Basics Of Air Distribution

Titus

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Thank you for downloading this guide. If you're like most of us, you likely have an engineering degree and have suddenly found yourself in a role that requires knowledge of HVAC systems. You're scrambling to get up to speed – and fast!

We know the feeling. It's the same one many of us experienced first starting out. And that's why we've written this guidebook – to deliver more context on how air flows in and out of buildings and interacts with the total HVAC system. We want to share our knowledge of innovation in air movement devices to help you feel confident and ready to overcome challenges in this newfound career path.

It's our goal to provide you with the highest quality training possible.

While the decision to work in HVAC may have been unintentional, let us congratulate you on it. It's a richly rewarding industry, not only for its complexities, but also for it being a critical conduit of comfort for indoor life (more on that later).

We hope you enjoy tracking the journey of airstreams. We also hope you'll let us know how else we might improve this guide for future generations of engineers.

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Basics Of Air Distribution

Most people don't think much about HVAC systems. Unless the system isn't working properly, the average building occupant doesn't consider how a space is pulling air in from outside and being cooled or heated to just the right temperature to keep them comfortable.

It doesn't occur to them how the one-hundred degree Fahrenheit, eighty percent relative humidity air outside in summertime Houston or the five degree Fahrenheit, fifty percent humidity air outside in wintertime Milwaukee turns into the comfortable air inside a building, regardless of season.

They also likely haven't thought about what happens to the air everyone breathes out, adding warmth and moisture to the space and altering humidity levels. Buildings are pretty airtight, but they aren't completely airtight. And since most office buildings' windows in the U.S. don't open, you can't keep putting air into the building. You have to exhaust air out of the building, too.

That's what separates you from the average building occupant. You do – or will – think about these things.

You'll know that a successful air distribution system is multifaceted. It's all about controlling humidity, providing sufficient ventilation to meet codes, improving air quality once air comes indoors and ensuring thermal comfort for occupants.

It's an important task. And unfortunately, not all aspects are under your control.

Before getting into the specifics of air movement, there are several conditions that make a space comfortable that any good engineer must understand and account for when designing a system. Some are perhaps obvious – air and radiant temperatures, air speed and humidity – while the others are perhaps less so, such as the metabolic rate and clothing of a building's occupants. The latter are the ones you can't control. The good news is that we have the tips and tricks you'll need to design a successful system.

If you're up for the challenge, read on.

