COMMERCIAL DISTRIBUTION SYSTEMS

Duct Design
Level 1: Fundamentals

Technical Development Program
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.

This module will look at the way commercial duct design creates an airflow conduit for interconnecting an air handler, rooftop unit, or fan coil with VAV and CV terminals and/or room air distribution devices as a means of delivering conditioned air to the occupants of a building. A step-by-step design process will be presented covering such aspects of duct design as zoning, load determination, layout, sizing, and determining static pressure losses for system fan selection. After completing the module, participants will be able to manually size ductwork using either a friction chart or a duct calculator. The second level TDP of duct design will cover the modified equal friction method of duct design, along with additional sizing and layout recommendations.
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Introduction

This Technical Development Program (TDP) covers the fundamental principles of duct system design for commercial building applications. The most popular duct sizing method – equal friction – is covered in detail. Modified equal friction, incorporating many of the benefits of static regain, is presented in the related TDP-505, Duct Design, Level 2. Although many other duct sizing methods exist (e.g. velocity reduction, T-method, extended plenum, constant velocity, static regain), none are widely used by designers and are beyond the scope of this training module. The reader should refer to other publications for information on these sizing methods.

It is recognized that the use of manual duct calculators is normal, and that computer-aided duct design is becoming more popular; however, it is important to learn the manual friction chart method of duct sizing that is the foundation of these other methods. This will provide the knowledge necessary to recognize possible design errors and understand the effects of various design decisions. Once properly covered, use of Carrier’s Duct Calculator for equal friction sizing will be presented.

Proper duct design requires performing load estimates to determine the zone and space cfm that the duct system will distribute. Once the cfm has been determined, the duct system components can be laid out. This includes locating the supply and return diffusers and registers to provide adequate air distribution to the spaces. Load estimating and room air distribution principles are covered in detail in other related TDPs.

This TDP will cover each duct design step in sufficient detail to permit the participant to lay out and size ductwork into a coordinated system that is energy efficient and cost effective to fabricate, install and commission. The Level 2 Duct Design TDP will present many areas of design enhancement, such as SMACNA Duct Construction Standards, duct design code requirements, fitting selection using loss coefficients, avoiding acoustic issues, unique VAV system duct features, and using life cycle cost analysis as a design criteria.

Level 1 Duct Design develops various aspects of sizing in detail because an oversized duct system will be difficult to balance and will increase the installed cost of the system. An undersized duct system will create higher than necessary air pressure drops, generate noise, and will not deliver the required airflow quantities.

Work sessions are included as part of this program to assist the participant in evaluating his or her understanding of these fundamental principles and sizing parameters.

Duct Design Criteria

Several factors must be considered when designing a duct system. Generally, in order of importance, they are as follows:

- Space availability
- Installation cost
- Air friction loss
- Noise level
- Duct heat transfer and airflow leakage
- Codes and standards requirements
Space Availability

The sizing criteria will often be defined by the space available to run the ductwork (Figure 1). Ceiling plenums, duct chases, and obstructions such as walls and beams often dictate that a certain size duct be used, regardless of whether or not it is the best size from a first cost or air friction loss perspective. There are most likely other building system components competing for the available space. Coordination is required to avoid sprinkler piping, power and communication conduit, light fixtures, and audio speakers. Header ducts and runouts are easier to locate, especially out in the perimeter areas of the floor. Larger trunk and branch ducts require greater coordination with equally large piping and conduit service utilities that tend to get located in the core areas of the building.

Duct Terms

Before we go any further, let’s look at a simple duct system (Figure 2) and define some of the terms we will be using in this TDP (also, see Glossary). The trunk (or main) duct is the supply or return duct that connects to the air source (e.g. air handling unit, rooftop unit or fan coil) and distributes the air around the building. Branch ducts extend outward from the trunk duct, forming a tree pattern across the floor. Runout ducts connect VAV (variable air volume) and CV (constant volume) terminals to a branch duct or directly to the trunk duct. A takeoff (as a fitting) either connects a runout duct to a branch or trunk duct in order to distribute air to a terminal, or connects (as a duct) the header duct to the room air distribution devices (diffusers, registers or grilles). The header duct distributes zone air from the terminals.
Installation Cost

First cost is often quite important. First cost is not only impacted by the size of ducts and types of materials used to construct the ductwork, but also by the number and complexity of the duct fittings, and the height/complexity of the site conditions impacting duct installation labor.

The ductwork portion of the example system costs shown in Figure 3 represent 15 percent of the total, indicating that most of the dollars are spent on creating the heating and cooling capacity. Keep in mind that duct system costs are predominantly labor, representing upwards of 85 percent of the total installed number. Designers need to think of labor-saving designs, and be prepared to consider many suggestions from the installing contractor on design modifications that will economize the fabrication and installation for their shop and field practices.

Air Friction Loss

Air friction loss is affected by the duct size and shape as well as the material and fittings used. For instance, round galvanized sheet metal has the lowest friction loss per linear foot, while flexible ductwork has the highest friction loss per linear foot. Also, the quality of fittings has a direct effect on the overall pressure drop of a duct system. Look to use smooth, efficient fittings with low turbulence to reduce the duct system air pressure drop, and use as few fittings as possible to lower the installation cost. A direct route using round duct with fewer fittings and size changes can have an overall friction loss that compares favorably with a similarly sized rectangular system with a longer route and size changes at each branch duct; but it will always be the more economical design.
Noise Level

An undersized duct system, that is, one with higher velocities, creates noise that is often objectionable to the occupants. Poorly selected or installed fittings also create turbulence, which creates additional noise and air pressure drops. Dampers used for balancing need to be located out of the turbulence and not too close to the diffusers and registers in the space. There are many ways to limit noise creation (Figure 4) that need to be followed when designing ductwork.

Heat Transfer and Leakage

Ductwork that runs through very warm or very cold areas can incur a heat gain or loss that effectively reduces the capacity of the cooling and heating equipment, and will likely result in occupant discomfort and higher operating costs. Leaky ducts have the same energy-wasting effect, and may create odors and stained ceiling tiles if duct thermal insulation becomes wet from the formation of condensation at the leak points.

ASHRAE 90.1 Energy Code dictates appropriate levels of insulation and joint seal levels for all ductwork in order to minimize these energy-wasting conditions. Figure 5 shows the extent of sealing required. Two extensive duct insulation tables in ASHRAE 90.1 cover all usages and climate areas.

**ASHRAE 90.1**
duct insulation requirements range from R-1.9 to R-10 for extremely cold climates.

ASHRAE 90.1 Energy Code