Technical Development Programs (TDP) are modules of technical training on HVAC theory, system design, equipment selection and application topics. They are targeted at engineers and designers who wish to develop their knowledge in this field to effectively design, specify, sell or apply HVAC equipment in commercial applications.

Although TDP topics have been developed as stand-alone modules, there are logical groupings of topics. The modules within each group begin at an introductory level and progress to advanced levels. The breadth of this offering allows for customization into a complete HVAC curriculum – from a complete HVAC design course at an introductory-level or to an advanced-level design course. Advanced-level modules assume prerequisite knowledge and do not review basic concepts.

Acoustic considerations for project designs are often overlooked. When overlooked, these issues result in noise issues that can be more expensive than if acoustic design were considered in project development. This TDP introduces system designers to the principles of acoustics and includes suggestions on how to address acoustic issues early in design. An approach is also presented on how to address an existing project with noise issues. Understanding acoustic design principles will help designers select and apply equipment and design distribution systems that more cost effectively meet the project’s total environmental quality (TEQ) goals.

This module has seven sections. The first explains acoustic terms and how to add and subtract sound levels. The second section discusses the methods used to establish an acoustic rating both indoors and outdoors, including how manufacturer sound data is generated. The next two sections describe how to determine the acoustic design goal and how to estimate the sound at the receiver using the source-path-receiver concept. Specific guidelines are provided on how to estimate the sound at the equipment to control noise. The next section discusses troubleshooting existing projects, followed by controlling vibration at the design stage. Finally, guidelines are provided for preparing acoustic specifications.

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Table of Contents

Introduction .................................................................................................................. 1
Acoustics Fundamentals ................................................................................................. 3
  The Sound Wave and Human Hearing ................................................................. 3
  Basic Acoustic Terms ............................................................................................. 5
  Wave Interference .................................................................................................. 7
Sound Power and Sound Pressure ............................................................................... 8
  Sound Pressure (Pascal’s - Lp) ............................................................................ 8
  Sound Power (Watts – Lw) .................................................................................. 9
Decibels ........................................................................................................................ 10
  Combining Sound Levels ...................................................................................... 10
  Converting from Sound Pressure to Sound Power .............................................. 11
  Adding Decibels ..................................................................................................... 11
  Adding Coherent Sound Sources ........................................................................ 11
  Adding Incoherent Sources .................................................................................. 12
Subtracting Incoherent Sources ................................................................................ 13
Effects of Multiple Identical Sources .......................................................................... 13
Calculating Log Average ............................................................................................ 14
Response to Changes in Sound Level ....................................................................... 14
Source – Path – Receiver Concept ............................................................................. 15
Calculating Sound Power from Sound Pressure ....................................................... 15
  Sound Fields .......................................................................................................... 15
  Directivity ................................................................................................................ 17
  Line and Point Sources .......................................................................................... 18
Transmission of Sound Energy .................................................................................... 18
  Noise Reduction (NR), Insertion Loss (IL), and Transmission Loss (TL) .......... 19
Reflection ................................................................................................................... 20
  Conservation of Acoustic Energy ........................................................................ 21
  Stiffness Controlled Transmission Loss .............................................................. 21
  The Mass Law ......................................................................................................... 22
Absorption .................................................................................................................. 22
End Reflection ............................................................................................................ 24
  Transmission Paths ................................................................................................. 24
Sound and Noise ......................................................................................................... 25
  Source of Noise ....................................................................................................... 26
  Broadband and Tonal Sound ............................................................................... 27
  Types of Noise ......................................................................................................... 27
Octave Bands .............................................................................................................. 28
Indoor Sound Issues .................................................................................................. 29
  Reverberation ......................................................................................................... 29
  Space Effect ............................................................................................................ 30
Duct Sound Issues ...................................................................................................... 30
Acoustic Ratings and Methods ................................................................................... 30
Measuring Sound ........................................................................................................ 31
  Filters ......................................................................................................................... 31
  Bandwidth of Octave Band Filters ...................................................................... 31
  Bandwidth of 1/3 Octave Band Filters ................................................................. 31
Introduction

This TDP module will introduce you to the fundamentals of acoustics and vibration as they apply to the HVAC field. While the system may heat and cool the building properly, a system that produces unwanted noise or vibration will not be acceptable to the tenants and the building owner. As designers and installers, we have an obligation to provide high quality installation for the customer, which means more than selecting equipment that meets only the thermal load requirements of the building. Only through proper design and application practices may we avoid problem jobs. It is more cost effective to design for acceptable sound levels than it is to correct problems once the system is installed.

This module will begin by describing sound waves and the basic terminology used in the field of HVAC acoustics. The next segment discusses measuring sound levels and rating methods used by the industry to describe and specify sound levels. The next segment provides guidance on determining the acoustical design criteria of a project. The module then illustrates how to utilize manufacturer’s sound data to predict the resulting sound levels in the conditioned space or at a property line. The following sections provide recommendations of how to approach projects with acoustical problems and control vibration. Finally, the module describes how to write an acoustics and vibration specification.