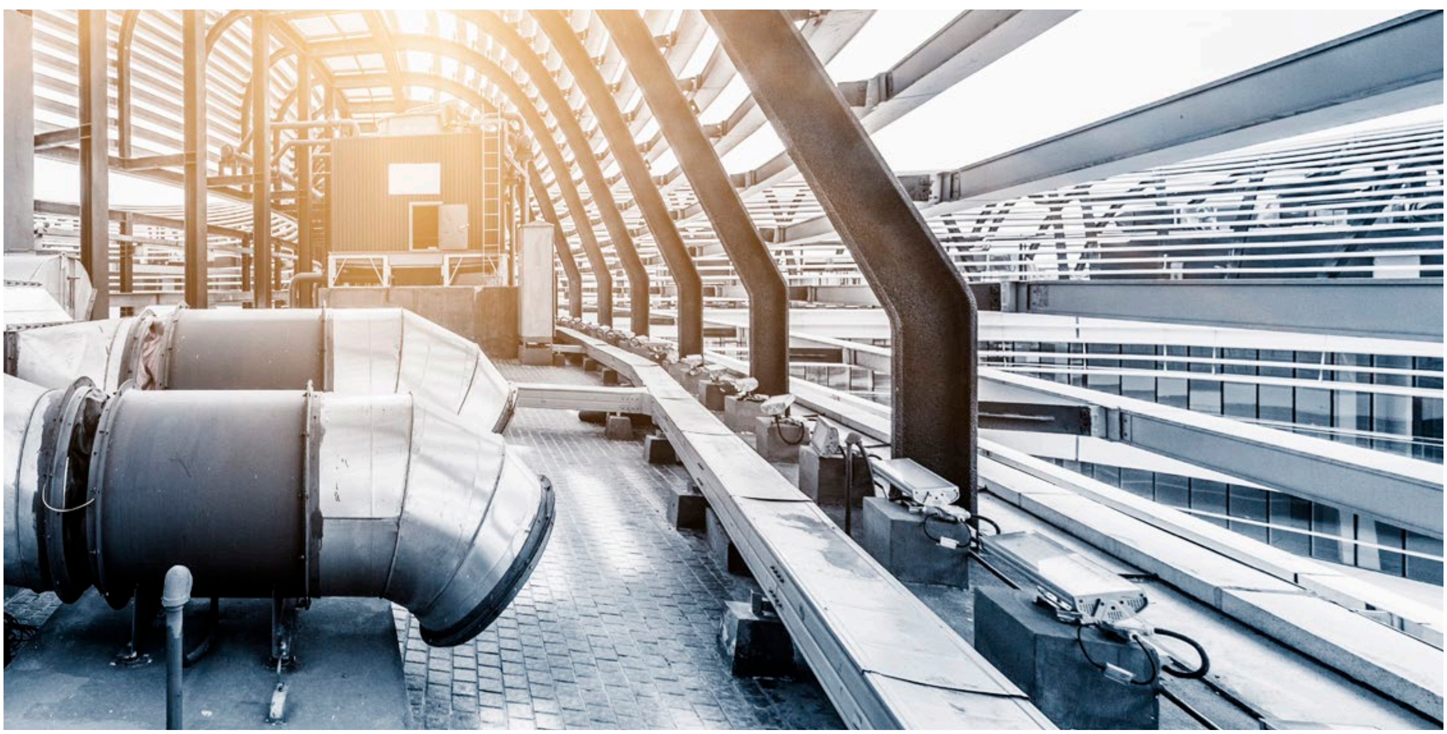
Designing for occupant health and comfort

You know when you're in a building and it's really hard to open a door, or the doors mysteriously blow open from the inside? While it may seem like poor door design, these phenomena can often be attributed to a poorly designed HVAC system, and the negative or positive internal pressure it generates.

While many buildings face these problems, it doesn't have to be this way. We know you will do better than that. To help get you there, we're going to tell you a little story about how air typically goes into and out of the average office building.

Bringing air in

It starts with outside air, also known as ventilation air or fresh air. Outside air is brought into the building through louvers and dampers that lead into the air handler. Though we may think of this air as "fresh," since it comes from outside, that's not always the case depending on the location of the air intake and the quality of the surrounding air. If intakes are near exhaust vents, or other sources of pollution, the cleanliness of the air may be jeopardized.



In addition to possible sources of pollution affecting the air quality, outdoor factors like humidity and temperature can vary from place to place and month to month. This can present an expensive and energy-intensive challenge when trying to maintain a consistent and comfortable internal environment using pure "fresh" air.

What's an engineer to do? In most buildings, you can use return air (also called recirculated air because it comes from the occupied space) and mix it with the required amount of outside air. This saves energy because the return air may be seventy-five or eighty degrees Fahrenheit, as opposed to ninety-five degrees Fahrenheit like Dallas in the summer. Seventy-five degree air costs less to cool to ASHRAE's requirement than ninety-five degree air.

Getting a handle on air handlers

Air handlers (also known as rooftop units, if they're on the roof) play a pivotal role in maintaining a consistent and comfortable air temperature. This piece of HVAC equipment, at minimum, brings in outside air – often mixing it with return air – and adjusts the temperature and humidity level of the mixture with heating or cooling/dehumidifying coils, and then uses a fan to move the conditioned mixture through ductwork into the building. Individual space temperature control is then maintained by adjusting the volume flow rate (usually through variable air volume, or VAV, boxes) or its supply temperature in accordance with the space's cooling and heating demands.

Occupied space:
Room with people in it.

