Carrier

Turn to the Experts.℠



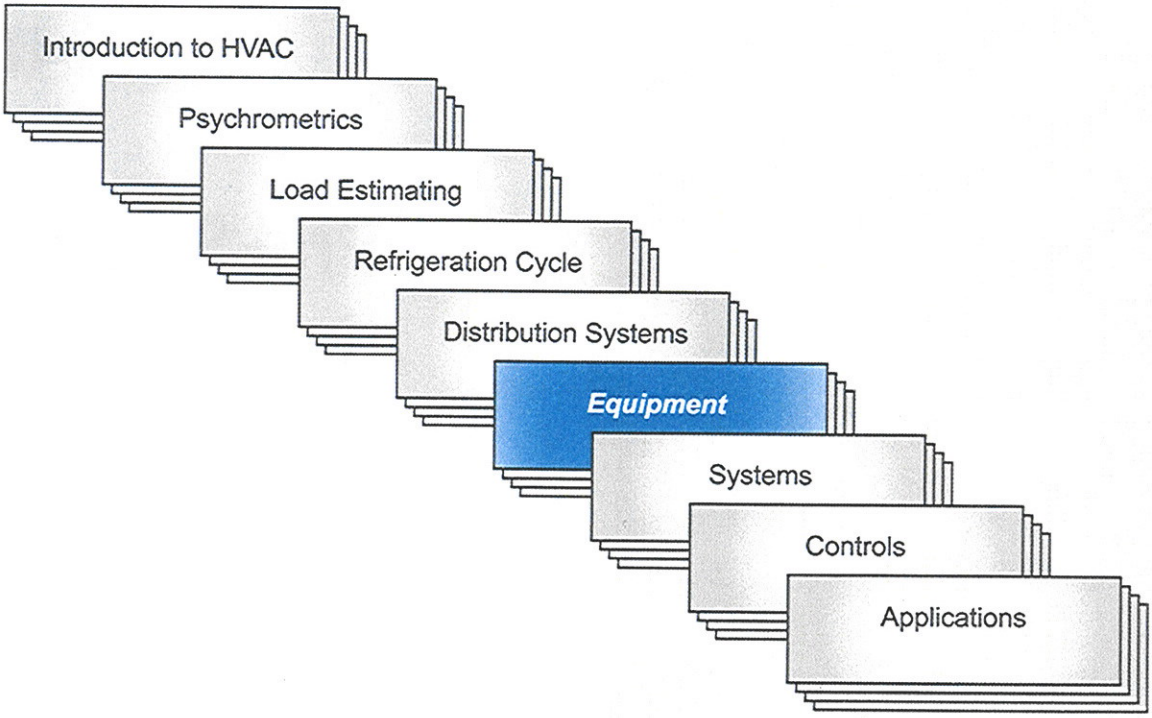
COMMERCIAL HVAC AIR-HANDLING EQUIPMENT

Central Station Air Handlers

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.



Air handlers do not just handle air. They also cool, heat, filter, and humidify. Central station air handlers are typically "built to order" with a wide variety of available options and accessories to choose from. Central station air handlers are available factory-designed for indoor use or for rooftop mounting. This TDP module will explain the types of equipment and the sectional components that comprise an air handler, both indoor and outdoor types, discuss modern construction methods for central station air-handling units, as well as the software programs used for selection.

© 2005 Carrier Corporation. All rights reserved.

The information in this manual is offered as a general guide for the use of industry and consulting engineers in designing systems. Judgment is required for application of this information to specific installations and design applications. Carrier is not responsible for any uses made of this information and assumes no responsibility for the performance or desirability of any resulting system design.

The information in this publication is subject to change without notice. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, for any purpose, without the express written permission of Carrier Corporation.

Printed in Syracuse, NY

CARRIER CORPORATION
Carrier Parkway
Syracuse, NY 13221, U.S.A.

Table of Contents

Introduction 1
Packaged, Central, and Custom Air Handlers 2
Packaged Air Handlers 2
Central Station Air Handlers 3
Custom Air Handlers 3
Selection Basis for Central Station and Custom Air Handlers 4
Basic Air Handler Unit Construction 5
Post and Panel Design 5
Structural Panel Design 6
Casing Design and Materials 6
Antimicrobial Coatings 7
Insulation Types 8
Single-Wall vs. Double-Wall 9
Seals 11
Air Handler Types 12
Indoor Units 12
Outdoor Units 13
Draw-Thru and Blow-Thru 14
Coils 15
Types and Construction 15
Drain Pan 16
Condensate Drain Trapping 16
Fan Section Characteristics and Performance 18
Supply Fan 18
Return Fan 19
Exhaust Fans 19
Fan Discharge Arrangements 20
Centrifugal Fan Types 20
Forward-Curved Impeller 21
Backward-Inclined Impeller 21
Airfoil 22
Plenum Style 22
VAV Fan Volume Control 22
Riding the Fan Curve 23
Inlet Guide Vanes 23
Discharge Dampers 24
Variable Frequency Drives 24
AMCA Fan Class 24
Fan Components 25
Fan Mounting 25
Discharge Isolation 26
Bearings 26
Drives 28
Motors 28

Unit Accessories 29
Filter Sections and Filters 29
Filter Types and Ratings 30
Impact of Filter Pressure Drop on Fan Selection 33
Access and Plenum Sections 35
Mixing Box Section 35
Exhaust and Economizer Sections 36
Air Mixers 36
Face and Bypass Damper Sections 37
Humidifiers 37
Ultraviolet Light Germicidal Lamps 39
Energy Recovery 39
Coil Energy Recovery Loop 40
Energy Recovery Wheels 41
Fixed-Plate Heat Exchanger 42
Heat Pipe Heat Exchanger 43
Additional Air Handler Configurations 44
Dual-Duct 44
Multizone 44
Texas Multizone 46
Triple-Deck Multizone 46
Air Handler Selection Example 47
Summary 49
Work Session 50
Appendix 54
Work Session Answers 54

Introduction

Factory-assembled central station air-handling units are generally one of the first items of air-conditioning equipment selected after the cooling load estimate is completed. In the system design process, a chilled water or refrigerant temperature level is established under which the chiller or condensing units will operate. In turn, this temperature is used to determine the design requirements for the air-handling equipment, including coils and fans. Because of its effects on other system components, it is imperative for the designer to have a thorough understanding of central station air-handling equipment and how it should be selected and applied.

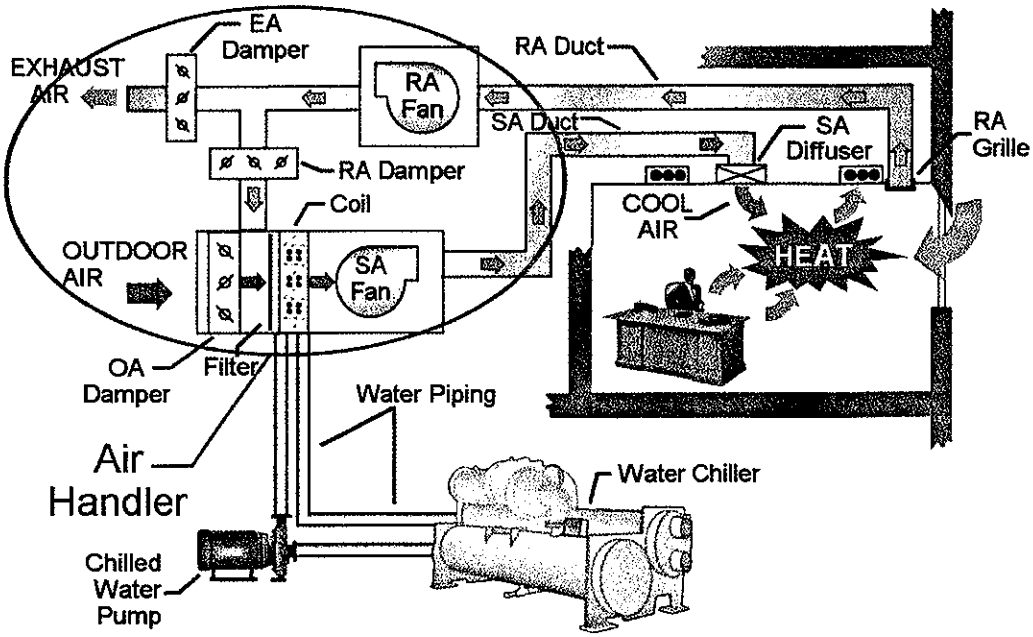


Figure 1

Where does the air handler fit in?

This TDP will outline the basic construction methods used in current central station air-handling units, the types of fans and their characteristics, common methods to modulate fans when used in VAV systems, and indoor air quality (IAQ) air-handling unit components like energy recovery and filtration sections.

Increasing concern about building health conditions and ventilation requirements has made IAQ a top consideration in today's HVAC equipment purchases. For air handlers, in addition to delivering conditioned air in the proper quantities and temperatures, effective filtration, minimal air leakage, energy efficiency and improved serviceability are also critical. As a result, the designer can no longer focus attention exclusively on the coil and fan selections. Casing design and performance should also be considered from the standpoints of thermal performance, air leakage, and serviceability. Therefore, this TDP module will explain both the components that make up an air handler, and how they are constructed.

Manufacturers are developing new products and integrating new materials and technologies to address these needs. More and more, features that were once available on "custom" units are being incorporated into "standard" air handlers.

Packaged, Central, and Custom Air Handlers

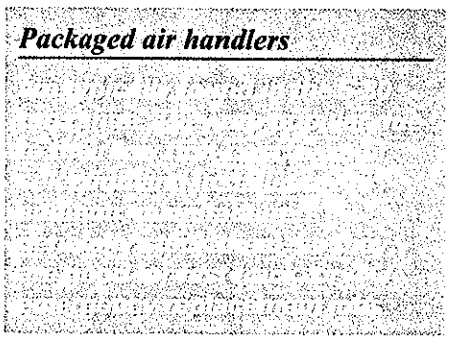
ARI Standard 430 defines central station air-handling units as "... a factory-made encased assembly consisting of a fan or fans and other necessary equipment to perform one or more of the functions of circulating, cleaning, heating, cooling, humidifying, dehumidifying and mixing of air; and shall not contain a source of cooling or heating other than gas or electric heat. This device is capable of use with ductwork having a total static resistance of at least 0.5 in. wg."

Although the term "fan coil" is frequently used interchangeably with air handler, ARI defines fan coils as being "non-ducted," or applied to systems operating with less than 0.25 inch static resistance.

In the commercial HVAC market, air handlers range from simple "packaged" air handlers up to approximately 15,000 cubic feet per minute (cfm) range, to large central station air handlers capable of delivering over 100,000 cfm. Let's take a moment to look at the differences between them.

Packaged Air Handlers

Packaged air handlers have a fixed fan and coil configuration. They are typically used for low pressure comfort cooling and heating applications that require less than two inches external static pressure. Packaged air handlers have a more limited set of options than central station air handlers, generally composed of heating coils, mixing boxes, and discharge plenums.



Characteristics

- **Fixed fan and coil configuration**
- **Limited to <15,000 cfm (30 tons)**
- **Low-static applications only**
- **Limited options available**
- **Indoor applications**
- **Single-wall casing**
- **Manufacturers stock them**

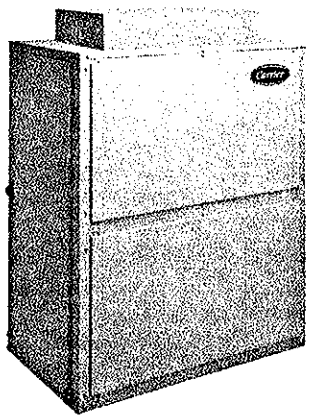


Figure 2

Packaged Air Handler

Most often, they are matched to split system condensing units and heat pumps, although optional chilled water coils may be available. Several manufacturers provide matched performance ratings with their condensing units and certify these ratings under ARI Standard 340/360 (Unitary Large Equipment). As a result, packaged air handlers are usually classified by nominal cooling tonnage, rather than airflow.

Central Station Air Handlers

In contrast, central station air handlers, sometimes referred to as "applied" or "built-up" air handlers, offer a wide range of component options to cover an almost limitless set of application needs, both commercial and industrial. Central station air handlers range in size from 1,500 cfm for small single-zone applications, to large, fully custom air handlers capable of delivering over 100,000 cfm to constant volume or variable air volume systems. Although the size range is large, the majority of comfort air-conditioning applications fall into the 1,500 to 50,000 cfm size range.

Characteristics

- Almost infinite component combinations
- Standard size range from 1,500 to 50,000 cfm
- Custom models available over 100,000 cfm
- Multiple fan and coil types and arrangements
- Draw-thru and blow-thru
- Wide range of accessory sections
- Indoor or outdoor models
- Built to order

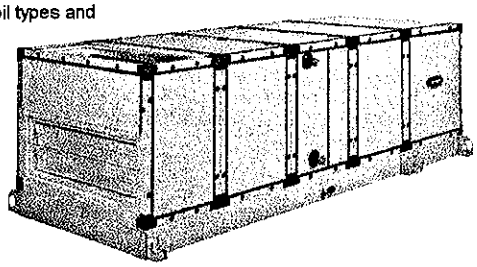


Figure 3

Central Station Air Handler

To simplify the design process and keep the time required to design, build, and deliver the air handler to a minimum, most manufacturers offer a "standard" catalog offering of pre-engineered sizes and components. These components are assembled by the designer in building-block fashion to suit the job requirements. In addition to traditional catalogs, some manufacturers offer computer selection software that facilitates the configuration and selection of a unit, along with detailed engineering drawings and data for submittal and ordering purposes.

Central station air handlers

are generally built to order due to their variety and complexity.

Custom Air Handlers

Custom air handlers are used where standard unit designs cannot easily be applied. Typical volumetric flow rates for custom air-handling equipment range from 50,000 cfm to 300,000 cfm or greater. However, custom equipment can also be found on a much smaller scale where space restrictions, strict sound requirements, low leakage rates or special materials and construction methods are required. These units are designed to meet the exact requirements of a given project and can include a staggering array of options and accessories.

Key Features:

- **Job-specific design**
  - Dimensions
  - Components
  - Configurations



Figure 4

Custom Air Handler

Custom air handlers

Custom air-handling equipment design is driven by the requirements of the application. When size restrictions are a major concern, the most efficient component selections are made to fit in the minimum available space. If sound is a primary concern, appropriate materials and components are selected and arranged within the cabinet to minimize the sound output power levels radiated through the cabinet, at the inlet and at the outlet of the unit.

Selection Basis for Central Station and Custom Air Handlers

The cataloged size of an air-handling unit often refers to the face area in square feet of the largest cooling coil that can be installed in that particular casing. Once the required airflow rate is established from the building load estimate and design requirements, the engineer will define a maximum permissible cooling coil face velocity. The maximum design air velocity is limited to prevent condensate on the coil surface from being blown off the coil surface and into downstream components. Coil velocity limits vary with coil fin material and coil design. Typical design air velocities for aluminum-finned coils are generally in the 500-550 feet per minute (fpm) range. For example, an application requiring 25,000 cfm operating at 500 fpm would require an air handler with a 50-square foot coil. This would then equate to a nominal size 50 air handler. Note that for a particular nominal size, actual coil face area can vary slightly between manufacturers, as they are generally rounded to a nominal unit size. Heating coils do not condense moisture, therefore do not exhibit moisture blowoff. Face velocities can be higher (900 fpm) and are limited by airside pressure drop.

Maximum cooling coil face velocity in feet per minute (fpm) is restricted by moisture blow-off.

Coil Moisture Blow-off Limits (fpm)			
Fins per inch	Aluminum	Copper	E-Coat
8	550	500	475
11	550	425	400
14	550	375	350

1. Limits apply to clean and properly maintained coils.
2. The limits shown are for Carrier 39 Series coils. Consult manufacturer for specific data.

Figure 5

Maximum Coil Velocity

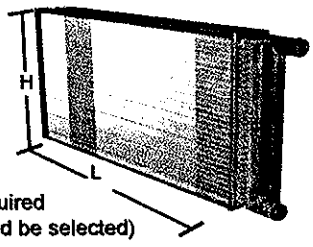
Without employing any energy recovery or gas-fired heating options, a custom air-handling unit is similar to a standard air handler in that it is typically designed around the total face area of the cooling coil required to meet minimum performance requirements. That is, the cooling coil dimensions are based on the maximum allowable face velocity, which varies with respect to coil duty and the tube and fin material options prescribed by the application.

The relationship between airflow volume (cfm), velocity (V) and area (A) is:

$$cfm = VA \quad \text{or} \quad A = cfm/V$$

Where:

$$A = H * L$$



Solution: A = cfm / V
A = 25,000 cfm / 500 fpm
A = 50 ft² cooling coil required
(nominal size 50 unit would be selected)

Figure 6

Air Handler Size Selection

An exception

However, regardless of the component, once the limiting factor is determined, its design and selection is optimized and the rest of the layout naturally revolves around this feature.

Basic Air Handler Unit Construction

Most central station air handler casings are designed using either "post and panel" or "structural panel" construction techniques. In addition, they may be designed for indoor or outdoor installation with single or double-wall panel construction. Let's take a closer look at these options.

Post and Panel Design

Post and panel designs employ a frame assembly using structural rails or posts that form a framework or "skeleton" to support the pre-formed casing panels and internal components. Once the frame is assembled, individual panels are attached to the rails to form the air handler enclosure. The panels are attached either with screws or quarter-turn quick release fasteners for faster installation and removal. The panels are generally gasketed or sealed to minimize air leakage. A benefit of post and panel construction is serviceability, as all panels can be removed individually for cleaning or direct access to internal components. In many cases, especially when quarter-turn fasteners are used, wall panels are mounted on hinges and function as access doors. This design technique eliminates the need for separate inset access doors, minimizing the potential sources for air leaks. Air leaks contribute to system inefficiency.

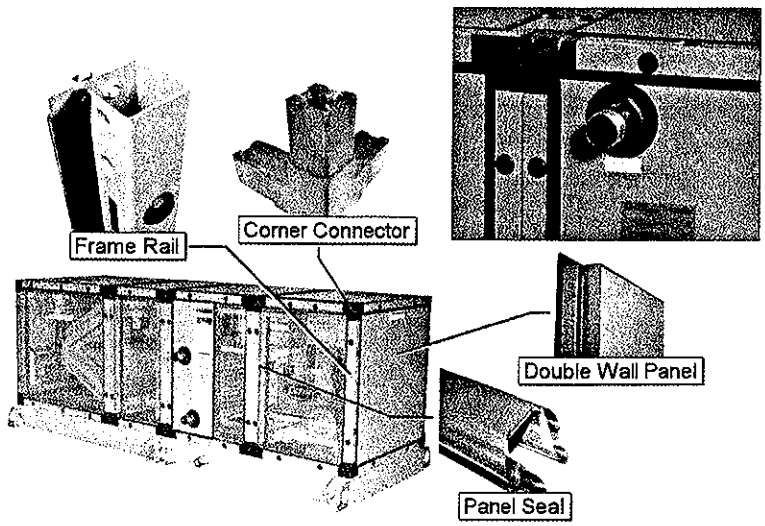


Figure 7

Post and Panel Construction

Post and panel construction lends itself to modular designed air handlers. One approach uses timesaving quick-connect latches that permit easy assembly and disassembly, eliminating the need for conventional bolt and screw assembly.