Acoustics is a topic that is not well known or understood by the average HVAC technician or designer. Much of the industry’s publications are intended for the acoustical specialists, making the topic confusing for most HVAC designers and contractors. This TDP module provides a working knowledge on the topic of acoustics with practical guidelines for commercial design. These guidelines will serve as a foundation of information that will help designers and technicians avoid and recognize the potential for acoustical problems in most applications. However, jobs with special or stringent acoustic requirements, such as concert halls, will often require the services of an acoustical engineer. Acoustics is an important part of the overall design process, encompassing equipment selection, application, installation, and air and piping distribution systems.
Ensuring desirable acoustical levels is more than selecting quiet equipment. If the air system is improperly sized or installed, unwanted noise will generate additional noise within the space despite the quiet equipment. Evidence of this can be found in a whistling diffuser or rumble from the ducts when the unit starts.

Sound can come from three sources: mechanical and electrical systems in the building (of which HVAC systems are usually the largest contributor), sound outside the building, and sound generated from sources in the building. The room sound level is the result of all three sources of sound. Sound control is a function of the sound sources, their intensity, frequency, and quality, and the type of activity in the space.

The total environmental quality of a building is determined through the decisions made in the design process. Total environmental quality is more than the comfort conditions of the space; lighting levels, interior design, acoustics, and vibrations all influence the comfort and productivity of building occupants. In HVAC design, this means that the acoustic and vibration goals must be established in the design phase as part of the comfort requirements for the building. An understanding of what sound and noise are and how they are generated and controlled will allow designers to develop specifications that achieve the design goals.

The purpose of acoustical design is to ensure effective generation of desirable sounds and exclusion of undesirable sounds. A sound is considered undesirable when occupants find it objectionable. Occupants may find sounds objectionable because of the volume, the vibration, or the pitch of the sound. Remember that some background noise in the space helps to mask background conversations and outside noise. The ideal background sound is one that is balanced, smooth, and steady. A balanced sound is one in which no one band is dominant over the sound spectrum. Smooth sound quality indicates no audible tones such as hums or whistles. Finally, a steady sound is one that has few fluctuations in level. For example, sound transmitted down the duct when the compressor turns on and off. These conditions are defined as sound quality.

Issues of acoustical quality within spaces have become a more important part of the design process in recent years. For some office buildings, the rental agreement may specify a maximum sound level that must not be exceeded in office spaces. In addition, the American Acoustical Society and the American National Standards Institute (ANSI) are setting much lower sound level criteria for acoustical design in school classrooms. While many projects with stringent acoustical requirements, such as concert halls, will use an engineer specializing in acoustics, every designer should have at least a rudimentary knowledge of acoustics. This knowledge will help avoid issues that may become a problem, understand the impact of manufacturer’s data to actual job conditions, and know when an acoustical specialist is required.
Acoustics Fundamentals

The first step in designing for acoustics is to understand what sound is, how we hear sound, and how sound is transmitted. Secondly, we must understand how sound is measured and what constitutes good sound quality. Throughout these discussions, terms will be introduced that are essential to understanding the topic. The science of acoustics has its own vocabulary and the terms used need to be understood.

The Sound Wave and Human Hearing

*Sound* is energy. Sound energy is transferred through a fluid as the result of a series of minute dynamic changes in the atmospheric pressure caused by alternate compressions and expansions of the fluid. For human hearing, the fluid is usually air. These small pressure variations cause our eardrums to vibrate, which causes our hearing mechanism to work. The rate at which these pulsations occur is called the *frequency* and is described in cycles per second (1 cycle per second equals 1 Hz). Each cycle is one complete expansion and contraction. The speed at which these variations travel is a function of the fluid they are traveling in.

The human ear is sensitive to a very wide range of pressure fluctuations from about 20 cycles per second to around 20,000 cycles per second. The response can vary with each person. We receive most of our sound through our ears; however, at frequencies below 31.5 Hz, we can begin to feel sound vibrating our body and this low rumble can be even more objectionable than a stronger, higher frequency sound.

The speed or frequency at which the sound waves occur is perceived as pitch or *tone*. The sound level we hear is also a function of the pressure of the waves or the *amplitude*. Amplitude is a measure of the strength of the sound wave. Like throwing a pebble in water, the amplitude starts out strong and slowly diminishes in strength as the wave moves out in all directions.

The human ear responds to a very wide range of sound pressure amplitudes from the sound of fluttering of butterfly wings to the roar of jet engine. The audible sound pressure varies from two ten thousand millionths of an atmosphere (2.94 x 10^-9 psi), to two thousands of an atmosphere (0.0294 psi). This is one million times stronger than the lowest level.

The part of the ear that we see is the external ear, which serves to help us locate sounds in space. At the end of the ear canal is an eardrum. When *sound pressure* reaches the eardrum, the eardrum membrane vibrates in unison with the sound pressure. Behind the eardrum are three small bones that mechanically amplify the motion of eardrum and couple the resulting vibrations to the inner ear as pressure waves. In the inner ear, these sound waves are changed to a series of nerve impulses that are sent to the brain, where the brain decodes the impulses, resulting in our “hearing sound.”