ASHRAE STANDARD TO KNOW

ASHRAE Standard 62.1: Ventilation for Acceptable IAQ

Standard 62.1 reveals the requirements for acceptable ventilation for indoor air quality (IAQ). Its purpose is to specify minimum ventilation rates and other measures intended to provide indoor air that is acceptable to provide adequate comfort to the occupants and minimize adverse health effects. ASHRAE defines acceptable IAQ as no known contaminants at harmful concentrations in the air and a substantial majority of the people exposed do not express thermal comfort dissatisfaction.

EXPERT INSIGHT

Although heaters in HVAC systems all heat up air, they do so for different reasons. And where you put the heating coil depends on why you're warming up the air.

The fan can be oriented in either a blow through configuration or a draw through configuration, depending on the fan's location with respect to the coils. Putting the fan before the coils is a blow through configuration (because it's blowing air through). Whereas after the coils is a draw through configuration (because it draws air through). If the air mixture entering the cooling/dehumidifying coil needs to have an even flow for optimal heat transfer, a draw through configuration is your best bet. If you need to, you can use a blow through configuration, you would just need to move the coil further way from the fan to allow the air to become more uniform. The benefit of this is that heat from the motor isn't added to the airstream after the coil. The disadvantage is that it adds length to the unit, which not only takes up more space but also increases cost. That's why draw through configurations are more common in air handlers.

Coils not only heat and cool the air mixture, they are often selected to remove moisture as well. Air handlers have both cooling/dehumidifying and heating coils, and where they are placed within the unit can depend on the application and conditions under which it'll run. There are four different heating coil applications: preheat, reheat, heating and warm-up.

Heating application one: Preheat

Preheat is used to protect the HVAC system from sub-freezing temperature air. Let's say you have a unit drawing in one-hundred percent outside air. You need to protect the cooling coil from freezing in the winter when the air reaches subzero temps. To do so, the heating coil is put before the cooling coil to warm up the air before it passes through.

Heating application two: Reheat

The heating coil goes after the cooling coil in reheat situations, such as when air needs to be dehumidified. You cool the air down to a temperature that dries the air out, but that air is too cold to provide to the space. The heating coil heats it back up before it's sent to the space.

Heating application three: Heating

Heating is, just as it sounds, when you need to warm air up in order to provide warm air to the space. In this case, coil location isn't as important. If you need to protect the cooling coil, you can still place the heating coil before it, but if not, it does not matter.

Heating application four: Warm-up

Warm-up is similar to heating, but is used in the morning before the building is occupied if the space became too cold overnight. It's short-term whereas heating is used for longer-term situations. Coil location doesn't matter here.