Structural Panel Design

In structural panel casing designs, the side panels are designed to carry the load of the top panels and internal components without the need for a separate frame structure. Load-bearing wall panels are fastened to the floor panels and the top or roof panels are supported by the walls. For service access, individual panels may be removed one or two at a time, but not all at once. As a result, structural panel designs rely more heavily on inset doors for service access.

One benefit of the structural panel design is that the manufacturer has greater flexibility to increase wall thickness for strength to handle extremely high static pressure applications, higher insulation requirements, or improved acoustic performance.

Structural panels

- Unit structure is achieved by load-bearing side wall panels
- Side panels support top panels and internal components
- Individual panels may generally be removed, but not all at once
- Inset doors are primary means of service access
- Design allows manufacturers to vary wall thickness more easily to accommodate high-pressure or high thermal resistance applications
- Panels and sections typically sealed with foam gaskets and caulking

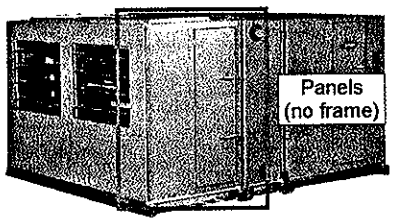


Figure 8

Structural Panel Casings

Casing Design and Materials

As a general industry standard, manufacturers use galvanized steel to build air-handling units. Galvanizing is a zinc coating process. Galvanizing is highly effective at preventing corrosion of the steel substrate with the following limitations:

- Bare steel can become exposed at the sheet metal edge where it is cut or where holes are punched. Rust may form at this edge, undermining the surface galvanizing.
- Scratches can expose bare steel allowing rust to form. Scratches may occur during the manufacturing process, installation, or maintenance.

Galvanizing also has the characteristic that the zinc coating may itself develop surface corrosion in the form of zinc oxide that is sometimes referred to as white rust. For these reasons, most manufacturers offer an option for painted casings.

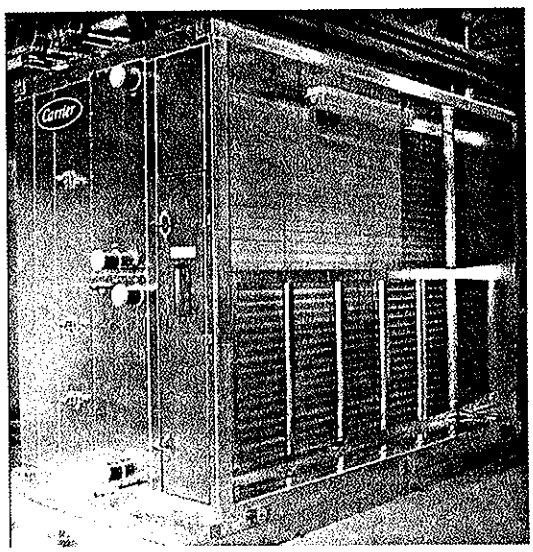


Figure 9

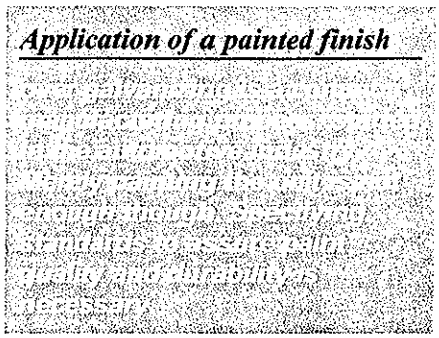
Galvanized Casing

Paint Quality and Durability Standards

American Society for Testing and Materials (ASTM) B 117 Standard Practice for Operating Salt Spray (Fog) Apparatus - describes the apparatus, procedure, and conditions required to create and maintain a salt spray (fog) test environment. Units are typically specified to withstand 500 hours salt spray.

ASTM G 85 Standard Practice for Modified Salt Spray (Fog) Testing - describes apparatus and procedures for cyclic testing of painted specimens, which is a more aggressive test of durability. A test duration of 125 hours is often specified.

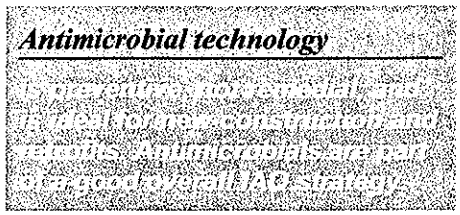
Application of a painted finish



With all the attention given to indoor air quality, alternate casing and lining materials such as paint, aluminum, and stainless steel, are becoming more widely used on comfort cooling systems.

Antimicrobial Coatings

Antimicrobial technology



Antimicrobial coatings are also becoming more commonplace to deter the growth of bacteria, fungus, and mold. They are applied to the inner liner of double-wall casings, fiberglass insulation, and condensate drain pans.

Antimicrobials are materials that prevent, inhibit, or suppress the growth of microbes, such as bacteria, mold, fungus, or yeast. Antimicrobials fall into two categories: organic (hydrocarbon based) and inorganic (metallic-ion based). They can be solids, liquids, or gases.

A multitude of materials exist; the key is to select the right technology for the application.

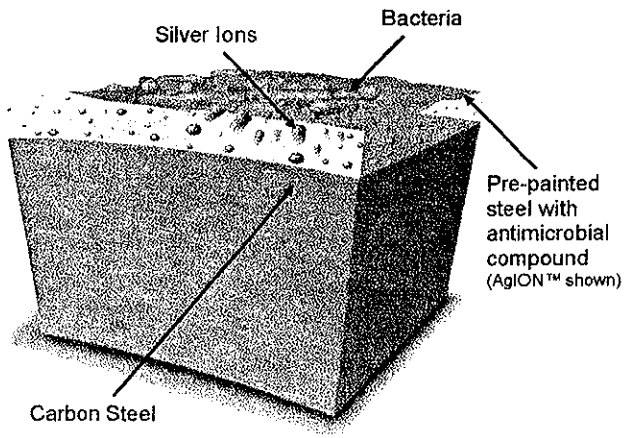


Figure 10

Cross Section of Coated Air Handler Panel

The following are important considerations when choosing an antimicrobial:

- Efficacy
  - Ensure that the chosen technology is right for the application
- Longevity
  - Understand the life expectancy / maintenance requirements
- Safety
  - Should pass long-term toxicity and biocompatibility tests
  - Meet UL Standard 723 (ASTM E-84) for smoke and flame spread

- Regulatory Status
  - The Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA) regulate antimicrobials
  - Should be EPA registered for use in HVAC components
  - Should be FDA listed for some applications related to food service
- Cost
  - Affects feasibility of applications

An example of an inorganic-based antimicrobial product that has been EPA approved for HVAC applications, and FDA approved for food service is Carrier's AgION™. Let's take a look at how this works. The AgION™ antimicrobial compound is a fine powder that withstands over 1400° F.

The silver ions reside in an open zeolite matrix structure. The zeolite acts as an ion pump causing a controlled release of silver ions over the life of the product. Silver ions – silver atoms with an electrical charge – are attracted to oppositely charged hydrogen ions – commonly found in most bacteria and microbes – like a magnet. Once the two ions connect, the hydrogen ions are no longer available for other chemical bonds, abruptly halting the bacteria and microbes' respiration and growth.

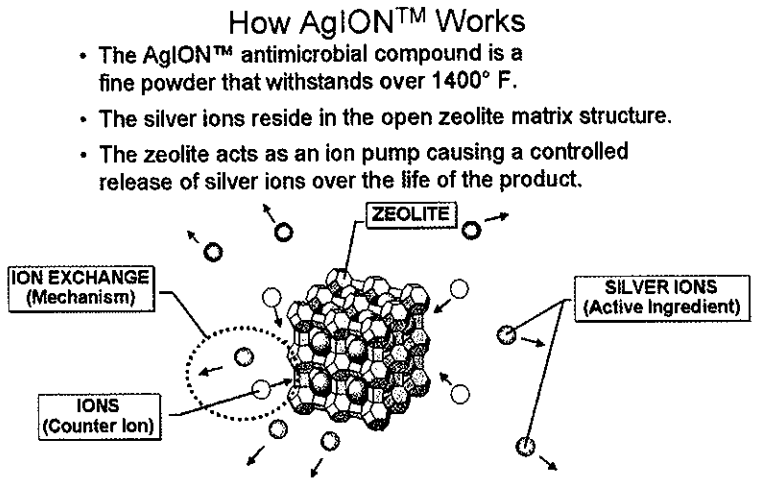
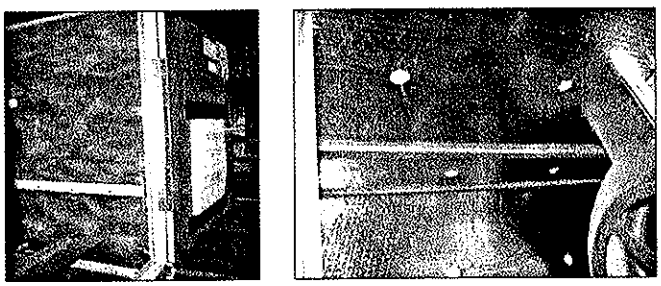


Figure 11

Silver Ion Antimicrobial

Insulation Types

Thermal performance of the air handler casing is important in today's energy-conscious market. Fiberglass is still the most widely used insulating material in air handlers. It provides good thermal performance at an economical cost and is easy to install. While it is available in many variations of thickness, density, rigidity and coatings, air handlers typically use two types of insulation; unfaced for double wall, and matte-faced for single wall units.



- 1-inch matte-faced fiberglass 1½ and 3 lb density available
- 1-inch foil-faced insulation reduces the potential for mold or bacteria and is easier to clean

Figure 12

Insulation – Single Wall Units

The R-value is the unit of measurement used to express the insulation's thermal resistance to heat transfer. The difference in thermal performance between density options is small. Only when you increase the thickness of fiberglass insulation do you see a difference in thermal performance. A 1-in. layer of insulation with a density of 1½ or 3 pounds yields the same approximate R-value. Increasing the thickness, however, would increase the R-value. The impact of insulation density is in sound transmission, where higher density provides greater attenuation.

While polyurethane foam insulations have been used extensively in appliances for years, they are just starting to be used in air handlers. With an R-value equal to about R-6 per inch, they can reduce the heat transfer through the casing by nearly 50 percent over fiberglass. Foams also offer several additional benefits over fiberglass:

- They do not absorb moisture. This is a very important point, because, wet fiberglass provides little insulating quality and can lead to the growth of mold and mildew and severe IAQ problems.
- They contain no fibers to get into airstream.
- They have a rigid board structure, so they eliminate any possibility of air leakage through the insulation.

Single-Wall vs. Double-Wall

The central station air handler market has begun to move away from single-wall construction to double-wall designs. The primary reason is the concern over the release of glass fibers from the insulation into the airstream and into the occupied building. The insulation used in single-wall air handlers is typically fiberglass with a rubberized or acrylic matte facing. The matte facing is designed to prevent erosion of the insulation that is exposed to air moving over it in the normal velocity ranges encountered in air-handling equipment. However, it is inevitable that some fiberglass fibers will be released into the airstream. Matte-faced insulation is also difficult to clean without damage to the facing. Facing damage will lead to erosion and increased fiber release. In recent years, a reinforced foil-faced insulation has been introduced to provide a higher level of cleanability in single-wall units.

Most codes also require that the air handlers, regardless of insulation type, meet the requirements of the National Fire Protection Agency (NFPA) Standard 90A for maximum limits on smoke generation and flame spread. This means that for single-wall units, the insulation itself must meet the NFPA standards, while on double-wall units the panel assembly must pass.

Double wall construction sandwiches the insulation, either fiberglass or foam between the outer casing and an interior metal liner. This prevents exposure of the insulation to the moving airstream, thereby minimizing the possibility that fiberglass particles can be carried into the space. In addition, the metal liner is easier to clean and may be painted or constructed of a variety of materials to suit the applications.

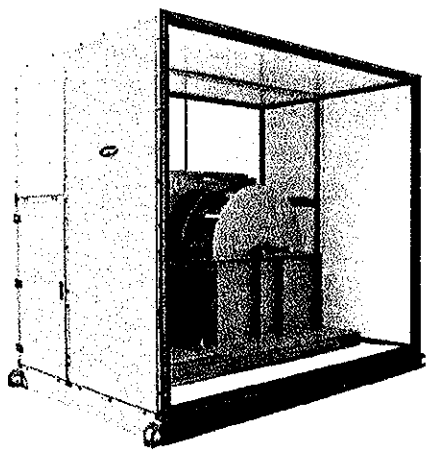


Figure 13

Double-Wall Construction

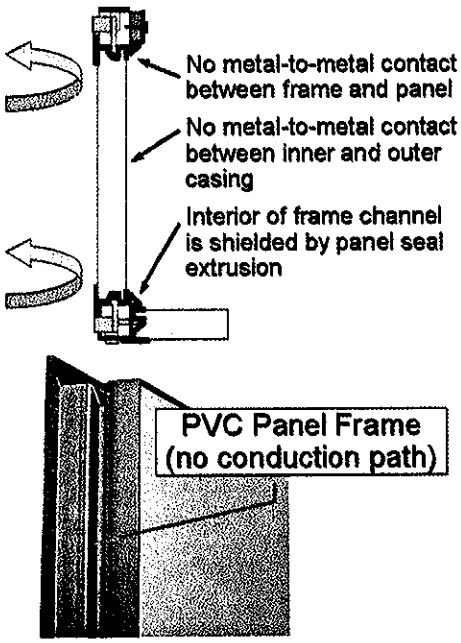


Figure 14

Thermal Break and Double-Wall Panel

Traditionally, engineers have specified panel metal gage for air handler casings. However, with recent advances in materials and technology, engineers recognize new laminate panel designs have allowed stronger, lighter, more thermally efficient casings to be developed. They also understand that strength is a function of entire structural design, not just surface skins and recognize that panel deflection is a more accurate measure of strength. As a result, they are replacing traditional sheet metal gage specifications with a maximum deflection specification for the panel assembly as shown.

Panels constructed with polyurethane foam form an extremely rigid, lightweight casing panel. In the panel shown here, the inner and outer skins have a flange formed along the edges to lock into an extruded PVC frame. When the panel is assembled, the cavity is filled with insulation that bonds to the inner surfaces of the steel pans and PVC frame to create a rigid, one-piece panel. The rigidity helps prevent the panel from deflecting under load, to minimize the chance for air leakage at the seal between the panel and the frame.

The PVC frame also provides a continuous thermal break to minimize heat transfer between the inner or outer surfaces of the panel, minimizing the possibility of the panels sweating.

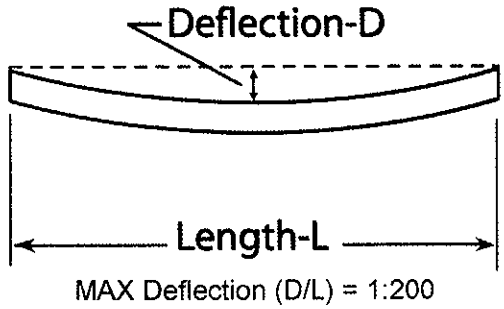


Figure 15

Panel Maximum Deflection

Seals

Seals are an integral part of a low-leak air handler. Advances in material and manufacturing technology have led to new products, which are being integrated into air handler product designs. Closed cell foam gaskets lose their resiliency with age, but are effective in joints that are not repeatedly opened, such as between sections. In a joint that may be opened from time to time, such as access or panel joint seals, foam gaskets may not reseal as well as when they were new. Joints that are frequently opened should have a resilient seal that is designed to maintain its shape and sealing ability after repeated compression cycles. As a result, automotive-type bulb seals are becoming more prevalent in standard air handlers today.

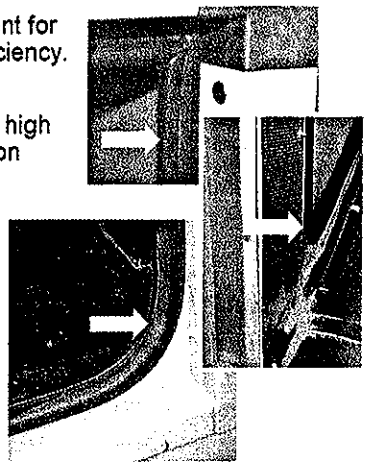


Figure 16

Casing Seals

Air Handler Types

Indoor Units

Indoor air handlers may be built in horizontal, vertical, or stacked configurations, and allow air inlet and discharge connections on top, bottom, and sides. This allows the designer greater flexibility to accommodate obstructions and other obstacles when making duct connections. To facilitate rigging and installation into existing equipment rooms or tight spaces, indoor units are frequently shipped to the jobsite in separate sections. Once in place, the sections would be connected together and installation completed. Care should be taken to allow adequate service clearances in accordance with manufacturers' recommendations.

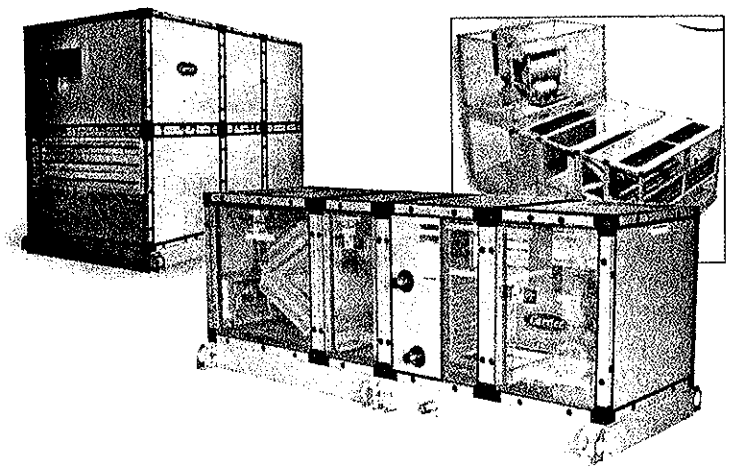
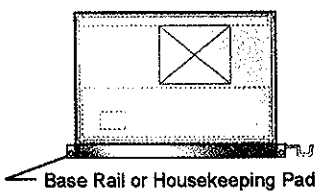


Figure 17

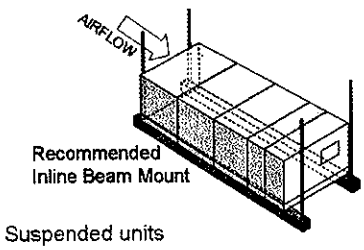
Indoor Air Handler Types – Horizontal, Vertical, Stacked

Units may be floor-mounted or suspended. Floor-mounted units may require space beneath them to allow room for construction of a condensate drain line trap. Since the condensate drain outlet is usually at the lowest point in the unit, the unit may have to be raised off the floor. This can be done by means of a concrete housekeeping pad or structural steel rails under the unit. However, most manufacturers can provide base rails ranging from 6 to 12 inches in height as an integral part of the unit to save the contractor time and money. If the base rails are high enough, the condensate drain trapping can be accomplished within the base rail height.



Floor-mounted units

- AHU must be elevated enough to allow for condensate drain trapping
- Factory-supplied base rails (full perimeter recommended)
- Field-constructed rails or concrete housekeeping pad
  - Added labor and material costs



Suspended units

- Follow manufacturer recommendations on unit support
- Locate units over NON-critical spaces to prevent:
  - Water leaks that could damage sensitive equipment or materials
  - Sound that could be objectionable
  - Restricted service access

Figure 18

Indoor Unit Mounting Considerations

Outdoor Units

Units intended for outdoor installation are designed to withstand weather conditions such as sun, wind, rain, and snow. The casings are generally constructed using G-90 mill-galvanized steel, which has a higher corrosion resistance (more zinc) than typically used on indoor units. Many manufacturers also offer painted casings for appearance as well as added durability. The exterior should have the appropriate salt-spray rating for the installation's requirements. Additionally, stainless steel or aluminum construction of the exterior panels should be used where corrosion poses serious risk to unit integrity.

