disrupting their office productivity.

His journey included patenting a soundproofing curtain, creating a manufacturing plant for acoustical panels and soundproofing products, and ultimately, to becoming a certified Industrial Noise Control Engineer. As of early 2020, Commercial Acoustics operates out of a 12,000 square foot production facility and custom fabricates acoustic panels for installation in restaurants, schools, and offices across the Southeast US. They also manufacture a number of sound membranes and acoustical sound masking systems.

While consulting on a multi-family project, one client requested a list of products to achieve their sound ratings, and pricing for those products. It was at this time that he stumbled across a unique polymer that was able to achieve STCs in the high 50's on metal studs while maintaining installed costs around \$1 per square foot. Better still, this "EVA" (Ethyl Vinyl Acetate) was durable, since it didn't harden and degrade at room temperature like typical Mass Loaded Vinyl products. Unlike specialty drywall products or resilient channel, it was simple to install and achieved equally strong field ratings.

Commercial Acoustics partnered with the manufacturer of this product line, and after adjusting polymer blends, additives, and extrusion techniques, tested hundreds of variations at Riverbank Acoustical Labs in Chicago, IL. The result was Wall Blokker, a product that now sells in movie theaters and high-rises across the country as the firm's flagship product.

By combining the newest engineered materials with their expertise in acoustics and soundproofing, Commercial Acoustics was able to achieve outstanding results for their customers.

The Commercial Acoustics team continues to grow, and now offers consulting services and custom solutions to architects, contractors, developers and end clients across the globe – in multi-family, hospitality, commercial and healthcare projects.

Walker and his team were awarded the National Multifamily Housing Council's Innovation Award of 2018. The team provided an integrated approach of design-assist by reviewing a key checklist for soundproofing methods, flanking paths, and new materials technology to provide higher STC ratings at a lower cost to the end consumer. Those techniques and methods are outlined in the handbook below.

Chapter 1: Basic Theory - Simplified

To understand the best ways to mitigate sound issues and properly identify them, it is critical to have a basic understanding of acoustics. By understanding how we measure and define core acoustical properties, you can diagnose issues and right-size solutions.

Core acoustical properties include:

- Frequency (Hz): measured in Hertz, frequency is the pitch of a sound. There are low-frequency sounds such as fog horns, designed to travel far distances (since low frequency waves travel much further). High frequency noises such as whistles, however, are much more easily blocked.
- Amplitude (dB): measures how “loud” a sound is. Most complex sounds have differing amplitudes (or volumes) at various frequencies. The average volume at all of the frequencies is called dBA.
- Duration/Fluctuation (sec): some sounds can be much more annoying or distracting than others. This is often a product of its fluctuation. Just like how a fan can help you sleep at night, our ears adjust to noise levels over time. Quickly changing noise levels catch our attention. The more impulsive a noise is, the more problematic it often becomes.

The focus of this handbook is practicality. If you need target STCs and assembly tests, flip to that section. However, the fundamentals on which those are based are expanded upon here for further understanding.

Take a look at the following example in Figure 1 of 3 common noise sources, and then we’ll explore each of these properties further.

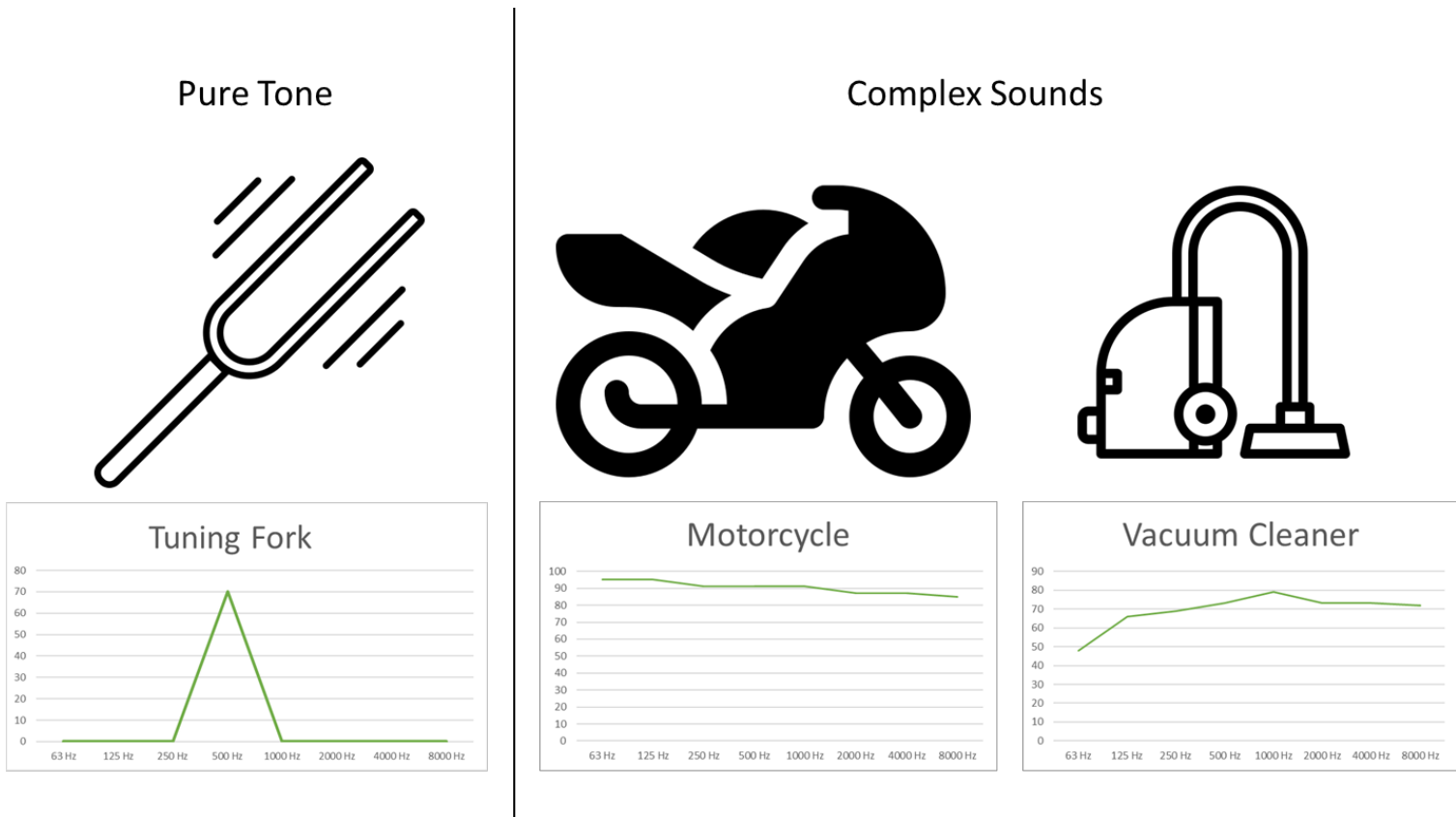


Figure 1: Examples of Noise Sources by Frequency