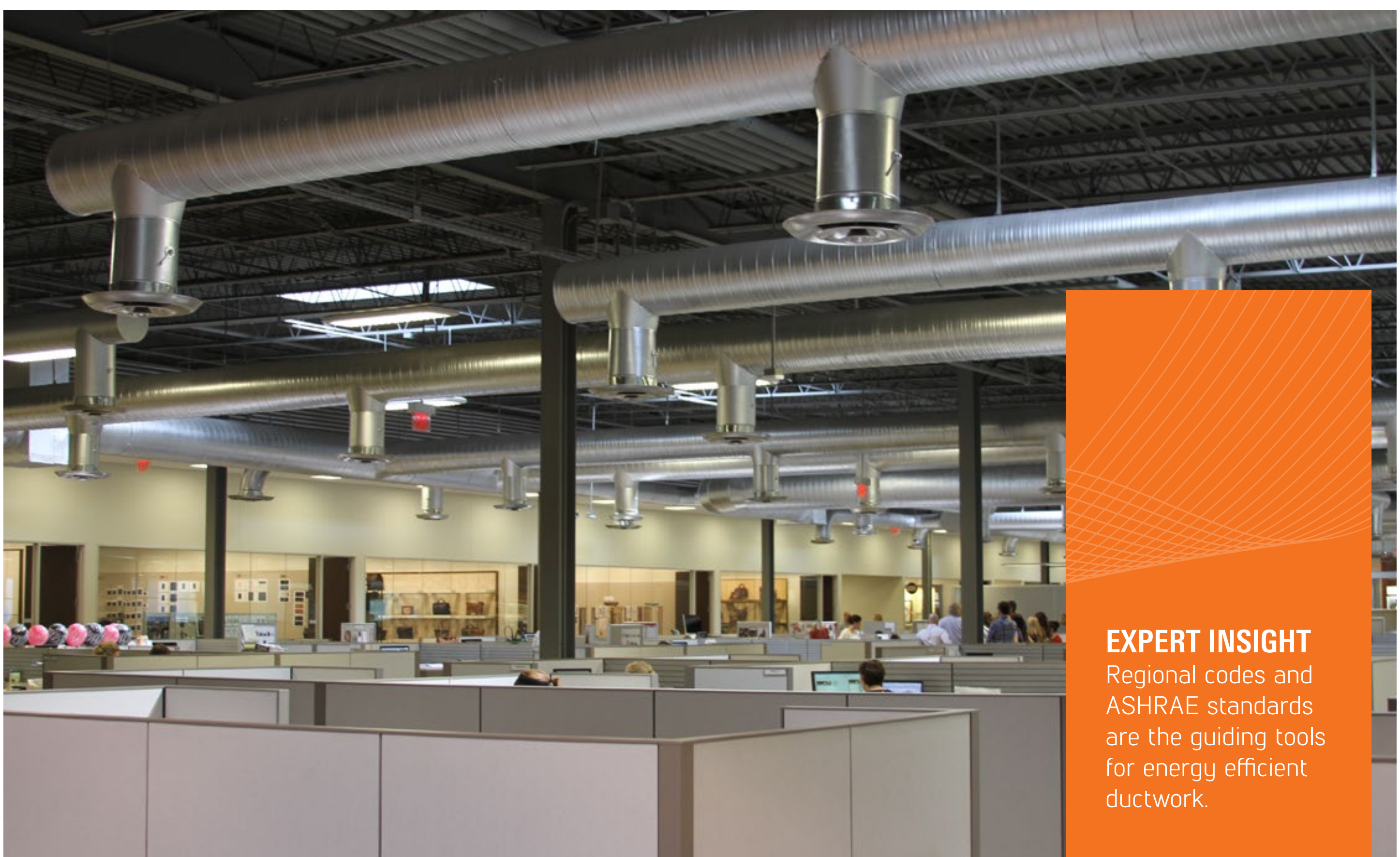
From here to there: The importance of duct design

Duct design, when done properly, will ensure the supply air is distributed adequately. It also helps energy costs stay low and maintain proper indoor air quality.

Available space is a key consideration when planning to run ductwork, so ceiling heights are one important factor. You also need to acknowledge piping, light fixtures, speakers and other communication conduits, ceiling beams and walls. While it may be the intuitive solution, using smaller ducts in the hopes of accommodating these necessities isn't always a good idea. If they're too small, they won't be able to carry enough air and/or they'll contribute to a noisy system. On the flip side, ducts that are too big are likely to lose both air and energy, undermining system efficiency and wasting money.

ASHRAE and SMACNA provide recommendations regarding acceptable ductwork section velocities. To help avoid noisy ductwork, all ductwork sections must fit tightly together and all connections need to be sealed. Dampers can also be used to lessen noise.

When ductwork is designed poorly, it can pull pollutants into the airstream and can also lead to back-drafting, or drawing dangerous exhaust gases, like carbon monoxide, into the supply airstream.



EXPERT INSIGHT
Regional codes and ASHRAE standards are the guiding tools for energy efficient ductwork.

How ductwork is installed also influences how the system functions. For instance, ductwork that runs from warm to cold areas will lose efficiency, and poorly installed fittings can increase the noise level.

After going through the ductwork, our airstream heads towards the heart of the HVAC system to be distributed.