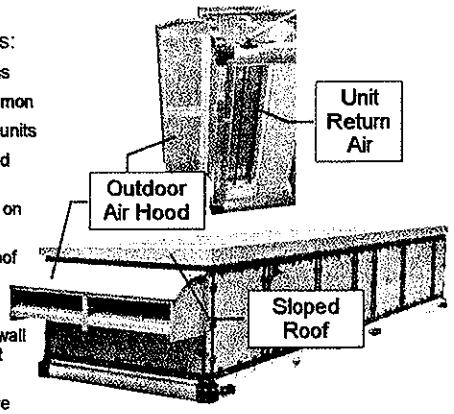


Figure 19

Outdoor Air Handler Design Features

Most outdoor units are designed to sit on a continuous curb like a packaged rooftop unit. They may also be installed on slabs, structural steel rails, or piers.

Because air handlers frequently operate at high static pressures, rain and outside air may be drawn in through any small cracks or openings. As a result, outdoor units generally employ the following design features:

- single-piece designs or weather-tight connection flanges
- sloped roofs that overhang the side panels to shed rainwater and provide positive drainage of melting snow. On units with single-side access, roof should slope away from the access-side of the unit. Roof panels should have standing-seams construction to allow water runoff without risk of penetration of the exterior skin.
- horizontal or bottom inlet air openings. Top inlets and discharge connections are discouraged due to potential leak risk
- high quality seals or caulk on all seams
- air inlet hoods with mist eliminators or weather-tight louvers
- exhaust hoods with insect screens
- double-wall construction with at least 2-inch walls to minimize thermal heat transfer and provide additional sealing surfaces

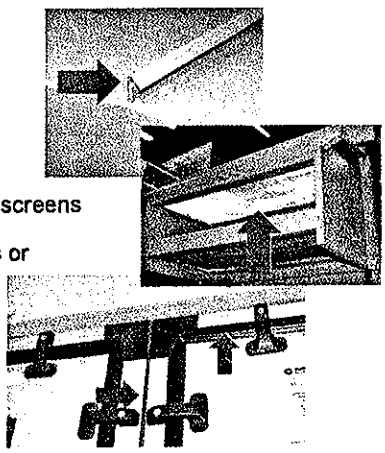


Figure 20

Additional Outdoor Air Handler Design Features

Draw-Thru and Blow-Thru

Central station air-handling units are generally classified as "draw-thru" units or "blow-thru" units, based on the relative position of the cooling coil with respect to the supply air fan. In draw-thru units, the cooling coil is located upstream on the inlet side of the fan. The fan draws, or pulls, the air through the cooling coil and other components and discharges it from the fan outlet directly into supply air ductwork. Draw-thru units are by far the most common, as they provide even air distribution over the cooling coil.

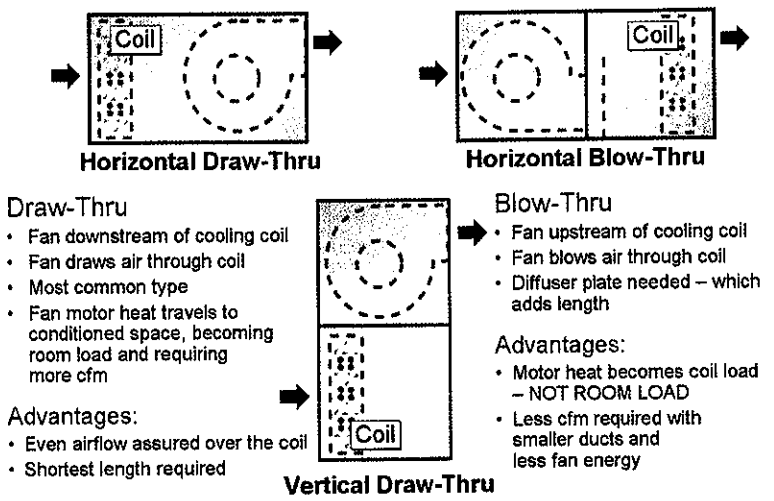
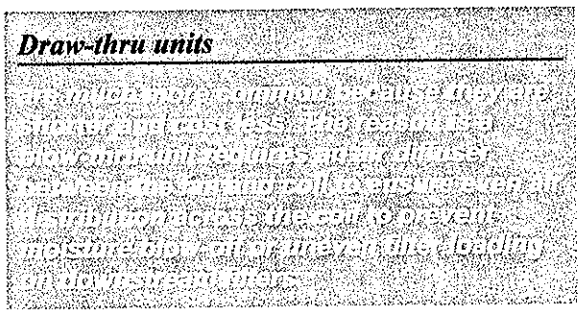


Figure 21

Draw-Thru and Blow-Thru Configurations

In a blow-thru unit, the cooling coil is on the discharge side of the fan, which blows or pushes the air through the coil. Blow-thru units have the advantage of allowing a reduction in the supply airflow vs. draw- thru units because the fan motor heat is immediately absorbed by the cooling coil as an equipment load, not transferred to the supply duct and conditioned space.



Coils

Most air handlers will typically include a section with cooling coils, heating coils or both. Cooling and heating coil sections are generally designed with tracks or coil mounting rails that accept a family of coils of various rows and circuiting.

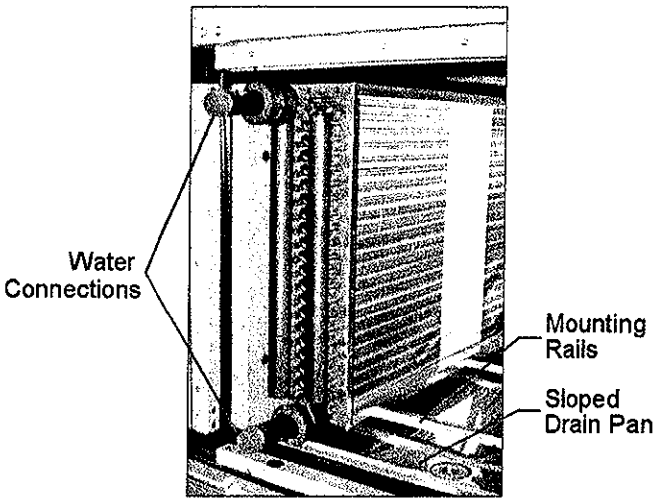


Figure 22

Cooling Coil Section

Types and Construction

Cooling coils are designed for use with chilled water or liquid refrigerant (direct expansion, or DX cooling coils). These are available in a variety of row depth, fin spacing, fin design, fin material, circuiting, and, in the case of DX coils, a variety of coil split arrangements.

Coil row offerings may vary from 2 to 12 rows with 4, 6, and 8 being predominantly used in the comfort air-conditioning industry.

Aluminum and copper are the materials used almost exclusively for both the tubes and fins of cooling coils, with copper tubes being used for the vast majority of commercial comfort applications. Aluminum fins are mechanically bonded to copper tubes by an expansion process as shown in Figure 24. Aluminum fins are used most extensively for air-conditioning duty. Copper fins, being more expensive, have limited usage but are definitely required as a minimal precaution against coil corrosion in applications where the coil is exposed to airborne materials such as hydrogen sulfide, sulfer

- Types
  - Chilled water (CW)
  - Direct expansion (DX)
  - Variety of rows, fin spacing, and splits
- Materials (Common)
  - Plate fins
    - Aluminum
    - Copper
  - Copper tubes
    - Multiple wall thicknesses
- Casings
  - Galvanized steel
  - Stainless steel

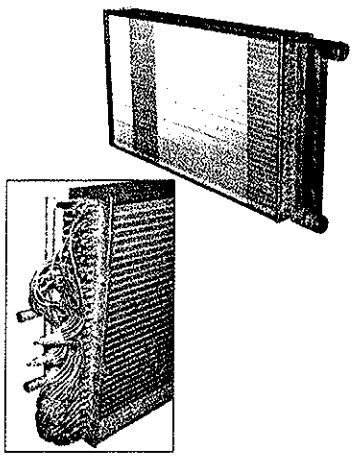


Figure 23

Cooling Coils

dioxide or (in high concentrations) carbon dioxide. Highly corrosive atmospheres, such as those encountered in many industrial process applications, may require special coil coatings to insure protection beyond that afforded by copper fins. Each of these situations should be individually analyzed with the aid of consultation from the equipment manufacturer. A more detailed description of coil construction features, circuiting, performance, and selection can be found in TDP-614, Coils: Direct Expansion, Chilled Water, and Heating.

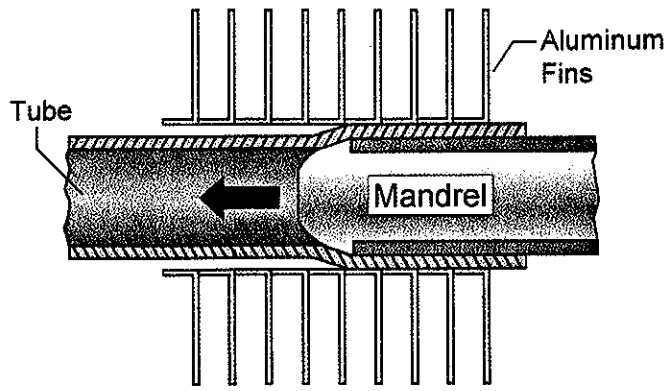


Figure 24

Mechanical Bonding Fins and Tube

Drain Pan

Cooling coil sections will always contain a drain pan to collect the condensate water extracted from the air passing over the coil. ASHRAE Standard 62 requires drain pans that do not allow standing water. To meet this requirement, drain pans will generally be sloped to a recessed bottom drain outlet. Drain pans will generally be constructed of galvanized or stainless steel, and may be coated with antimicrobial coatings to inhibit the growth of mold and bacteria.

Drain pans must be insulated to prevent the condensation of moisture on the outside of the unit casing. The insulation within the drain pan should be closed-cell foam, which is water resistant, and should be the full thickness of the casing insulation at the drain outlet to provide adequate thermal resistance. Fiberglass is not acceptable for this purpose as it will absorb water, lose its insulating properties, and provide a site for mold and bacterial growth.

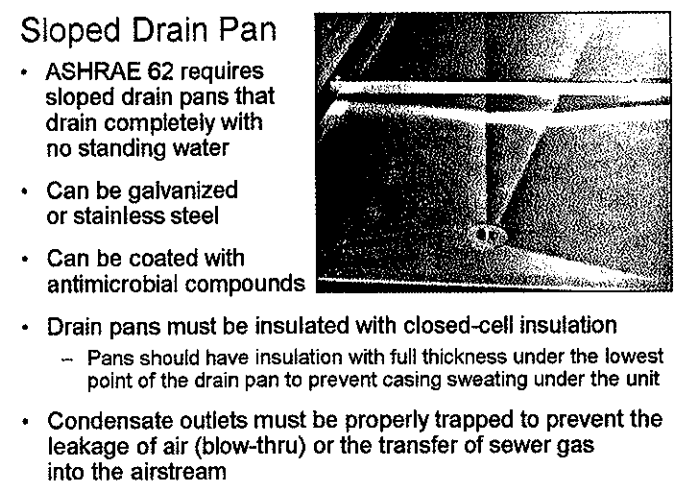


Figure 25

Cooling Coil Sections – Drain Pan

Condensate Drain Trapping

Condensate drain outlets must be properly trapped to isolate the air-handling system from the building drain system. Without traps on draw-thru units, air may be drawn into the air handler, introducing potentially objectionable smells and gases into the building. It can also impede water flow into the drain and cause water to backup into the drain pan. On blow-thru units, conditioned air can be lost, reducing the efficiency of the system.

The trap depth will be dependent on static pressure, either positive or negative, at the drain location. When calculating trap depth on draw-thru or blow-thru applications, remember that it is not the total static pressure, but the upstream or downstream static resistance that is trapped against. For instance, when calculating the trap depth for a cooling coil condensate pan on the draw-thru side, trap against the coil pressure drop in that coil section and any other pressure drops upstream of it.

When calculating trap depth on draw-thru or blow-thru applications, remember that it is not the total static pressure, but the upstream or downstream static resistance that is trapped against. For instance, when calculating the trap depth for a cooling coil condensate pan on the draw-thru side, trap against the coil pressure drop in that coil section and any other pressure drops upstream of it. Example of draw-thru trap:

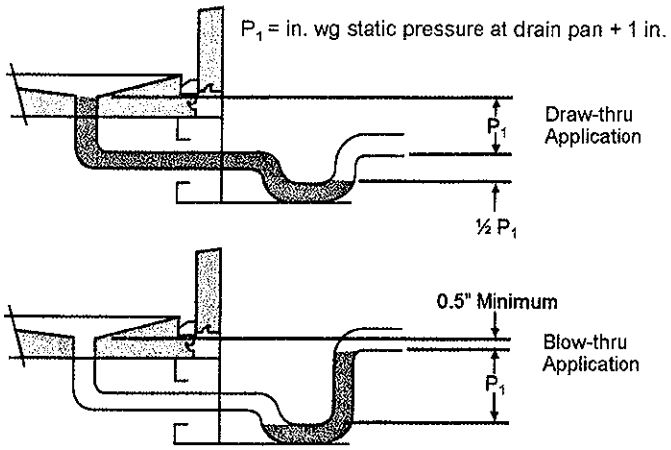


Figure 26

Condensate Trap Construction

- Return duct 0.5 in. static
- Mixing box 0.4 in. static
- Filters 0.2 in. static
- Heating coil 0.2 in. static
- Cooling coil 1.2 in. static

Total 2.5 in. static

To calculate trap depth,

If calculating the trap dept for the cooling coil, the total trap static would be 2.5 in. plus 1 in. safety factor (P_1 = negative static pressure +1 in.) as shown.

Traps on draw-thru units must store enough condensate to prevent losing the drain seal at start-up. The "minimum ½ P_1" dimension ensures that enough condensate is stored.

To determine the trap dimension for blow-thru units, find the coil's maximum positive pressure and add ½ in. safety factor. This figure is normally the fan total static pressure (P_1 = fan total static pressure).

For all units, provide condensate freeze-up protection as required. On units with internal spring isolators, be sure the unit is mounted to allow sufficient clearance for the required drain trap depth.

Fan Section Characteristics and Performance

Central station air handlers offer the designer the option to position fans in a variety of locations within the air handler to operate as supply, return, or exhaust fans. In addition, multiple fan wheel types increase the flexibility of an air-handling unit to meet differing application requirements. Each fan location has its advantages and disadvantages, making each a better application under specific circumstances.

Once an air handler unit size, configuration, and component selections are complete, the fan can be selected. Due to the variety of components offered, air handler fans are selected on the basis of total static pressure (TSP), rather than external static pressure (ESP), which is common on packaged HVAC products. Therefore, static pressure losses of all components of the airside system, both inside the air handler (dampers, filters, coils, etc), and external (ducts, dampers, diffusers) must be included in the fan total static pressure requirements. Most manufacturers provide selection software to aid in this process. Quite often, more than one fan will meet the performance requirements. At this point, the system designer must select the best fan, considering first cost, operating cost, and acoustics. For variable air volume (VAV) applications, part load stability must also be evaluated.

Supply Fan

Every air handler will have a supply air (SA) fan that must overcome all static pressure losses in the duct system, including internal unit components. Supply fans are offered in both draw-thru and blow-thru configurations. A draw-thru supply fan is intended to have the fan discharge connected directly to a supply duct fitting. The inlet will be connected to other sections of the air handler. A blow-thru supply fan differs from a draw-thru unit in that the casing is connected to additional downstream sections such as coil, filter and discharge plenum sections. Blow-thru fans with downstream coils or filters should have a diffuser plate, as shown by the dotted line in Figure 27, mounted downstream to break up the high velocity discharge air profile leaving the fan to ensure even air distribution over the downstream components. The diffuser may be built into the fan section, or a separate section type, depending on the manufacturer.

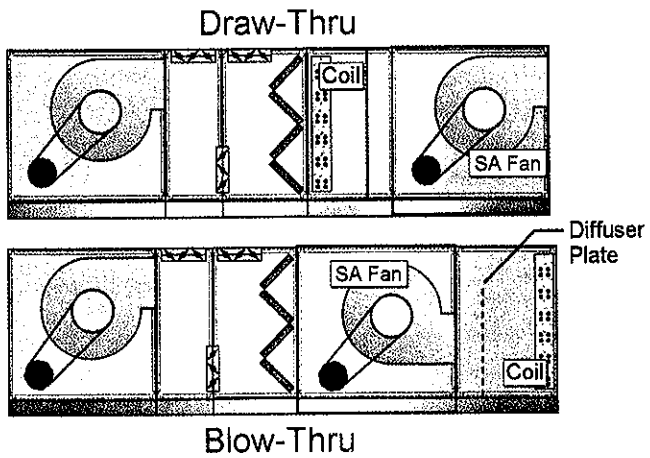
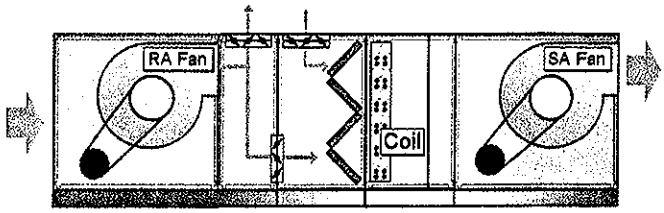


Figure 27

Supply Fan Locations

Return Fan

Return air (RA) fans are used in applications with long or complex return duct runs. Without them, the supply fan would over-pressurize the building in an attempt to push the air back through the return. This can cause problems opening doors, excessive exfiltration, excessive pressurization of membrane roofs, and other building problems. Return fans are configured to run anytime the supply fan is operating, and are generally sized to handle the same airflow as the supply fan, less any direct exhaust (such as toilets, fume hoods, etc) that is not returned to the AHU.



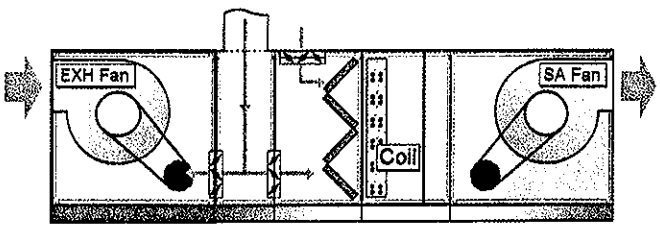
- Prevents excessive building pressurization
- Used in systems with high return duct pressure drops
- Runs only when supply fan is operating
- Generally controlled by building pressure sensor or tracks the supply fan on VAV systems
- Sized for less airflow than supply fan

Figure 28

Return Fan Features

Exhaust Fans

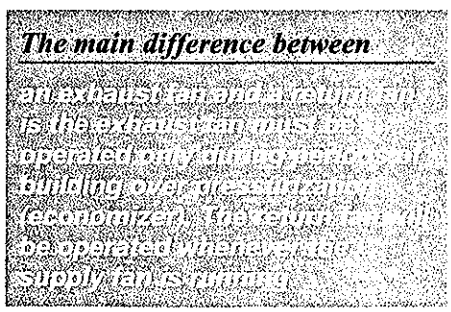
Exhaust fans are generally used where the return duct static losses do not require a return fan. The exhaust fan purpose is to alleviate temporary building over-pressurization conditions, which would exist during periods of time when the unit is in economizer or "free cooling" mode, bringing in a high percentage of outdoor air and barometric relief dampers cannot be used effectively. During these times, the mixing box return air damper would be closed or nearly closed. The exhaust fan would then be started to evacuate the exhaust air from the building and maintain reasonable building pressures.



- Prevent excessive building pressurization
- Operates only during "economizer mode" or when a high percentage of ventilation air is being drawn in
- Return air damper closed or nearly closed
- Sized to prevent building overpressurization

Figure 29

Exhaust Fan Features



Fan Discharge Arrangements

Discharge options provide the system designer with the flexibility to assemble air-handling unit combinations that fit the mechanical space and permit duct alignment that is efficient and simple to fabricate.

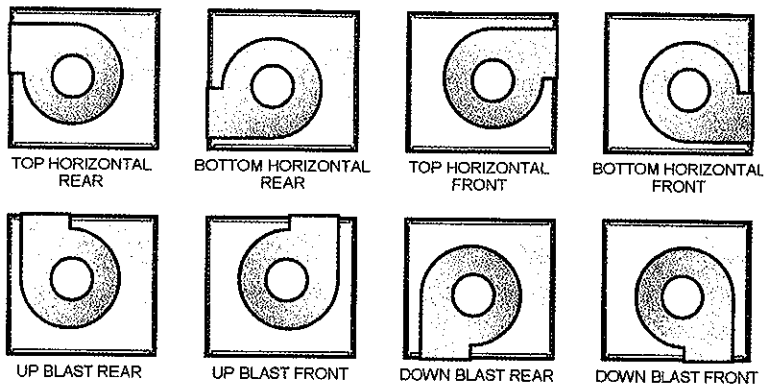


Figure 30

Fan Discharge Arrangements

Centrifugal Fan Types

As mentioned previously, most air handler manufacturers also offer multiple fan wheel types. While custom air handlers sometimes incorporate the use of axial, tubular, and mixed flow fans in high airflow applications, they will not be discussed in detail in this book. Refer to TDP-612, Fans: Features and Analysis, for discussion on these types of fans. Centrifugal fans are most commonly used in air handlers, which we will discuss here.

Twin fan arrangements (two fan wheels on a common shaft) are often used by custom manufacturers and some packaged air handlers to provide more uniform airflow across coils and are often selected to reduce the aspect ratio often associated with large flow rates.

Critical applications

Forward-Curved Impeller

Forward-curved (FC) centrifugal fans have a large number of blades that are curved in the direction of airflow. They produce large volumes of air at low static pressures, typically up to about 5 in. wg. They are fairly lightweight and provide a cost-effective solution to many applications. As a result, they are generally the designer's first choice when the application permits.

Characteristics:

- Most commonly used wheel in HVAC
- Light weight – lowest cost
- Operates at static pressures up to 5 in. wg max.
- 24 to 64 blades
- Low rpm (800-1200 rpm)

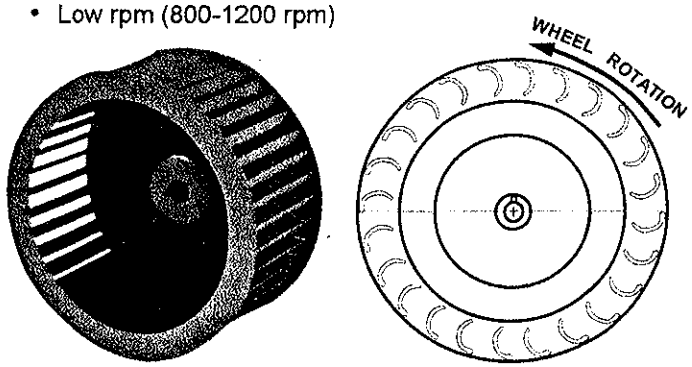


Figure 31

Forward-Curved Wheel Design

DWDI fan wheels

pull air in both sides at once. SWSI wheels (shown here) utilize a single side inlet.

Backward-Inclined Impeller

Backward-inclined (BI) centrifugal fans have blades with tips that point in a direction opposite their direction of rotation. They have fewer, heavier blades than forward-curved fans, and as a result they operate at higher speeds, producing lower volumes for a given fan size, but are capable of producing higher static pressures.

Characteristics:

- For medium to high air capacity and pressure applications (4 -10 in. wg)
- Comparison to airfoil:
  - Less efficient
  - Higher sound levels

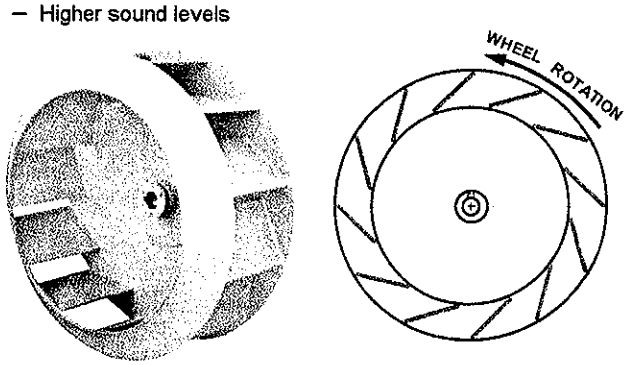


Figure 32

Backward-Inclined Wheel Design

Airfoil

Airfoil (AF) centrifugal fans are an aerodynamic variation of the backward-inclined fan. In contrast to the backward-inclined single-thickness blades, airfoil fan blades are double-thickness, with an airfoil cross-section. As such, they have similar performance characteristics, but with improved efficiency. They are generally preferred over their backward-inclined counterparts, even though they have slightly higher cost.

Characteristics:

- Aerodynamically designed – double thickness airfoil shape for maximum efficiency
- For medium to high air capacity and pressure applications (4 -10 in. wg)
- Lower sound levels than backward inclined fans
- Higher cost due to efficiency of design

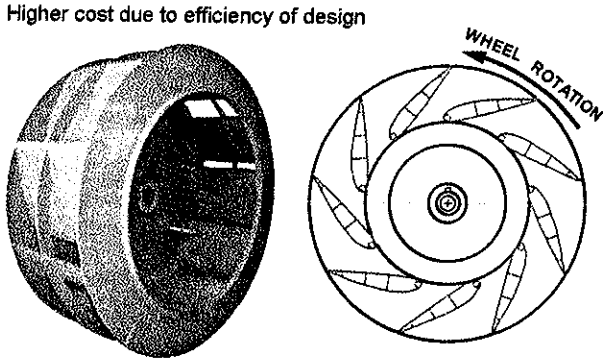
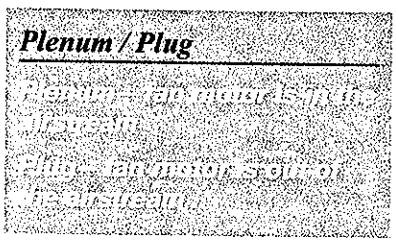


Figure 33

Airfoil Wheel Design

Plenum Style

Plenum fans are un-housed centrifugal fans that pressurize a plenum chamber rather than accelerate air into a duct. Generally, plenum fans use single-width, single-inlet (SWSI) airfoil wheels. The ability to field connect outlet ducts to the plenum in many configurations is the salient benefit of a plenum fan.



Characteristics:

- Single-Width; Single-Inlet (SWSI)
- Operates at static pressures up to 10 in. wg
- Best application with limited space or multiple ducts

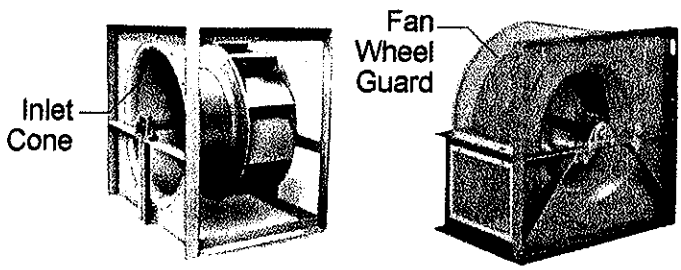


Figure 34

Plenum fans (SWSI)
Fan wheel guard photo courtesy of Barry Blower

VAV Fan Volume Control

Central station air handler fan sections are frequently used in variable air volume (VAV) systems. As its name implies, the airflow required by the system varies based on the position of the dampers in the VAV terminals. As a result, the fans need to employ some means of part load control. Let's take a look at the most common methods. Refer to TDP-613, Fans in VAV Systems for a complete discussion on fan modulation.

Riding the Fan Curve

The simplest method is called riding the fan curve. No additional control devices are necessary, and therefore it can be an easy, cost-effective solution. The fan simply reacts to a reduction in airflow according to its pressure-volume characteristics. Since the fan is running at a constant speed, the performance will track along its constant speed curve.

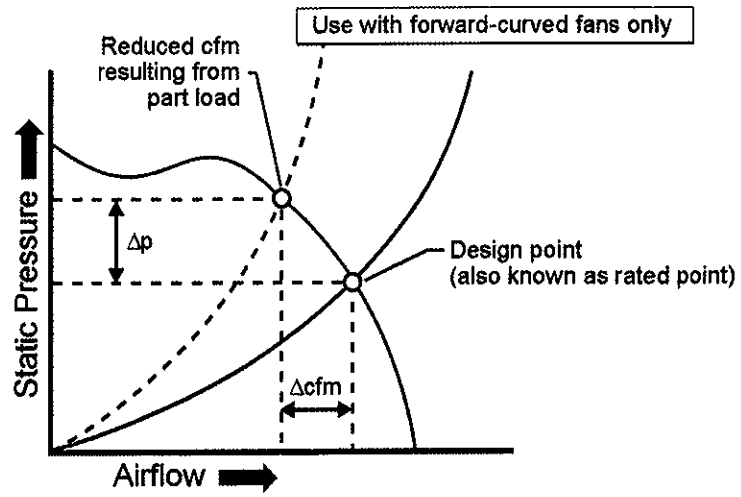


Figure 35

Riding the Fan Curve

This method should be used only on forward-curved centrifugal fans, which have a relatively flat system curve. In other words, large changes in airflow only result in small changes in static pressure. Care must be used to ensure that the additional static pressures encountered at low flow do not exceed the VAV terminal damper limits. Speed curves of backward-inclined and airfoil are too steep for this method of control to be used.

Inlet Guide Vanes

Figure 36 shows a close-up view of a typical inlet guide vane (IGV) assembly. The IGV is fastened to each inlet of the fan and is controlled from a fully open to fully closed position by a static pressure regulator using a sensor in the supply ductwork. A damper actuator moves the control arm to modulate the vanes. Inlet guide vanes reduce the fan capacity and required brake horsepower by reducing the area of the fan inlet. By adding pre-swirl to the air as it enters the fan inlet, they increase the fan efficiency. The drawbacks to IGVs are high first cost, setup and maintenance costs, and the increased pressure drop of the guide vane assembly. They can also be a source of additional unwanted noise. For these reasons, they are rapidly being replaced with variable frequency drives.

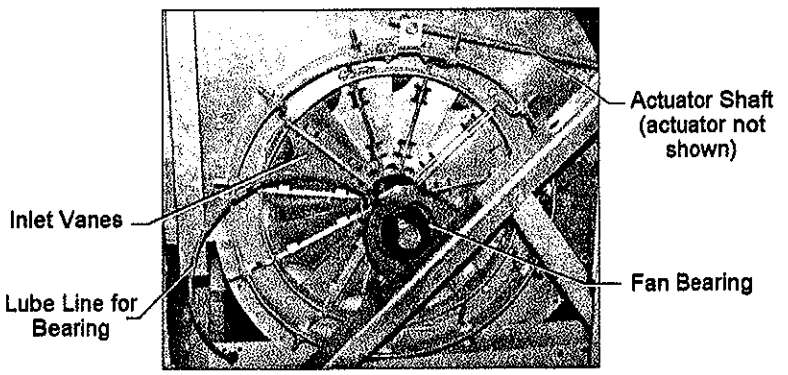
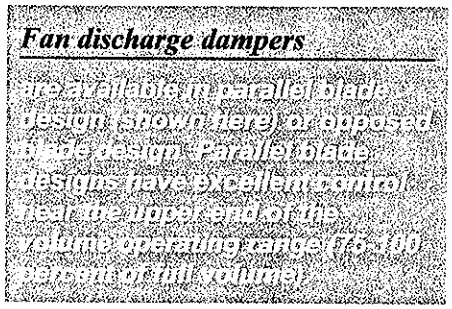


Figure 36

Inlet Guide Vanes

Discharge Dampers

Fan discharge dampers may be applied only to forward-curved centrifugal fans as shown in Figure 37. They must not be used on backward-inclined or airfoil impeller designs, as damage can occur to the fan housing, duct, and dampers due to the high pressures that are possible if the damper was to close. While they reduce fan capacity with an accompanying brake horsepower savings, they are rarely used today.



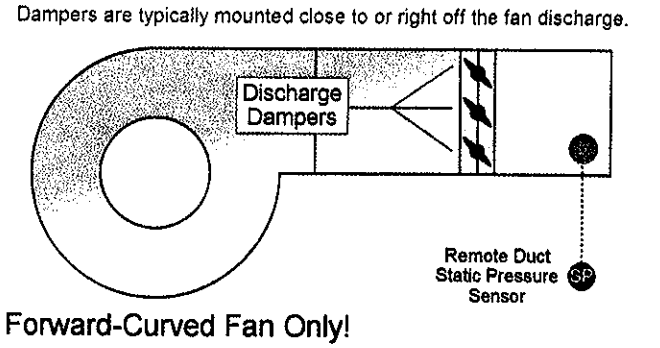


Figure 37

Discharge Dampers

Variable Frequency Drives

Over recent years, improved reliability and lower first cost have allowed variable frequency drives (VFD) to replace inlet guide vanes as the most common method of fan volume control. They provide the most flexibility with the least maintenance. They also yield the highest energy savings of all the volume control methods and do not contribute to fan noise.

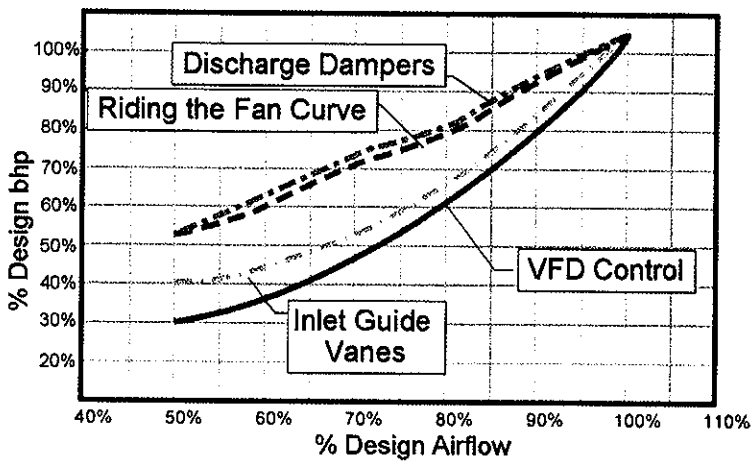


Figure 38

Comparison of Fan Modulation Methods

AMCA Fan Class

The Air Movement Control Association, Inc. (AMCA) has established classifications for centrifugal fans that define fan class as a function of minimum operating performance (AMCA Standard 99). There are three classifications: Class I, II, and III, with Class III being the highest performance. The class standards are based on a concept of mean brake horsepower per square foot of outlet area. A representative graph of performance for a given type of centrifugal fan is shown.

Performance is defined as a function of fan static pressure (in inches of water gauge) and fan outlet velocity (in feet per minute). Outlet velocity is used rather than airflow volume to enable the classification to apply to both large and small fans.

A system designer has two criteria, fan performance and fan construction, when selecting a fan. By defining fan performance, the AMCA classifications indirectly represent the structural limitations of a centrifugal fan design. For a given size of fan, a Class III version will be more sturdy and rugged than a Class II version simply because of the static pressure, velocity, and horsepower requirements to perform in that class. Either fan, however, may be operated at the same performance point (i.e., in the Class II range) and work equally well for the application. Even though a Class II fan will work, the system designer may specify Class III simply to get a more ruggedly built fan.

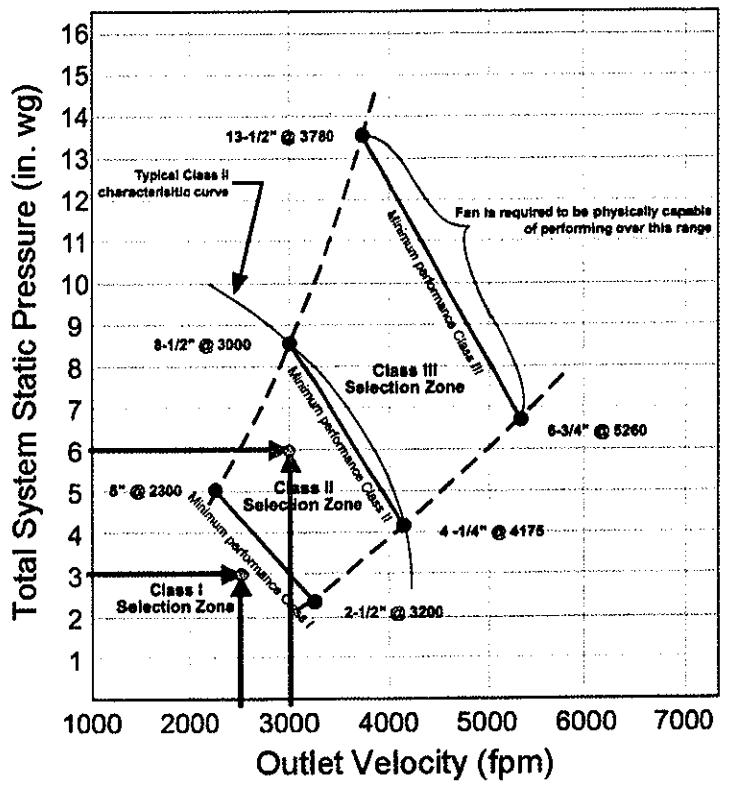


Figure 39

AMCA Fan Construction Class

If the fan discharge velocity is 3000 fpm and the total system static pressure is 6 in. wg, the operating conditions fall within the AMCA Class II range and a Class II fan should be considered for this application. If the fan discharge velocity is 2500 fpm and the total system static pressure is 3 in. wg, the operating conditions fall within the AMCA Class I range and a Class I fan could be used for this application.

Fan Components

Fan Mounting

Depending on the application, a system designer may choose to specify the air-handling unit with internal isolation of the fan and motor, or choose to externally isolate the entire unit. Coil sections, mixing boxes, and other modules, may be isolated as a complete assembly. In this latter circumstance, internal fan isolation is redundant. Fan sled, or assembly, isolators with a one or two-inch static deflection are most common.

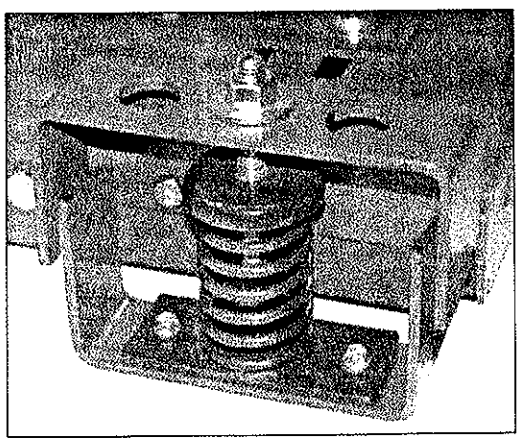


Figure 40

Fan Spring Isolation (Standard 2-inch)

Discharge Isolation

The fan discharge must be isolated to prevent transmission of vibration and noise to the attached ductwork. The traditional method of accomplishing this transition is with a short section of flexible, canvas duct.