Two system options – many different outcomes

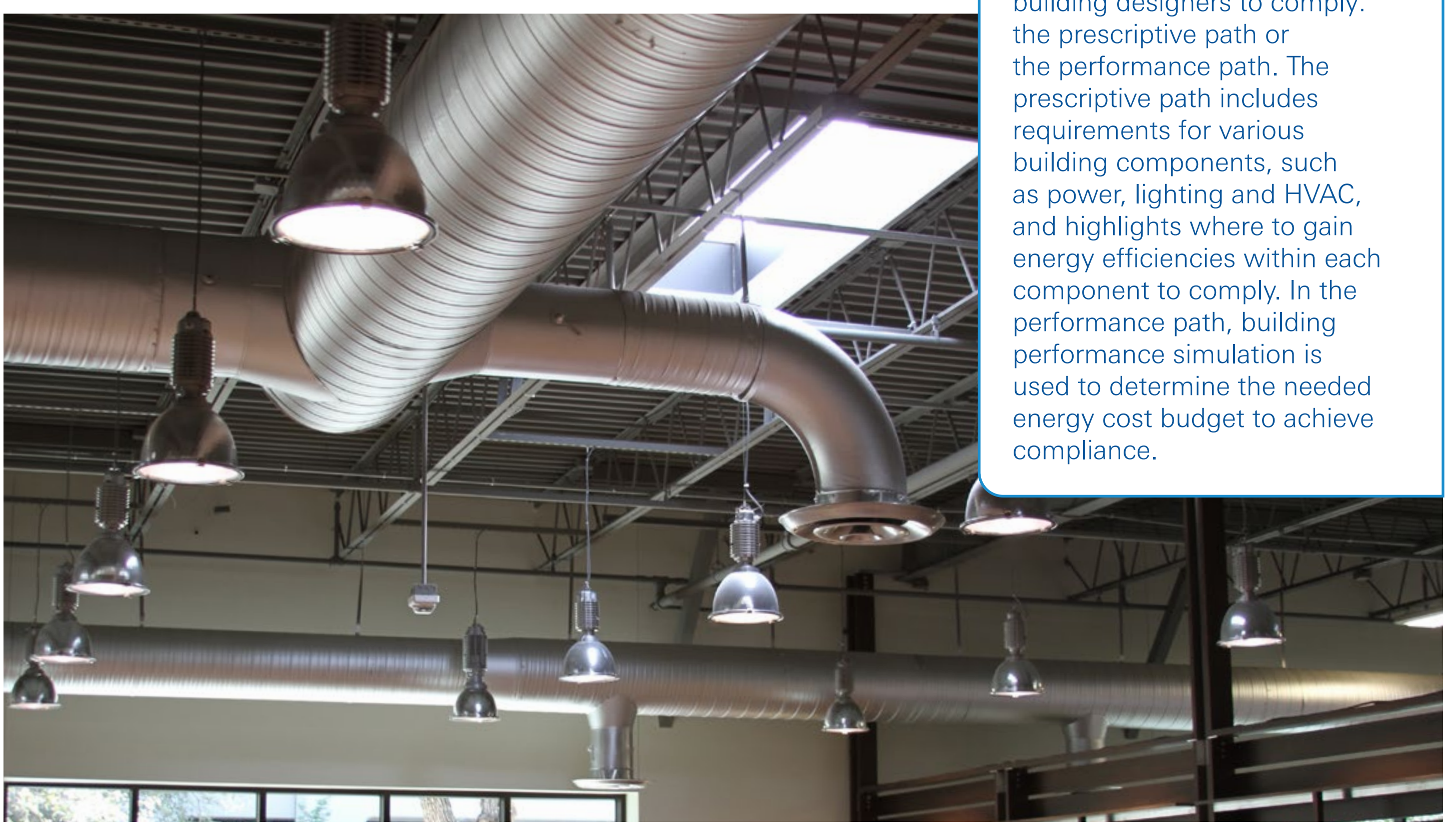
There are two types of systems that vary in either airflow or temperature. Constant air volume (CAV) varies temperature and keeps the volume constant. Variable air volume (VAV) varies the airflow depending on the actual space temperature and the temperature setpoint. CAV systems work much like the airflow in your house. The volume of air is consistent, and the temperature changes to meet the load of the space. VAV systems, on the other hand, were invented in the 1970s to reduce the energy usage of a building by adjusting the airflow to meet comfort needs as the occupant load changes throughout the day.