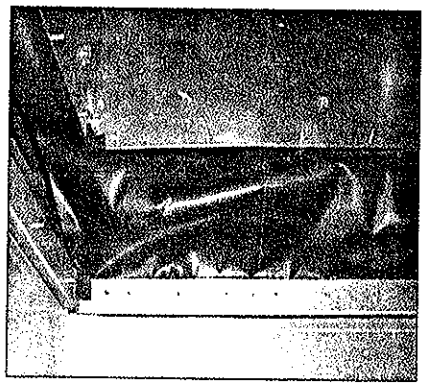


Figure 41

Traditional Canvas Connector

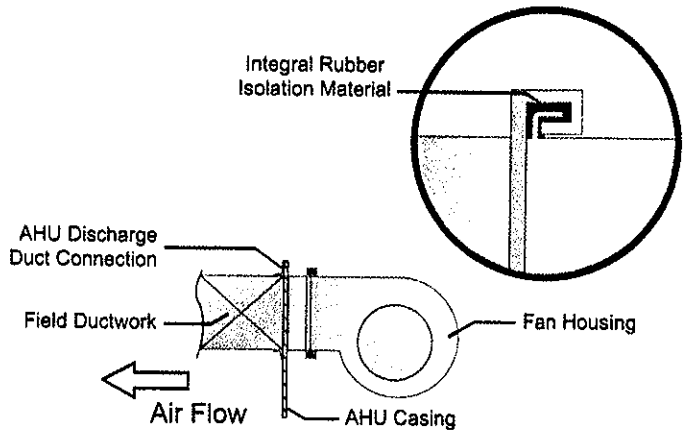


Figure 42

Rubber Connector

Some manufacturers use a vibration-absorbing rubber isolator that performs the same as a rubber-in-shear isolator in lieu of canvas.

Bearings

Fan manufacturers use several different types of bearings in their product line. That is because the bearings on a small gas furnace are subject to a different loading than those on a large central station air-handling unit. The important terms that one should understand apply to many bearing types. Fan manufacturers work with bearing suppliers to establish a level of quality and assure the bearing life expectance required by the HVAC industry.

Bearing Life

The life of a bearing is a function of the number of revolutions it experiences before developing evidence of fatigue in the moving elements. The terms that have been used in the industry are B_{10}, L_{10} and B_{50} or L_{50}. The terms B_{10} and L_{10} mean the same thing, as do B_{50} and L_{50}. The current terms to be used are L_{10} and L_{50}.

The American Bearing Manufacturer's Association (ABMA) defines L_{10} as the bearing life associated with a 90 percent reliability rate when operating under normal conditions. Normal operation means the bearing was kept clean, properly lubricated, operated at a reasonable temperature, and free of dust and debris with perfect alignment. In reality, this may not be the case, so the actual life of the bearing can be shortened based on the application conditions. However, following the manufacturer's installation and maintenance requirements will help extend the life to the manufacturer's specified values.

The designation L_{50} indicates the duration in hours that one half (50 percent) of the bearing can be expected to survive without showing evidence of failure. Conversely, it is the life at which one half of the bearings can be expected to fail. Thus a bearing with a longer L_{50} life rating for a given application can be expected to perform more reliably than another bearing with a shorter L_{50} life rating. L_{50} life equals five times the L_{10} life.

To get a L_{50} life equal to a L_{10} 100,000 life, you must specify the L_{50} life to be 500,000 hours.

Bearing life is useful when specifying a level of bearing construction. When required to provide a given life such as L_{10} all equipment manufacturers must supply the same capability bearing for the same given application. A 100,000 hour L_{10} bearing will have a life over twice as long as 40,000 hour L_{10} bearing and hence should last longer on a similar field application.

Hours and Years

How long is 200,000 hours? The following table converts hours to years based on different daily usage.

Hours	Years		
	8 hours per day	16 hours per day	Continuous Duty
40,000	13.7	6.8	4.6
100,000	34.2	17.1	11.4
200,000	68.4	34.2	22.8
400,000	137.0	68.4	45.8
500,000	171.0	85.6	57.0
1,000,000	342.0	171.0	114.0

Bearing Selection

Most manufacturers select their bearings as an integral part of the air-handling unit fan design. Some of the main selection criteria include shaft diameter and weight, motor horsepower range, weight and location on the shaft, maximum fan speed, fan wheel weight, and the direction of belt pull.

Ball bearings with stamped steel housings are well suited for applications with light loads, as in smaller equipment. The use of these bearings is limited to fan products with ¾ inch and smaller diameter shafts, and one horsepower and smaller motors, such as small fan units.

Air-handling units will tend to use ball, spherical, or tapered roller pillow block or flange-mount bearings. Once the application exceeds the speed limit for the contact seal and lubrication capabilities of the solid housing, a pillow block bearing is typically specified. The pillow block design incorporates a friction-free seal and a larger grease cavity. Higher speeds can then be attained and the rollers become the limiting factor instead of the seal.

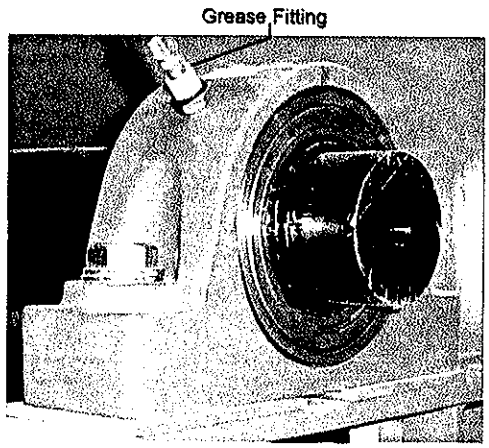


Figure 43

Typical Pillow Block Bearing

To enhance accessibility, it is often desirable to extend the bearing lubrication lines to the drive side of the fan. In some cases customers want the lubrication lines and fittings extended to the cabinet exterior so that bearing lubrication can be performed without stopping the unit. But, customers should also consider the downside of extended lube lines. Bearings should be inspected at the time of lubrication to look for improper operating conditions or signs of failure. If lube lines fail or vibrate loose, lubricating grease may never reach the bearing, creating an ideal condition for premature bearing failure. Also, bearings can be over-lubricated, in which case seals are dislodged, allowing the surplus lubricant to escape.

Drives

The one fan component that is most subject to wear is the drive. The primary function of the fan sheaves and V-belts is to transfer the speed and horsepower of the motor to the fan. In addition, the drive components must be selected to withstand the high-torque overload condition and belt slippage that occurs when the fan starts.

The fan drives are either fixed drive or adjustable drive. When a unit is furnished with an adjustable drive, the fan sheave diameter can be changed to fine tune the fan speed and performance.

The service factor indicates the drive's ability to perform reliably during overload conditions. Continuous duty fans are often specified with a higher service factor.

- **Belt drive is most common on central station units**
  - Adjustable pitch for low bhp
  - Fixed-pitch for bhp >15
- **Service factors typically 1.5 or higher**
- **Drive losses typically 3 to 5%**
  - Typically NOT included in fan selection software

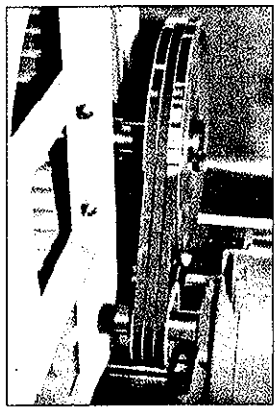


Figure 44

Types of Motor and Drive Arrangements

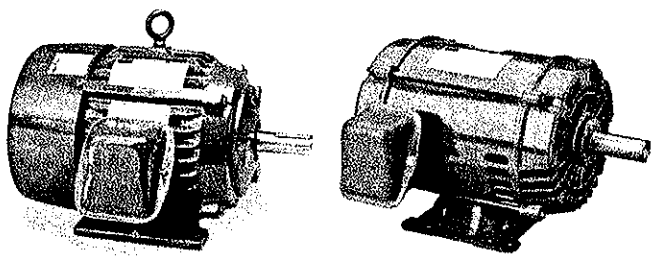
Overload Service Factors						
Percent Overload	0	25	50	75	100	150
Service Factor	1.0	1.1	1.2	1.3	1.4	1.5
Note: Design horsepower is equal to the indicated horsepower times the service factor. For continuous duty (16-24 hours per day) add 0.1 to the service factor						

The fan drives are either fixed drive or adjustable drive. When a unit is furnished with an adjustable drive, the fan sheave diameter can be changed to fine tune fan speed and performance. Although this is good for balancing the system, it is suggested that variable pitch drives be replaced with fixed pitch drives once the desired drive speed is obtained since variable pitch drives are more difficult to keep in balance.

Motors

Customers may have specific motor requirements dictated by environmental conditions or other system considerations. In addition, motors used with variable frequency drives must be specifically rated for use with VFDs.

A totally enclosed fan-cooled motor is a motor that is equipped for exterior cooling by means of a built-in fan. TEFC motors are used when water may splash or drip on the motor. An open drip proof motor has openings for ventilation air to cool the windings inside. The openings are positioned such that droplets from above would not interfere with the motor operation.



Totally Enclosed Fan-Cooled (TEFC) Motor

Open Drip Proof (ODP) Motor

Figure 45

Fan Motor Types

The Energy Policy Act of 1992 (EPAct) enacted by Congress set minimum efficiency levels for motors manufactured alone or as a component of another piece of equipment using general purpose motors rated for continuous duty and induction motors of NEMA designs A and B. Design A and B refers to the insulation class used in the motor and is based on the temperature rise above the cooling medium (air).

Unit Accessories

Most air-conditioning jobs today require more than just the basic air-handling unit components. Air handlers must also be responsible for mixing, heating, cleaning, and humidifying the air. Therefore, a number of accessory components are available which may be used to provide these supplementary functions. Much of the flexibility of application, which central station air handlers possess, comes from the variety of basic unit components (fan types, coil types, etc.) as well as accessory items which are offered with the unit.

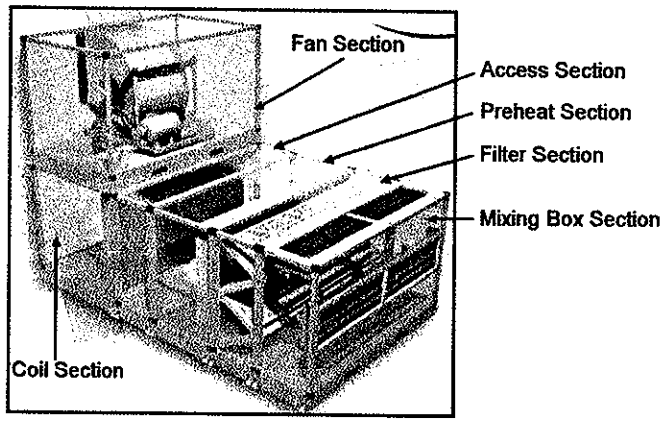


Figure 46

An Example of an Air Handler with Multiple Components

Filter Sections and Filters

Filtration is an important factor in maintaining indoor air quality and system efficiency. Multiple filtration options give the system designer necessary flexibility to specify the arrangement, media type, and media efficiency necessary to meet a customer's unique requirements. While the system application will dictate the level of filtration required, the internal air handler components (coils, fans, etc.) must be protected from airborne contaminants. For this reason, most air handlers will have filtration installed in a draw-thru position following the mixing box, and upstream of the first component or coil section. Critical applications such as hospitals, and clean rooms, and laboratories may also have additional filtration, commonly referred to as "final filtration," in the blow-thru position following the fan. This additional filtration traps fan belt dust and any contaminants that may have been drawn into the unit through casing leaks or access door openings.

The efficiency of air filtration is a matter of engineering design that is oriented to the application for which the space is intended. The particulate matter which filters are intended to remove varies from leaf-size particles all the way down to objects as tiny as bacteria and gaseous fumes. This broad range of particle size precludes the design of a single, all-purpose filter. As a result, multiple-filter designs have been developed, each offering a different efficiency, to accommodate different applications.

Filter Types and Ratings

Driven by market demand for improved indoor air quality, ASHRAE developed a new standard for testing and rating filtration efficiencies. Primarily aimed at higher efficiency filtration, ASHRAE Standard 52.2 provides a more absolute method of testing and rating filtration performance, particularly in the 0.3 to 1.0 micron particle size range. Instead of the traditional dust spot and average arrestance ratings used previously, new filter efficiency ratings are expressed in terms of Minimum Efficiency Reporting Values or MERV numbers, which range from 1 to 20, with 20 being the highest efficiency. While there is no exact correlation between past efficiency ratings and the new ratings, they can be approximated.

Filter Classifications Based on Particle Size			
Particle Size (Microns)	Typical Pollutant	General Efficiency	Typical Filter Type
0.1 to 0.3	Sea Salt, Carbon Dust, Combustion Smoke	Ultra-High	HEPA/ULPA
0.3 to 1	Tobacco Smoke, Copier Toner, Bacteria	High	Bag or Cartridge
1 to 3	Legionella, Auto Emissions, Welding Fumes	Medium	Bag or Cartridge
3 to 10	Pollen, Mold, Dust Mites, Sanding Dust	Low	Pleated or Throwaway

Reference ASHRAE Std 52.2-1999 for more detailed information.

Figure 47

Filter Selection Criteria

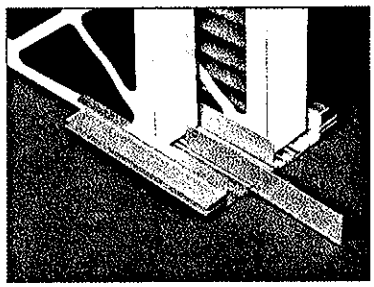
For more detailed explanation of filter ratings, see TDP-644, Filtration.

Each manufacturer of central station air handlers offers its own line of filtering systems. The efficiency range and types of filtering systems offered may vary from manufacturer to manufacturer but some of the most commonly used types will be described here.

Panel Filters

Panel filters are the least expensive and the most commonly used type of filter in the comfort air-conditioning industry today. As its name implies, these filters have a flat, rectangular shape. A number of standard rectangular sizes are available, typically in depths of one, two, or four inches. Panel filters achieve what is generally categorized as low efficiency filtration, up to approximately 30 percent, or MERV 6. This typically represents the minimum acceptable quality of filtration for comfort air-conditioning applications.

- Most commonly used for air conditioning
- Minimum filtration capability
- Up to MERV 6
- Throw-away:
  - Cardboard frames (shown)
  - Metal or plastic screens
  - Fiber or spun glass fill
  - Adhesive coating
  - Pleated media available
- Permanent
  - Metal frame and filter media
  - Cleanable



- High velocity in vertical arrangement (shown above)
  - 400 to 700 fpm
  - Commonly called "flat filters"
  - Shortest airway length

Figure 48

Panel Filter

Panel filters are designed in both throwaway and permanent types. The throwaway type usually has cardboard frames, with either metal or plastic perforated screens for the entering and leaving air sides. The filtering media can be made from any of several types of fiberfill; spun glass fiber and hemp fiber being two commonly used types. Frequently, the density of the fill increases from the entering to the leaving air surface of the filter. An adhesive coating is usually applied to the filter media while the filter is being made to improve its particle-holding capability.

The design of permanent style panel filter is very similar to that described for the throwaway. The major difference is that the framework and filter media are metal.

Panel filters are usually installed on the intake side of the fan upstream of the coil(s). They can function as either high velocity or low velocity filters depending upon the filter cabinet design in which they are installed.

Flat Filter Section

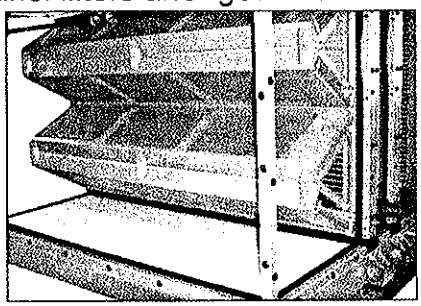
A high velocity filter, or flat filter section, orients the panel filters in a straight vertical manner. This arrangement yields the shortest possible airway length, which is important for installations where space is limited. It is also the most cost effective. The velocity through the filters approximates that for the cooling coil. Normal face velocities range from 400 to about 550 feet per minute.

Angle Filter Section

Figure 49 shows a typical low-velocity filter, or angle filter section. Angle filter sections use panel type filters arranged in a series of V-banks to achieve lower air velocities across the filters than at the cooling coil. Typical filter face velocities of 350 feet per minute or below enable the panel filter to operate more efficiently than in a high velocity flat application.

As with most types of filter sections, access to the low velocity filter section for filter replacement or servicing is accomplished through an access door at the end of the casing. Angle filter arrangements provide increased contaminant-holding capability, which lengthens the interval between filter changes in comparison to a high velocity filter arrangement.

Panel filters arranged in a "V" bank



- **Commonly referred to as "angle filter" sections**
- **Reduces velocity through filters to about 350 fpm**
  - **Better filtration efficiency**
  - **Lower pressure drop vs. high velocity (flat) filter section**

Figure 49

Angle Filter Section

Bag Filters

One alternative to panel filters, which offers medium efficiency filtration up to approximately 75 percent or MERV 12, is a bag filter. This filter removes fine dust particles that cause surface soiling.

The bags are constructed of a special blend of paper and fiber in the shape of a bag. This shape creates an extensive filter surface area, which results in low air velocities across the filter. Standard as well as extra-length bags are typically offered, the latter being used where larger-than-normal air quantities are involved.

- **Medium to high efficiency**
- **Up to MERV 12**
- **Removes "fine" dust particles**
- **Greater filter area**
  - **Lower velocities**
  - **More dirt absorption**
- **Throw away when dirty**
- **High velocity pre-filters recommended**

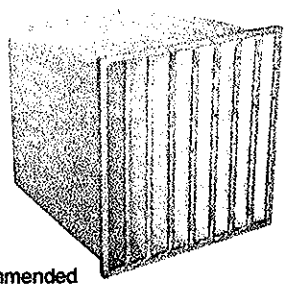


Figure 50

Bag Filter

Since these filters have a higher efficiency and more complex design than panel filters, they cost considerably more. Therefore, high velocity pre-filters are usually installed upstream of the bag filter to remove large particulate matter and reduce the replacement frequency of the bag filter. Most bag filter sections provide pre-filter tracks in the filter section for this purpose.

Cartridge Filters

Cartridge (or box) filters provide medium to high efficiency filtration in the 75 to 95 percent range (MERV 12-16).

Cartridge filters have pleated media installed in a rigid frame constructed of metal or plastic. The filters are typically 6 or 12 inches deep. There are two styles of filter cartridges: cartridges with header frames and those without, to accommodate either side-loading or front-loading filter racks.

Filters without headers have a simple rectangular box shape. They mount into a front-loading filter frame that is gasketed to minimize air bypass around the filter.

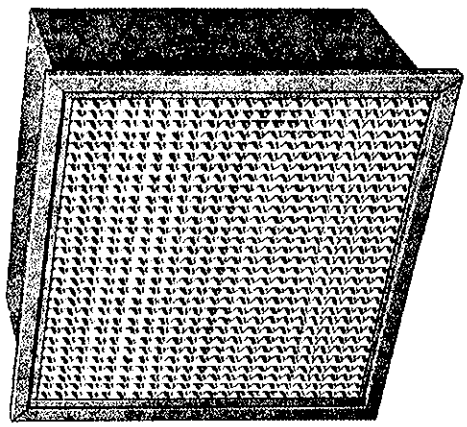


Figure 51

Cartridge filters will not sag at reduced cfms in VAV systems.