ASHRAE STANDARD TO KNOW

ASHRAE Standard 90.1: Minimum Requirements for Energy Efficiency

Standard 90.1 provides the minimum requirements for energy-efficient design of most buildings, except low-rise residential buildings. It provides the minimum energy-efficient requirements for design and construction of new buildings and their systems, new portions of buildings and their systems, and new systems and equipment in existing buildings. It also includes criteria for determining compliance with these requirements.

There are two paths for building designers to comply: the prescriptive path or the performance path. The prescriptive path includes requirements for various building components, such as power, lighting and HVAC, and highlights where to gain energy efficiencies within each component to comply. In the performance path, building performance simulation is used to determine the needed energy cost budget to achieve compliance.



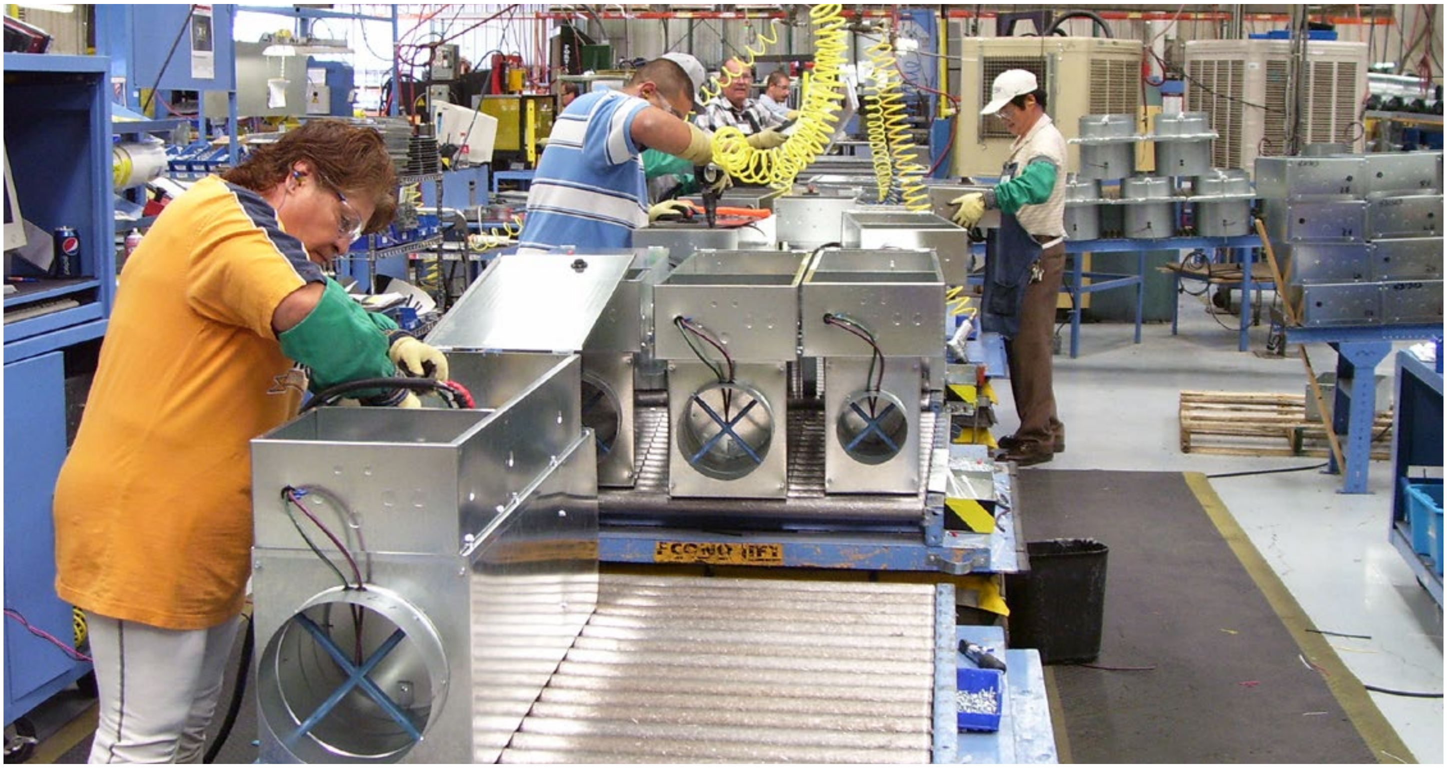
Consider a building and its relationship to the sun throughout the day. The sun starts on the building's east side, warming it up, but the west side of the building stays cool. If the building has a CAV system, and the same amount of air is being provided to both sides, then one side will be uncomfortable. For instance, if the temperature is set to provide comfort to the warmer side then, at the same airflow, the system would be overcooling the cold side. Not only is this uncomfortable, it wastes energy.

A VAV system in the same situation would provide more airflow to the warmer side and less airflow to the cooler side, increasing comfort and using less energy. For instance, an office building's conference rooms aren't always occupied. When there's no load in the space (meaning, an empty room), it doesn't take much airflow volume to keep that room at just the right temperature. But when the room is occupied, VAV systems can increase airflow. It's this flexibility that makes VAV systems better suited to maintain comfort as building conditions change.

Now let's look at the structure of what makes up a VAV system. Last we left our airstream, it was going through the ductwork, and at this point, it comes to a VAV box.

VAV boxes vary the airflow into the space. There are three main types of VAV boxes: single duct, dual duct and fan powered boxes. There are also a handful of other types, such as bypass, induction and retrofit boxes, but since we're covering the basics, we won't go into those here.

EXPERT INSIGHT
If you're curious to learn more about bypass, induction and retrofit boxes, check out the ASHRAE Design Guide for Air Terminals.



The single duct box is the simplest and most common. It consists of an inlet, typically round, that's mounted in a rectangular casing. Supply air passes through the inlet and out the discharge to the diffusers or grilles in the room.

Inside the inlet is a damper that opens and closes around a pivot point, controlling how much air can go through the box. The damper is mounted on a shaft that goes into the control box. At the end of the shaft and outside the airstream is an actuator. The actuator has a motor that rotates the shaft to open and close the damper.

Connected to the actuator is a controller – the brains of the VAV box. Today, most VAV boxes are tied into the building management system (BMS) by way of direct digital controls (DDC) versus traditional stand-alone analog devices. From there, a temperature sensor (or thermostat), typically located on the wall in a room the VAV box is supplying, is connected to the controller.

Still with us? Here's where it all comes together.

All of these components work to maintain the temperature the thermostat is set to, known as the setpoint. When the setpoint and the temperature the thermostat is reading are different, that information is sent to the controller. The controller either says, "It's too hot, we need more airflow!" or, "It's too cold, there's too much airflow!" and it sends a signal to the actuator to open the damper. The damper rotates to open until the room temperature equals the setpoint temperature. This control loop happens continuously throughout the day to maintain comfort.

Fan boxes, another type of VAV box, are also referred to as powered induction units (PIUs). There are two types of fan boxes: series and parallel.

Ceiling plenum: Open space in the ceiling meant for air circulation.

Primary airstream: Main air jet.

Backdraft damper: Damper that prevents supply air from escaping through the fan section in a parallel series fan box.