The filter is held in place by retaining clips or springs in a front-loading filter rack. Due to the cost of cartridge filters, pre-filters are generally used upstream to trap the larger particulates and extend the life of the cartridge. Cartridge filters with headers may be mounted in front-loading racks as described earlier, or into side-loading racks, similar to flat or angle filter sections. The filter has a one-inch header frame around the filter, which is used to hold it in place in the filter track.

The advantage of side-loading filters over front-loading is that they require a shorter airway length, as they do not need upstream space for service access to replace the filter. They are also faster to replace than front loading.

HEPA Filters

HEPA stands for High-Efficiency Particulate Air. These filters are also referred to as "absolute" filters since they achieve efficiencies of 99.97 percent or higher (MERV 16 or higher) and can remove particles as small as 0.3 microns or less from the airstream. Applications for this type of filter include hospital operating rooms, research laboratories, pharmaceutical plants and any other applications where atmospheric contamination must be prevented.

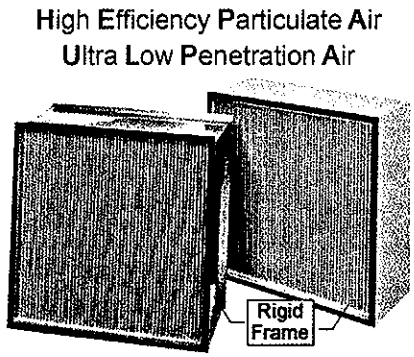


Figure 52

HEPA/ULPA Filters

HEPA filters are installed in special front-loading frames specially designed to prevent any air leakage through them. The filter frames are very rigid to eliminate deflection under pressure. They are also gasketed and caulked in place, typically with silicone-based adhesive caulking. HEPA filters are almost always installed as "final" filters.

Due to the extremely high cost of HEPA filters, upstream filtration of the types described previously should always be used to minimize the HEPA filter replacement.

"Ultra-Low Penetration Air" Filters

An ULPA filter is an extended paper media filter built in a rigid frame having a minimum particle-collection efficiency of 99.999 percent on 0.12 micrometers. The media area can range from 89 square feet to 242 square feet with an initial resistance range of 0.31 in. wg to 1.0 in. wg. Final pressure drop measurements are from 0.70 in. wg to 2.0 in. wg.

Electrostatic Filters

The electrostatic filter removes particulate matter from the air by placing an electrical charge on particles and collecting them on electrostatically-charged surfaces. Efficiencies for this type of filtering method are comparable to that of bag filters. However, electrostatic filters have a lower pressure drop than bag filters. Saving the replacement media cost associated with bag filters makes the electrostatic filtering method attractive for certain applications.

- Dirt particles are electrically charged
- Ionizing grids (opposite charge) in the filter attract charged dirt particles
- Efficiency similar to bag filters
- Permanent and cleanable
- Can be separate and field coupled to AHU
- Preceded by upstream low-efficiency pre-filters

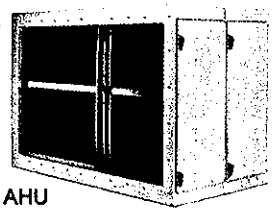


Figure 53

Electrostatic Filter

There are currently very few central station air-handling manufacturers who offer electrostatic filters as a part of their standard commercial product line. Large commercial applications usually utilize the appropriate size unit purchased as a separate component from one of the large filter manufacturing firms, making any necessary field modifications to couple the unit with the air handler. Usage of electrostatic filters is predominantly restricted to the residential and light commercial markets.

Impact of Filter Pressure Drop on Fan Selection

You may want to select an air handler with dirty filters so that, in theory, the unit will have enough horsepower to deliver the same amount of air when the filters are dirty. On a constant volume unit, that would only work if the unit contained an airflow measuring station and could adjust the flow accordingly using a VFD. Otherwise, the point of operation moves along the rpm line as the static pressure in the system changes.

Three things happen when you order the fan with sheaves selected for dirty filters:

1. The sheaves will be replaced with a smaller size by the air balancer because the airflow is too high when filters are clean. When the filters load up, airflow is reduced.

2. If an air balance is not performed, the cooling coil may exhibit moisture carryover due to the considerable increase in airflow.
3. The fan motor trips out on overload with the forward-curved centrifugal fan because of the increase in bhp.

Example: Selecting a forward-curved fan for dirty filter pressure drop

In this example, we are showing a forward-curved fan rated at 15,000 cfm, 1010 rpm, 17.8 hp, and selected with 100 percent dirty 60-65 percent cartridge filters and pre-filters. The dirty filters result in a total static pressure (TSP) of 4 in. wg. Clean filters, however, would have resulted in a TSP of only 2.55 in. wg.

If we follow the 1010 rpm line down to 2.55 in. wg reflecting the clean filter TSP, we would have a clean filter cfm of 21,000! Also note that the horsepower goes from 17.8 bhp to about 28 bhp because the forward-curve fan continues to draw hp as the cfm increases.

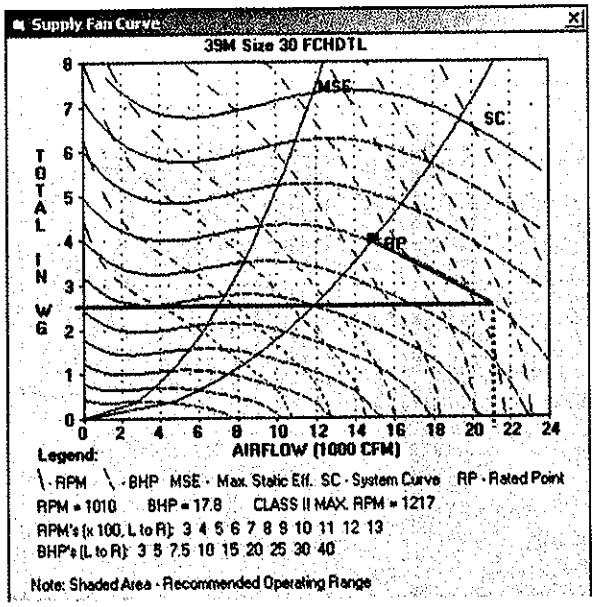


Figure 54

Forward-curved fan selection using dirty filter pressure drop

If dirty filters need to be taken into consideration, do one of the following:

1. Make the final fan selection with the clean filter rpm but use the motor horsepower requirement for dirty filters.
2. Make the final fan selection with the dirty filter rpm and use the motor horsepower requirement for dirty filters only if the engineer plans on using a VFD and airflow measurement station or if it is a VAV system.
3. Use an airfoil fan when the difference between dirty and clean filter pressure drop is greater than 1 in. wg. That way, the difference between clean and dirty airflow is minimized.

Example: Using an airfoil fan

The design airflow is 15,000 cfm, the total static pressure with dirty filters is 4.0 in. wg, the resulting fan rpm is 2210, the clean filter TSP is 2.25 in. wg.

To find the operating point with clean filters, follow the 2210 rpm line down to 2.55 in. wg. Clean cfm will be 16,700 cfm. Since airfoil fans are non-overloading (bhp lines run parallel with rpm lines) the bhp does not change. However, coil blow off is possible due to the increase in airflow.

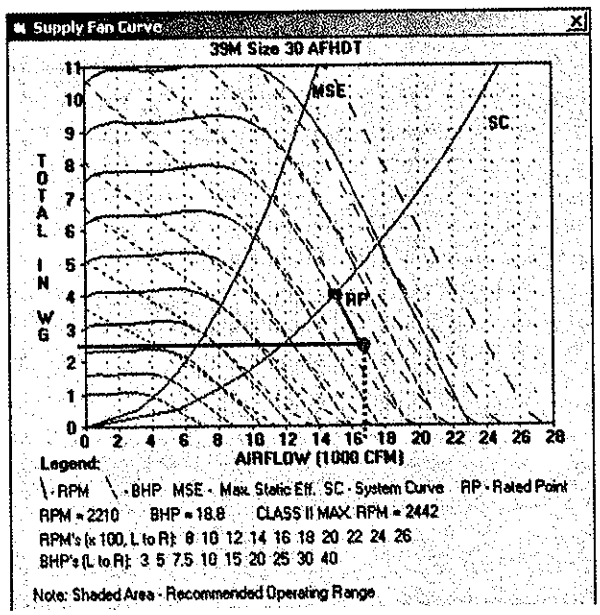


Figure 55

Airfoil Fan Example

Access and Plenum Sections

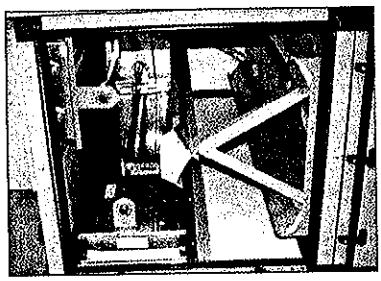
Access and plenum sections are used to provide space between other components for service access, and for additional components to be installed at the jobsite, such as humidifiers, sound attenuators, etc. They are generally available in a variety of airway lengths and can be equipped with drain pans if necessary. Plenum sections are simply access sections without doors. They are useful where cost is a primary concern and the section does not require frequent access.

Blow-thru plenums are basically a section with a discharge air opening that is used primarily to facilitate duct connection. On units with bottom openings, safety grates are frequently used to prevent people or tools from falling in.

Mixing Box Section

The mixing box is an air plenum with two air inlets, each of which contains a volume control damper. When installed in its normal position, at the entering-air end of the air-handling unit, this accessory will provide the proper mixture of return and outdoor air.

The interconnecting linkage between the dampers closes one while the other is opening. While this example shows the damper intakes on the bottom and rear of this component, either opening can also be located on the top, or sides of the mixing box for added flexibility.



- Dampers
  - Parallel and opposed blades
  - Various leakage rates available
    - Check manufacturer's data
- Recommend:
  - Parallel blade for return air
  - Opposed blade for outdoor air

- Plenum with two air inlets
  - Outdoor air
  - Return air
- Positions controlled to provide:
  - Ventilation air
  - Free cooling (economizer)
  - Indoor air quality (CO_2)
- Dampers are interconnected
  - When one opens, the other closes

Figure 56

Mixing Box Characteristics

Manufacturers may offer several damper options that provide different leakage rates, and pressure drops. Low-leakage dampers are important when an air-handling unit cycles on and off. When the unit is off, loose-fitting dampers allow unconditioned outdoor air to leak into the building, conditioned air to leak out, or both. Leakage through a damper that is supposed to be closed means that energy is being wasted and the air-handling system is less efficient than it could be.

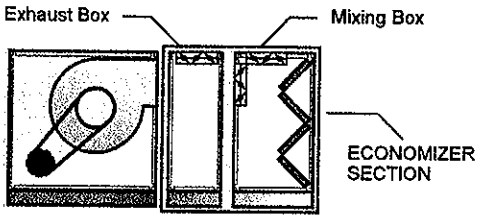
For most continuous-duty units, the outdoor air and return air dampers are rarely fully closed (except during economizer or unoccupied operation). During normal operation, the more important damper criteria are low-pressure loss and quality construction.

Manufacturers use various terms

such as low-leakage and ultra-low-leakage to describe the leakage rates. Therefore, the most meaningful comparison is to quote actual leakage volume or leakage per square foot of damper area.

Exhaust and Economizer Sections

An exhaust box is generally used immediately downstream of a return air fan section to allow air to be exhausted from the system. Some manufacturers offer separate exhaust box sections, which can be mated with a standard mixing box. Others offer a single section containing exhaust, return and ventilation air dampers in a single section. This is commonly referred to as an economizer section.



- Used downstream of return fan
- Provides outlet to relieve excess air from building
- Maintains space pressurization
- Dampers are controlled by space pressure sensor, or linked to mixing box dampers

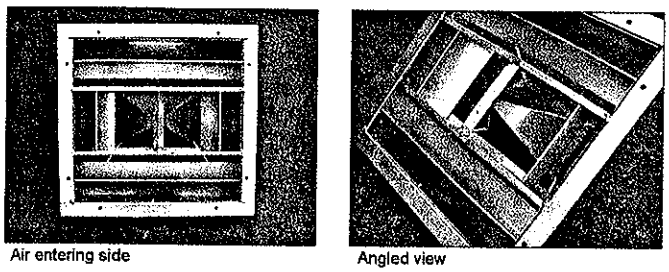
Figure 57

Exhaust and Economizer Box

Air Mixers

Under certain winter conditions, outdoor air entering an air-handling unit may not mix well with return air. Variations in air quantities and temperatures contribute to the problem. The colder outdoor air will stratify to the lower part of the unit, increasing the risk of coil freezing.

Static air mixers are stationary devices made up of multiple, directional-turning vanes that purposely cause turbulence in the combined airstream (outdoor air plus return air) to promote mixing. They are generally installed immediately down-stream of the mixing box section.



Installed downstream of Mixing Boxes

Directional turning vanes

- Air velocity 1000 fpm through mixer
- Causes turbulence and forces air to mix
- Minimizes temperature stratification
- Helps prevent coil freeze-ups or nuisance freezestat tripping

Figure 58

Static Air Mixer

The quantity of air going through the mixing section creates a pressure drop and causes the air to pass through the passages in the mixing section at some nominal design velocity. The mixing efficiency for the mixer is specified at various reference airflow points.

While they perform reasonably well in constant volume systems, in variable air volume (VAV) applications, they quickly lose their mixing effectiveness as airflow is reduced below the design rate. This is typical in VAV air handlers where the unit rarely operates at design airflow, especially immediately after a morning warm-up cycle has terminated and the unit starts the cooling mode. This is the point when most freezestat trips occur. Airflow through the unit is reduced to a very low level because the building's cooling requirement is minimal.

The total system cfm drops to the sum of the minimum airflow set points of the terminals. Therefore, it is extremely important that the designer evaluates the minimum system airflow and ensures that it is above the minimum required by the air mixer.

Face and Bypass Damper Sections

Another accessory that may be used with an air-handling unit is a face and bypass damper section. Two sets of interlocked dampers are installed, generally in one section. The face damper is located directly in front of the cooling coil and the bypass damper is located above the coil, controlling airflow through a bypass duct around the coil.

This arrangement can be used with heating or cooling coils. They control heating capacity by diverting air around the coil, rather than throttling the hot water or steam to the coil. This minimizes the possibility of coil freeze-up in cold climates.

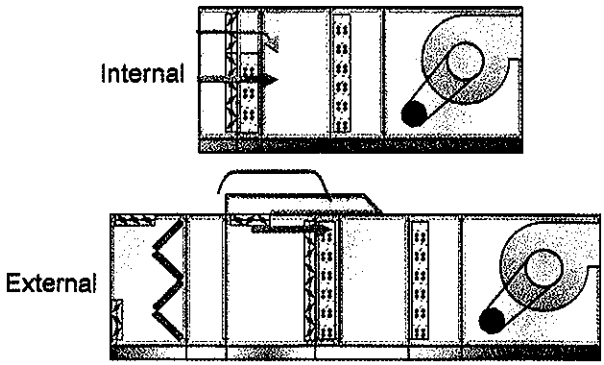


Figure 59

Face and Bypass

In cooling applications, face and bypass dampers are generally used only with chilled water coils, not direct expansion (DX) refrigerant coils. In chilled-water applications they are effective in high latent load applications. In conjunction with a chilled-water valve, they can reduce the leaving air temperatures off the cooling coil providing more dehumidification. This dehumidified air is then mixed with bypassed air to bring it up to an acceptable level for distribution to the space.

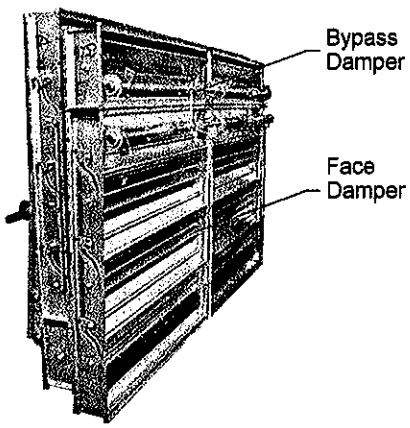


Figure 60

Face and Bypass Dampers

On applications employing face and bypass sections, the fan selection and air distribution system must be designed for an air quantity about 10 percent above design dehumidified air volume. This additional air quantity compensates for leakage through a fully-closed bypass damper and for air quantity variations when the dampers are in intermediate positions.

Traditionally, face and bypass has been discouraged in DX systems because if the controls allow the face dampers to close or significantly reduce airflow across the coil, the coil could freeze up and cause liquid refrigerant to flood back and cause compressor damage.

Humidifiers

Maintaining proper humidification is an integral component of indoor air quality. When humidity levels are low, higher room temperatures are generally necessary to maintain thermal comfort. Low relative humidity also increases respiratory complaints caused by drying membranes in the nose, throat, and respiratory system.

Very low humidity (and very high humidity) is detrimental to human comfort, health, and productivity. In winter, controlling relative humidity to approximately 30 percent and 35 percent at normal room temperatures has been shown to be the optimum range.

There are several types of humidifiers, differentiated by the moisture source. The spray humidifier section consists of a header and spray nozzles with a strainer which may be field installed.

The sprays operate on a water pressure of 15 psi or more. The humidifier should be installed directly ahead of the chilled water coil to permit drain water to flow to the condensate pan and out through the condensate piping. Spray humidifiers may result in dust accumulation in the occupied space if the supply water has any dissolved salts. Spray humidifiers may be used with copper or aluminum finned coils when naturally soft city water is available. If the water is contaminated, dissimilar fin and tube materials may result in a significant reduction of coil life due to corrosion. When industrial gases such as hydrogen sulfide, sulfur dioxide or carbon dioxide are present in the spray water or in the outdoor air, use of an all copper coil is recommended.

When face and bypass damper control is used, controls should be set so that there is always a minimum flow of air through the spray apparatus. A solenoid valve should be installed in the water line or other suitable precautions taken to shut off sprays when the fan is not running

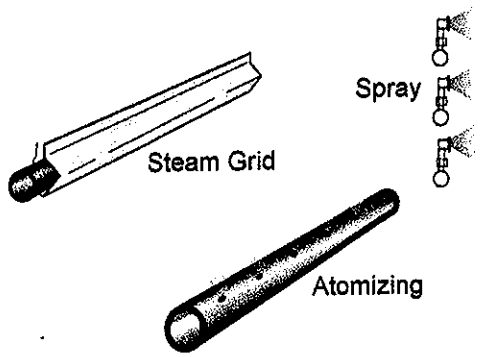


Figure 61

Types of Humidifiers

The atomizing spray humidifier assembly is made of a single horizontal pipe placed on the leaving side of the cooling coil and above the condensate pan. Brass, cone-shaped, 1/8" nozzles with a spray angle of 70 degrees are screwed into the pipe. Each nozzle has a fine mesh brass strainer. To minimize nozzle clogging, it is recommended that the supply pipe also have a strainer. The atomizing sprays operate on city water pressure of 15 psi or higher.

The steam grid humidifier is constructed of an open or slotted pan that encloses a steam pipe with drilled holes in the pipe to distribute the steam. The pan is pitched to facilitate condensate drainage. A condensate trap and liquid leg is required when operating under negative pressure to prevent "hold-up" of condensate in the pan. The steam supply to this humidifier should be odor free to prevent build-up of objectionable odors in the conditioned space. Automatic water make-up must also be provided to maintain the proper water level in the steam generator.

These types of humidifiers

Spray humidifiers and atomizing spray humidifiers are not recommended for use on blow-thru type units. On these units, the humidifiers are located on the positive pressure side of the fan and spray types may cause leakage at the joints in the casing. Steam grid types are, however, acceptable for blow-thru units.

Ultraviolet Light Germicidal Lamps

The quality of indoor air is difficult to assess. But, in all situations where IAQ is a problem, there are three factors present: a contaminant, susceptible occupants, and a mechanism to transport the contaminant. In many cases the transport mechanism is the HVAC system.

In HVAC systems, bioaerosols are of particular concern. Bioaerosols are airborne particles that may be living organisms, spores, or fragments of living organisms. They include pathogens (viruses, mold, and bacteria), allergens (mold and bacteria that cause allergic reaction), and toxins. In the air, bioaerosols behave like gases in that they float in the air and can remain suspended for hours. UV-c lamps kill stationary particles, not particles in the moving airstream.

- According to BOMA (Building Owners & Managers Assoc.), the average condensate drain pan is cleaned only 3.5 times per year
- Condensate drain pan and evaporator coil may be sources of mold/bacteria growth under certain conditions (68-86° F)
- Limits biological growth on evaporator coil and condensate drain pan
  - Maintains design air pressure drop
  - Helps reduce maintenance costs
- General rule of thumb sizing:
  - 1 lamp per 12 ft² of coil surface @ 12" distance from coil

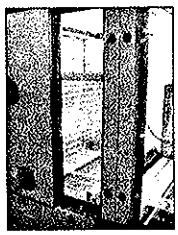




Figure 62

UV-c Germicidal Lamps

The best placement

of an ultraviolet germicidal UV-c lamp is on the downstream side of the cooling coil over the drain pan. This permits simultaneous irradiation of both areas. By attacking the bioaerosols at their source, they do not have the opportunity to enter the airstream or penetrate the building through the ductwork.

Ultraviolet germicidal irradiation can effectively kill biological contaminants in an HVAC system. Within the entire spectrum of ultraviolet light, UV-c, the portion designated as the "c" bandwidth (200-290 nanometer wavelength) has been proven effective at killing contaminants by disrupting cellular growth.

By preventing biological accumulation, UV-c lamps prevent coil fouling and the resulting increase in pressure drop. This is an added energy-saving benefit.

Energy Recovery

Although many building owners, architects and engineers recognize the benefits of introducing more outdoor air into a conditioned space, many are concerned about the impact on equipment and operating costs. As a result, heat recovery technologies, which transfer heat between exhaust and ventilation airstreams, are becoming more and more popular. There are

ASHRAE Standard 62

Ventilation for Acceptable Indoor Air Quality:

- Defines the minimum outdoor air ventilation rates required to achieve acceptable indoor air quality
- Standard has been adopted by all building codes

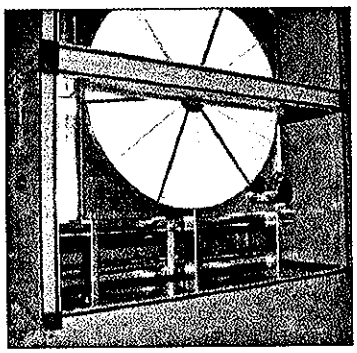


Figure 63

Why Energy Recovery?

two basic seasonal scenarios for air-to-air energy recovery in comfort applications. The first is to transfer heat and moisture from the exhaust stream to the supply stream during winter months. The second is the reverse function: to transfer heat and moisture from the supply stream to the exhaust stream in the summer.

Providing a comfortable and healthy indoor environment for building occupants is a primary concern for HVAC design engineers. ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) Standard 62, Ventilation for Acceptable Indoor Air Quality, contains ventilation design requirements for commercial and residential buildings. This standard, which is referenced in part or whole by most building codes in the United States, recommends outdoor air quantities per person to avoid adverse health effects. With half of all illnesses attributable to indoor airborne contaminants, the EPA (Environmental Protection Agency) has declared indoor-air quality a public health priority.

The latest revision of the ASHRAE standard for ventilation (62N) takes into account the non-people related indoor contaminants (off gassing from wallpaper, carpets, etc.) to come up with a blended rate of cfm per square foot and cfm per person. For example, if the non-people ventilation requirements for a certain space are 2 cfm per square foot for a 1000 square foot zone, the people-related ventilation requirements are 5 cfm per person, and the zone is designed for 100 people, the effective ventilation rate is 2 * 1000 = 2000 cfm (non-people) + 5 * 100 - 500 cfm (people) = 2500/10 = 25 cfm per person.

There are many possible applications of air-to-air energy recovery. Any building with comfort conditioning and relatively high levels of outdoor air, especially where latent cooling is a significant portion of the outdoor air requirement, is a likely application. Buildings with significant occupancy levels are usually good candidates. Typical applications may include schools and universities, gymnasiums, office buildings, hospitals, nursing homes, and retail shopping centers, to name a few.

There are also many heat recovery technologies available from which to choose. The most common types: coil energy recovery loop, energy recovery wheel, fixed-plate heat exchanger and heat pipe will be briefly described here.

It is important to note that ARI has established a rating and certification standard for air-to-air energy recovery ventilating equipment called ARI Standard 1060. For manufacturers who list their equipment under this standard, the designer and owner can have confidence and assurance that the manufacturers' performance data has been independently verified by ARI to be accurate and that it will perform as expected when installed. The scope of ARI 1060 includes energy wheels, fixed-plate heat recovery, and heat pipe equipment. For more information on energy recovery, refer to TDP-645, Energy Recovery Systems.

Coil Energy Recovery Loop

Often referred to as a runaround loop, a coil energy recovery loop is actually a heat recovery system and distinct from individual pieces of equipment like energy wheels or fixed-plate heat exchangers. Coil energy recovery loops are very flexible and well-suited to industrial applications or comfort applications with remote supply and exhaust ductwork. They use standard finned-tube coils to transfer heat to and from an intermediate working fluid such as water or antifreeze solution. A pump circulates the fluid between the two coils in closed loop. The loop must be equipped with a flow control valve to modulate the heat transfer rate. Also, an expansion tank is necessary

for thermal expansion and pressurization of the working fluid. The heat transfer rate must be controlled to prevent overheating or overcooling the supply airstream. If the outdoor airstream is very cold, an uncontrolled system may frost or freeze condensate on the coil in the exhaust stream.

Maintenance requirements

- Separate coils in exhaust and supply air
- Fluid pumped between coils
- Sensible heat transfer only
- Suited for applications where:
  - No cross-contamination of airstreams is allowed
  - Exhaust and supply airstreams are some distance apart
- Can use multiple coils

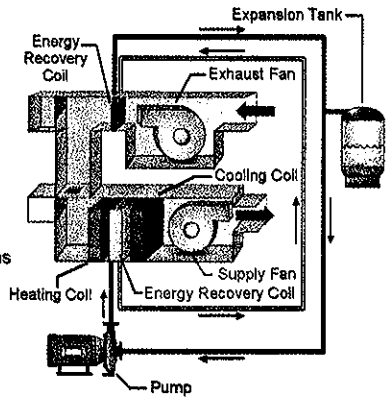


Figure 64

Coil Energy Recovery Loop Characteristics

By regulating the fluid flow through each coil and blending warm fluid with the cold fluid entering the exhaust coil, the total heat transfer rate is limited to the maximum possible without freezing. Overheating is prevented in the same manner. Runaround loops are well-suited for applications that must keep the two airstreams separate. They are useful for sensible heat recovery only. They can be designed to transfer heat in either direction. They are also uniquely capable of simultaneous heat transfer between multiple locations using the same circulating system.

Energy Recovery Wheels

An energy recovery wheel is also called a heat wheel and an enthalpy wheel. Although many people use the phrases interchangeably, the term heat wheel is used to distinguish a sensible-only application. Enthalpy wheel is used to distinguish a combined sensible and latent energy transfer application. In both cases, the fundamental piece of equipment is nearly identical. This discussion will use the term energy wheel as an all-inclusive class of rotary, air-to-air energy exchanger.

A rotary air-to-air energy exchanger has a revolving wheel filled with an air-permeable medium having a large internal surface area. The exchanger is designed to be positioned between two adjacent ducts with opposing flow directions. This establishes a counter-flow heat exchange pattern. The wheel rotates between 10 and 60 revolutions per minute depending on the application. When the wheel passes through the higher-temperature airstream, the media temperature increases as heat is transferred and stored in the individual filaments.

- Wheel rotates across exhaust and supply airstreams
- Can transfer both sensible and latent heat
- Effectiveness up to 80%
- Wheel is self cleaning

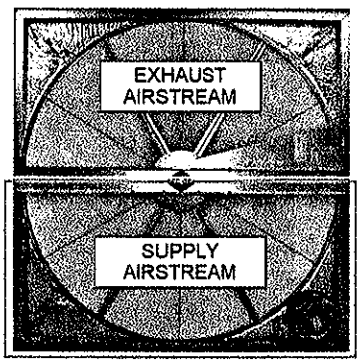


Figure 65

Energy Recovery Wheels

When the media wheel rotates into the low-temperature airstream, the filaments are cooled and release heat. This form of heat transfer is purely sensible and is driven by a temperature gradient between the high-and low-temperature airstreams. In most comfort applications, the temperature difference is relatively small as compared to some process energy recovery applications.

Latent heat transfer can occur in one of two ways. First, if the temperature and humidity gradients are sufficient, water may condense on the cold media in the high-humidity airstream. Moisture droplets held in the media are carried to the low-humidity airstream where they evaporate. The second and more reliable means of moisture transfer happens when the heat transfer media in the rotary wheel is coated with a desiccant film. In the high-humidity airstream, desiccant material adsorbs moisture molecules by the process of vapor diffusion. The molecules ride the rotating wheel and are released (desorbed) into the low-humidity airstream.

Although the overall process is considered energy transfer, the moisture absorption-desorption process described is actually a mass transfer event. It is driven by the water vapor partial-pressure gradient between the high-humidity and low-humidity airstreams. It is not dependent on the temperature gradient driving sensible heat transfer. This means that heat transfer can flow in one direction and moisture transfer can occur in the opposite direction because they are driven by different mechanisms.

Fixed-Plate Heat Exchanger

The heat transfer core of a fixed-plate heat exchanger is made from alternate layers of plates, formed and sealed at the edges to create two adjacent but separate airflow paths. Their most distinct advantage is that they have no moving parts. Energy transfer across the plates from one airstream to the next is completely passive and driven by the thermal gradient. Fixed-plate heat exchangers are useful for sensible heat transfer only. Latent heat transfer can occur only if the plates are made from water vapor-permeable material. Cross-flow is the most common arrangement. Counter-flow and parallel-flow exchangers have design and manufacturing complications that restrict their use. Units are available in many different materials, sizes and patterns, and are often modular, allowing combinations to fit large airflow applications. Plates are commonly spaced between 0.10 and 0.50 in. apart. Aluminum is the most commonly used material although plastics have been used without substantially affecting heat transfer efficiency. Airstreams are separated by folding, gluing or welding the plate edges and forming separate air paths. Spacing of the air paths is accomplished by molding integral dimples or ribbed patterns into the plates, or with external separators. Fixed-plate heat exchangers can be manufactured so there is little or no leakage between the airstreams. Most units are constructed with drains for removing condensate and wash water.

- Alternating layers of plates
- Form two separate but adjacent air passages
- Counter-flow or cross-flow designs
- Transfers heat between airstreams
- Generally sensible only (aluminum plates)
- Latent with vapor-permeable plates
- No moving parts

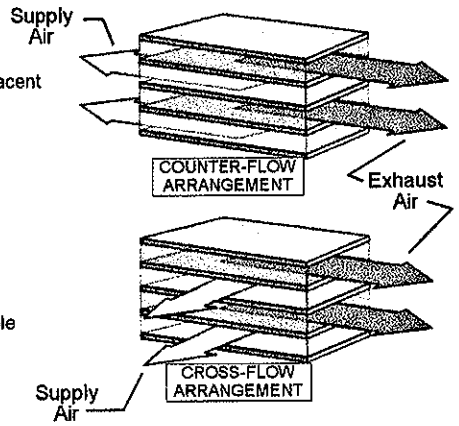


Figure 66

Fixed Plate Heat Exchanger Characteristics

Heat Pipe Heat Exchanger

A heat pipe heat exchanger has the appearance of an ordinary finned coil, but each successive tube is independent and not connected to any other tube. Each tube is built with an internal capillary wick material. The tube is evacuated, filled with a non-toxic refrigerant, such as R-134a, and individually sealed. With the tubes installed horizontally, one-half of the heat exchanger will act like an evaporator and the other half acts like a condenser. The high-temperature airstream passes through the evaporator half of the unit and the low-temperature airstream passes through the condenser half. The high-temperature airstream passes over one-half of all the tubes. As the working fluid (refrigerant) is warmed and vaporized in the evaporator half, the internal vapor pressure gradient drives the gas to the condenser end of the tube. In the condenser end, the fluid releases the latent energy of vaporization as it condenses, thereby warming the low-temperature airstream. Liquid refrigerant returns to the evaporator end through the internal wick.

- Finned-tube coil
- Tubes not connected
- Each tube charged with refrigerant
- Coil spans exhaust and ventilation airstreams
- Sensible heat transfer between air and coils
- Refrigerant in coils evaporates and condenses to transfer heat from one airstream to the other
- Works on vapor pressure gradient along tube
- Several arrangements available

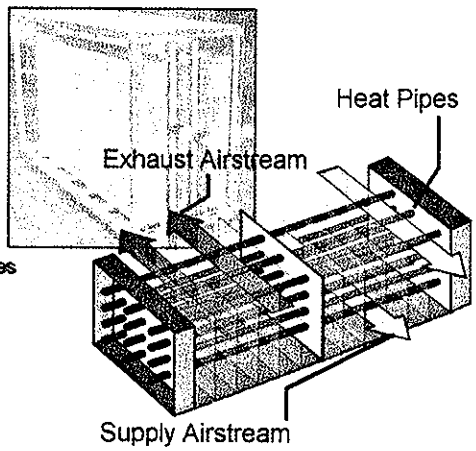


Figure 67

Heat Pipe Characteristics

Heat pipes are usually constructed of copper tubes with aluminum fins. Tubes are installed horizontally, but tilting the tubes one direction or the other can control the amount of heat transfer. For instance, operating the heat pipe unit with the evaporator end lower than the condenser end improves the liquid refrigerant flow back to the evaporator and increases heat transfer capacity. Reversing the arrangement retards liquid refrigerant flow and decreases capacity. Heat pipes are useful for sensible heat transfer only. Some latent benefit is achieved if a hot, humid outdoor airstream is cooled sufficiently to condense moisture on the evaporator end of the unit. Heat pipes can be installed so that cross-contamination between the two airstreams is near zero.

Additional Air Handler Configurations

Most of what we have discussed so far has been related to single duct, single discharge air systems. Let's explore when air handlers are used in other configurations.

Dual-Duct

Dual-duct is a blow-thru unit with a dual-coil section downstream of the fan. The coil section contains a cooling coil and a heating coil. The coils are installed in parallel with separate air outlets, one delivering cold air, the other hot or neutral air. The cooling and heating coils are commonly referred to as the cold deck and the hot deck, respectively. In a dual-duct system, separate hot and cold supply ducts are run throughout the building with hot and cold air being supplied to each zone. The hot and cold air is then mixed at each zone by a dual-duct mixing box to provide a volume of the proper temperature air to meet each zone's needs. Traditional dual-duct systems were constant volume. However, dual-duct systems are also used with variable volume systems.

- Blow-thru arrangement
- Normally a constant volume system
- Coil section with cooling and heating coils in parallel
  - Coils referred to as "cold " and "hot" decks, respectively
  - Provide simultaneous cooling and heating
  - May eliminate heating coil and use "neutral" air- becomes F&BP system
  - Separate cooling and heating supply air ducts throughout building
  - Zone mixing boxes blend air from both ducts to meet space requirements
- Fan sized for sum of zone peak cooling loads
- Cooling coil sized for block load (less than sum of peak loads)

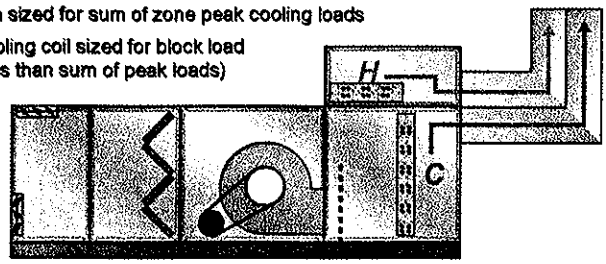


Figure 68

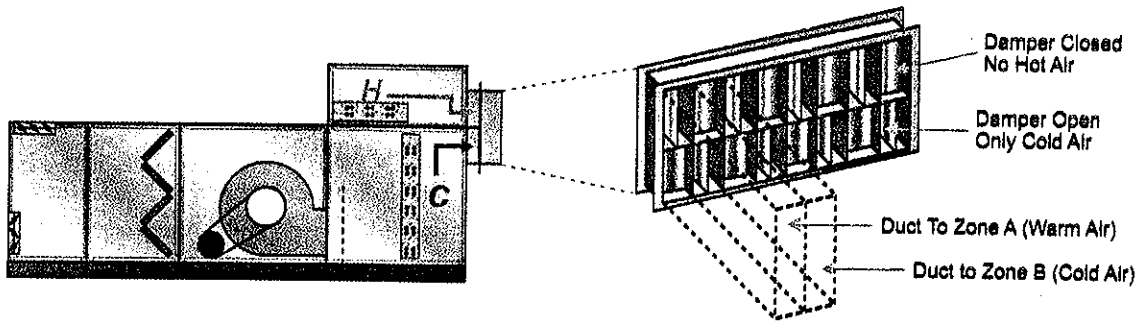
Dual Duct Air Handler

Multizone

A zoning damper section can be installed over the cold and hot deck duct openings of a dual-duct unit. This damper assembly is specially designed with multiple sets of dampers for use in a blow-thru configuration. The heating coil supplies warm air to the upper portion called the hot deck, while at the same time, the cooling coil supplies cool, dehumidified air to the lower portion called the cold deck. Zoning dampers in the heating and cooling decks are 90 degrees opposed to each other on a common shaft so that a nearly constant volume of air is supplied to each zone. The air temperature in each zone may be modulated from 100 percent heating capacity to 100 percent cooling capacity, based on the position of the zone damper. The number of zones available varies with unit size.

The zoning dampers are positioned by damper operators controlled from the various conditioned spaces. For example, shown is a multizone blow-thru unit, with discharge facing the reader. Note that some zones are calling for full cooling, some zones are being provided mixed air from the hot and cold decks for some intermediate load conditions, and some zones are providing heating. It should be noted that even though eight zones are shown here, two or more of the damper sections may be ganged together to provide from one to eight zones, depending on the job requirements and the corresponding air quantity requirement of each zone.

In many cases, the steam or hot water supply to the heating coil is shut off during summer operation (or any time that outside dry bulb temperature is greater than inside design dry bulb temperature), and control is achieved by using the heating section and dampers to bypass the cooling coil at partial load condition. In this mode the blow-thru unit is actually functioning as a zoning face-and-bypass system.



Constant Volume, Blow-thru variation of Dual Duct System

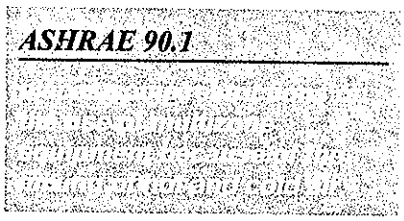
- Zoning dampers mounted on dual coil section in lieu of zone mixing boxes
  - Opposed dampers mix air from cold and hot decks into a common duct
    - When cold deck damper open-hot deck damper is closed to maintain constant volume
  - Each set of dampers supplies a separate zone in building with up to 18 zones/unit
  - Dampers controlled by space temperature
  - Separate supply air ducts to each zone

Figure 69

Multizone Damper Arrangement

The air quantity handled by the fan is essentially constant at all times. The quantity of air handled by the fan is the sum of the dehumidified air quantities required by each zone at the time of its peak load and is called the total air quantity.

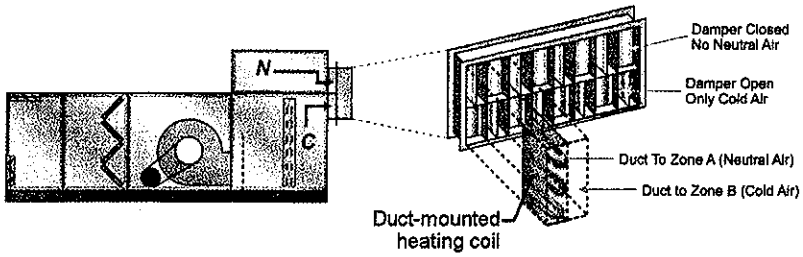
On the other hand, the air passing over the cooling coil varies in quantity and the maximum is established by the instantaneous peak building load or block load of the area served by the multizone unit. This is the dehumidified air quantity and is generally less than the total air quantity handled by the fan.



Therefore, it is important in selecting the blow-thru multizone unit that the dehumidified air quantity is used in determining coil performance and the total air quantity is used in the selection of the fan.

Texas Multizone

Another less common variation of the standard multizone system is called the Texas multizone, shown in Figure 70. The main difference between this and a conventional multizone system is that the air handler will have only cold and neutral decks, no heating. Zone dampers on the air handler will mix cooled and neutral air to maintain space requirements. Any heating is accomplished by individual heating coils located in each zone.



Multizone Variation

- AHU has cold deck and neutral deck-no heating
- AHU zoning dampers mix cold and neutral air to zones
- Heating coils located in separate zones as required
- Sometimes referred to as "Texas" multizone

Figure 70

Texas Multizone Damper Arrangement

Triple-Deck Multizone

In an effort to improve the energy efficiency of the multizone system, a variation called the "triple-deck" multizone has been developed. A triple deck system, as its name implies, adds a third "neutral" deck between the cold and hot decks, eliminating the mixing of cooled and heated air. The neutral deck contains no heating or cooling coil and simply allows a passage for unconditioned air to bypass the cold and hot decks. The zone dampers then mix this "neutral" air with air from either the hot or cold decks, depending upon the needs of each zone.

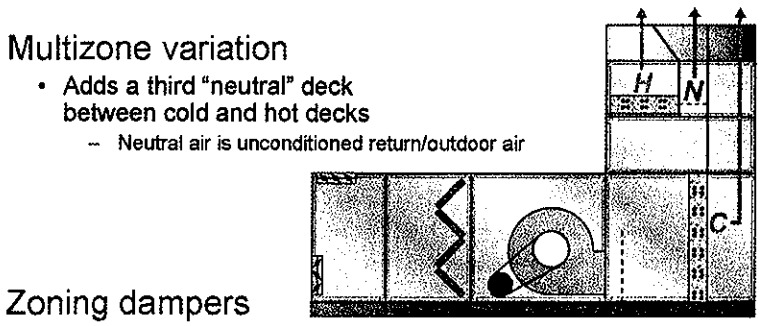


Figure 71

Triple Deck Multizone

Air Handler Selection Example

As mentioned previously, most manufacturers offer selection software for their standard central station product lines to facilitate layout, selection and ordering of the air handler.

The engineer will generally provide a list of the major components and performance required, based on the application and load requirements.

Let's take a look at a typical example. For purposes of this example, we will use the Carrier Air Handler Builder (*AHU*Builder) program, which uses a graphical interface.

Assume that the application requires the air handler to provide the following functions:

- mixing of outdoor and return air
- filter section with MERV 7 efficiency media
- heating section with hot water
- cooling section with chilled water
- fan with constant volume to handle 5000 cfm at 2 in. wg external static pressure

Let's take a look at a typical example.

Step 1:

Select unit size from menu or with sizing tool as shown in Figure 72. Size is based on coil face area.

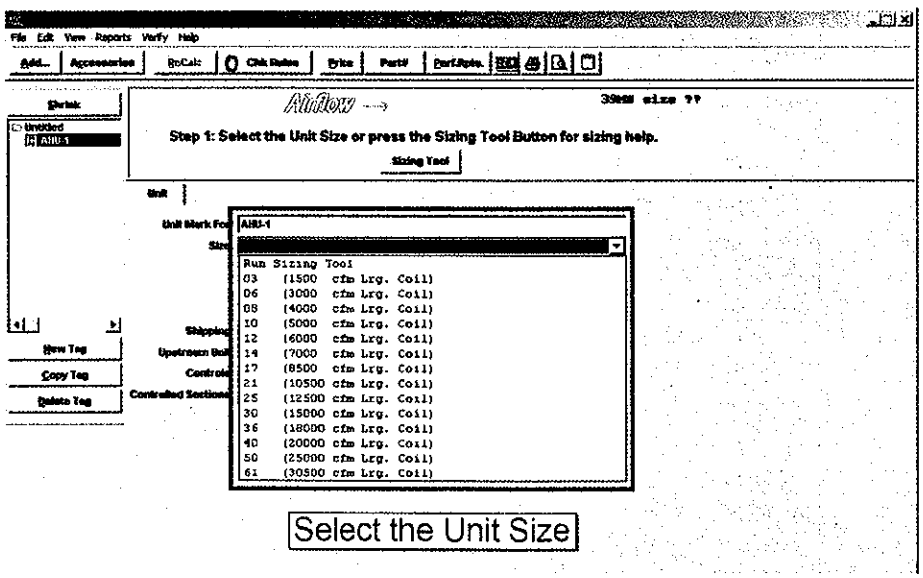


Figure 72

Unit Size Selection

Step 2:

Select the sections required from the list of available sections to meet the job requirements. For this job, we will select mixing box, angle filter, cooling coil, heating coil, and fan sections.

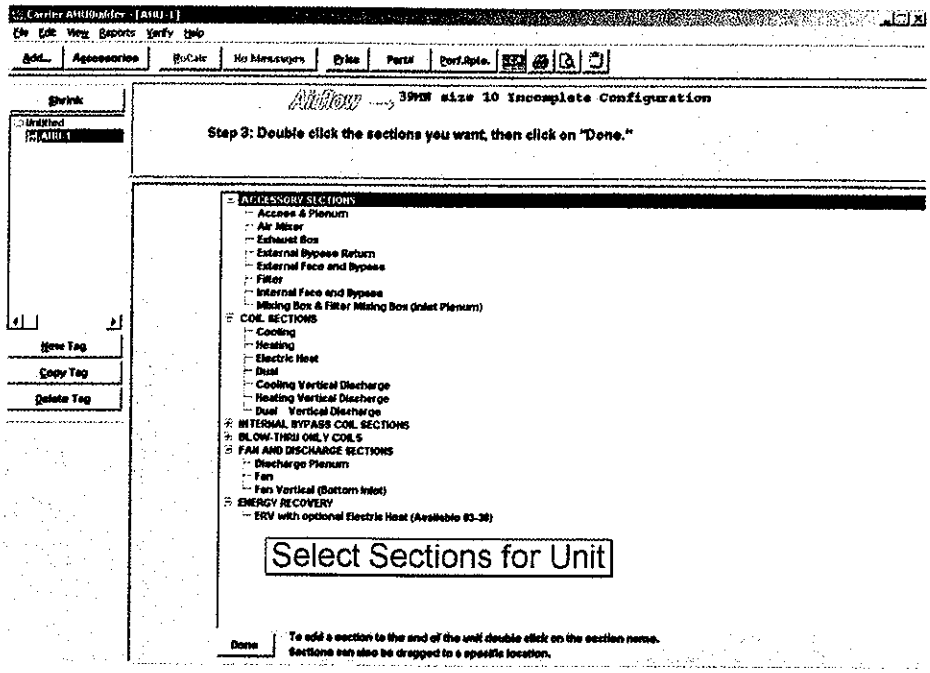


Figure 73

Section Selection

Step 3:

Once sections are selected, complete the configuration details for each section. Specific coil and fans and coils can be evaluated and selected during this process. The program contains configuration rules that will help prevent the user from improperly configuring sections, and offer hints on how to correct errors.

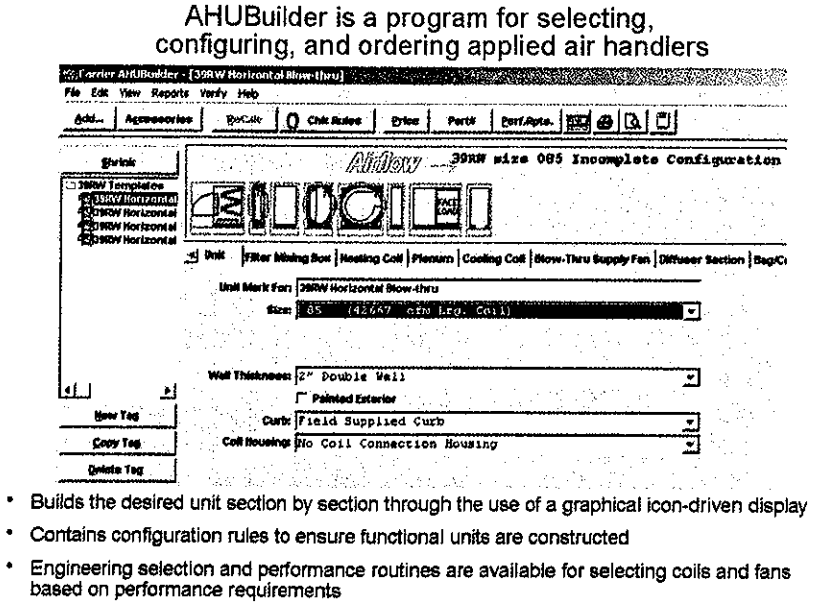


Figure 74

Configuration Rules

Once a selection is complete, the program will print submittal data, including performance reports, schedules and certified drawings. Figure 75 shows a certified drawing and Figure 76 shows a performance report. The program also allows drawings and schedules to be created in .dxf file format that can be imported directly into engineering CAD drawings.

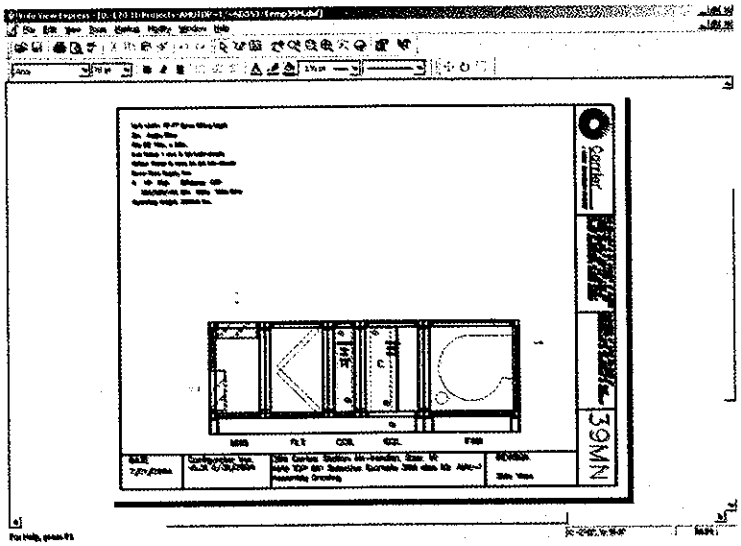
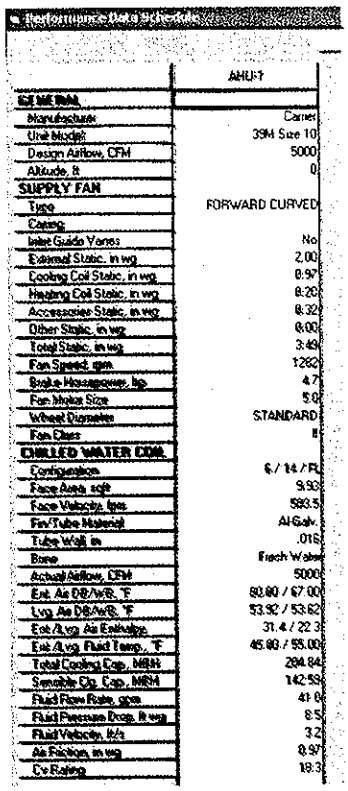


Figure 75

Sample Submittal Drawing



	AHU-1
GENERAL	
Manufacturer	Carrier
Unit Model	39M Size 10
Design Airflow, CFM	5000
Altitude, ft	0
SUPPLY FAN	
Type	FORWARD CURVED
Casing	
Inlet Guide Vanes	No
External Static, in wg	2.00
Cooling Coil Static, in wg	0.97
Heating Coil Static, in wg	0.20
Accessories Static, in wg	0.32
Other Static, in wg	0.00
Total Static, in wg	3.49
Fan Speed, rpm	1282
Brake Horsepower, bp	4.7
Fan Motor Size	5.0
Wheel Diameter	STANDARD
Fan Class	II
CHILLED WATER COIL	
Configuration	6 / 14 / FL
Face Area, sqft	9.93
Face Velocity, fpm	503.5
Fin/Tube Material	Al/Galv.
Tube Wall, in	.016
Rows	Fresh Water
Actual Airflow, CFM	5000
Ent. Air DB/WB, °F	80.80 / 67.00
Lvg. Air DB/WB, °F	53.92 / 53.82
Ent./Lvg. Air Enthalpy	31.4 / 22.3
Ent./Lvg. Fluid Temp., °F	45.00 / 55.00
Total Cooling Cap., MBH	284.84
Sensible Cooling Cap., MBH	142.55
Fluid Flow Rate, gpm	41.0
Fluid Pressure Drop, ft wg	8.5
Fluid Velocity, ft/s	3.2
Air Friction, in wg	0.97
Coil Rating	18.3

Figure 76

Performance Report

Summary

In this presentation on central station air-handling equipment, unit components have been discussed, as well as their arrangement and the accessories that are normally available for these units. Coil performance and some guidelines and recommendations on the application of air-handling units were also presented.

The types, performance and characteristics of fans types were explained. We learned one should not generalize about advantages and disadvantages of one type fan versus another type. Only by analyzing each situation can the designer determine which fan is the most advantageous.

IAQ requirements have affected the design features on modern central station air handlers. Many of the prominent design features discussed in this TDP, like double-wall construction, sloped drain pans, and low leak casings and dampers are all directed at upgrading the IAQ capabilities of the units.

Work Session

Questions may have more than one correct answer. Include all correct answers in your response to the questions below.

1. List the seven functions of a central station air handler as defined by ARI.

   _____ _____
   _____ _____
   _____ _____
   _____

2. True or False? A packaged air handler offers a wider size range with more features and flexibility than a central station air handler. _____

3. The size of a central station air handler is usually based on _____

   a) nominal cooling capacity.
   b) nominal heating capacity.
   c) the airflow through the unit.
   d) cooling coil face area.

4. Name the two most common types of casing construction used in central station air handlers.

   _____
   _____

5. The primary reason for the recent market trend toward double-wall air handlers is: _____

   a) double wall is lower cost than single wall.
   b) increased concern over indoor air quality.
   c) double wall air handlers are perceived as higher quality.
   d) double wall allows the use of anti-microbial coatings.

6. Which of the following features is NOT generally found on an air handler designed for outdoor installation? _____

   a) Sloped roof with standing seams
   b) Air inlet hood or louvers
   c) High-quality gaskets and seals
   d) Single wall, modular construction.

7. True or False? In a draw-thru air handler, the cooling coil is located on the upstream or inlet side of the fan. _____

8. True or False? Forward-curved fans are designed to operate at higher static pressures than airfoil fans. _____

9. Which of the following statements are true regarding AMCA fan class: _____

   a) A Class I fan may be operated under Class II or Class III performance requirements.

   b) A Class II fan may be operated under Class III performance requirements.

   c) A Class III fan may be operated under Class II performance requirements.

   d) All of the above.

10. Under identical operating conditions, _____.

   a) a fan bearing with an L_{50} life of 200,000 hours is equal to a bearing with an L_{10} life of 40,000 hours.

   b) a fan bearing with an L_{10} life of 500,000 hours is equal to a bearing with an L_{10} life of 40,000 hours.

   c) the L_{50} life represents the period of time all bearings of that type or designed will survive without fatigue failure.

   d) None of the above.

11. Which of the following air handler design features would more likely be found on a fully custom outdoor air handler than a standard central station AHU? _____

   a) Sloped roof with standing seams

   b) Outdoor intake hoods

   c) Service and maintenance vestibules

   d) G-90 galvanized casing panels

12. True or False? A filter with a MERV 15 rating is likely to be a 2-inch deep flat panel filter. _____

13. In a variable air volume (VAV) system, which type of fan wheel could be operated without fan volume control (allowed to ride the fan curve)? _____

   a) Forward-curved

   b) Backward-inclined

   c) Airfoil

   d) Plenum

14. Which types of energy recovery devices commonly provide both sensible and latent heat recovery? _____

   a) Energy recovery wheels

   b) Heat pipes

   c) Run-around loops

   d) Fixed-plate heat exchangers

15. True or False? A dual-duct unit is a specific blow-thru configuration that can deliver cold and neutral or hot air simultaneously. _____

16. True or False? In a multizone air handler, the fan and cooling coil are always selected based on the instantaneous "block" load of the area served by the air handler.

_____

17. The best placement of an ultraviolet light germicidal lamp (UV-c) within an air handler is immediately _____.

a) downstream of a cooling coil.
b) upstream of a filter section.
c) downstream of a heating coil.
d) downstream of a mixing box.

18. Face and bypass dampers: _____.

a) may be used as a means of capacity control for both heating and chilled water coils.
b) minimize the possibility of coil freeze-up in cold climates.
c) are not recommended with direct expansion cooling coils.
d) All of the above.

19. True or False? Variable frequency drives (VFDs) have replaced inlet guide vanes (IGVs) as the most common method of fan volume control. _____

20. For a coil constructed of the same materials and face area, rank the following factors in order of their impact on cost, from highest to lowest: fin spacing, circuiting, rows.

_____

_____

_____

Notes

Appendix

Work Session Answers

1. circulating, cleaning, heating, cooling, humidifying, dehumidifying, and mixing air
2. False
3. c and/or d
4. post and panel, structural panel
5. b
6. d
7. True
8. False
9. c
10. d
11. c
12. False
13. a
14. a
15. True
16. False
17. a
18. d
19. True
20. rows, fin spacing, circuiting



Turn to the Experts.

Carrier Corporation
Technical Training
800 644-5544
www.training.carrier.com

Form No. TDP-611
Supersedes Form No. T200-23B

Cat. No. 796-049
Supersedes Cat. No. 791-123