The two types have several shared commonalities. They have a casing with a discharge that's ducted to the grilles or diffusers in the occupied space. They have a supply air inlet with a damper that's ducted to the supply air handler that works just like the single duct box inlet. And they both have an induced air inlet that's usually open to the ceiling plenum, but can also be ducted to return air. The induced air inlet's function is to pull warm plenum air in when heating is needed, acting as free heating.

As the name implies, both types also have a fan. The key difference between the series and parallel fan boxes is the fan's location. If the fan is in line with the inlet and discharge, it's a series fan box. The fan is in series with the primary airstream, which is how it gets its name. Whether the air comes in from the supply inlet or the induced air inlet, it all goes through the fan.

A parallel box has all the same parts, but its fan is located at the induced air inlet, or parallel to the primary airflow. It's usually mounted on a fan deck and has a backdraft damper. The air that comes in through the primary air inlet never goes through the fan, only induced air does.

Although a small difference, the location alters the pressure and sound performance of the boxes.

EXPERT ADVICE

Fan box backdraft dampers are gravity-operated dampers that open when the fan is blowing on it. When the fan is off, the damper remains closed, prohibiting conditioned supply air from going out the induced air inlet into the plenum and wasting energy.

Because all the air of a series box has to go through the fan, the fan is on all the time and has to be big enough to handle the maximum airflow the box will experience (typically the cooling airflow). And because the fan is on the discharge side of the box, it'll boost the air to the space's diffusers so the supply air handler only needs enough pressure to get the air into the series fan box. The airflow and sound level in the space is constant which is why they are sometimes called constant volume fan boxes.

In a parallel fan box, the fan is on the induced air inlet, so it only turns on when heat is needed. It only needs to be big enough to handle the heating airflow.

One disadvantage to this is that the supply air handler has to have a higher pressure to get the job done because the fan can't help boost air to the space's diffusers. Also, since the fans turn on and off, the airflow volume and sound in the space will vary, which can be distracting for occupants and is why the parallel fan box is often called a variable volume or intermittent fan box.

The dual duct box is the last major type of VAV box. They aren't as popular as the other two types, but you'll run into them now and again (often in healthcare applications), making them important enough to discuss here.

Like all boxes, dual duct boxes have a discharge that's ducted to the diffusers or grilles in the space. The difference is that a dual duct box has two supply inlets (yes, two!) ducted to the supply air system. One is ducted to cold air and the other is ducted to hot air.

Each inlet has a damper to control the amount of airflow into the space. But instead of having hot water or electric reheat coils, like a single duct or fan box would have, dual duct boxes have ducted hot supply air. One benefit to this structure is that you can filter the supply air at the air handler. It's particularly handy in places where filtered air is of higher importance.

There are two types of dual duct boxes. The first is a non-mixing dual duct box. This is basically two single duct boxes strapped together with the unit's discharge ducted to the space. Here's the challenge to a non-mixing box: because the hot and cold air streams aren't mixed in the box, cold air goes down one side of the ductwork and hot air goes down the other.

For this reason, non-mixing dual duct boxes often only have cold or hot air coming in at any given time. In cooling, the damper in the hot duct would close and the cold air damper would modulate to maintain comfort. In heating, the reverse would happen. Be aware though – when switching between heating and cooling, there can be a moment when both dampers are closed and no air is coming from the box. That means ventilation air isn't actively being supplied to the space and temperature isn't being monitored although it typically only lasts for a very short period of time.

The other type is a mixing dual duct box. Just as the name implies, the box combines the hot and cold airstreams. There's a discharge and two inlets, as well as an area in the box for airstreams to blend together. Typically mixing baffles help ensure well-mixed air by forcing the two airstreams together before going out the discharge and into the space.

EXPERT INSIGHT

Active chilled beams are another energy-saving technology for healthcare facilities.

ASHRAE STANDARD TO KNOW

ASHRAE Standard 170: Ventilation of Healthcare Facilities

Standard 170 dictates the ventilation requirements in patient care areas and related support areas of healthcare facilities, including hospitals, nursing facilities and outpatient facilities.

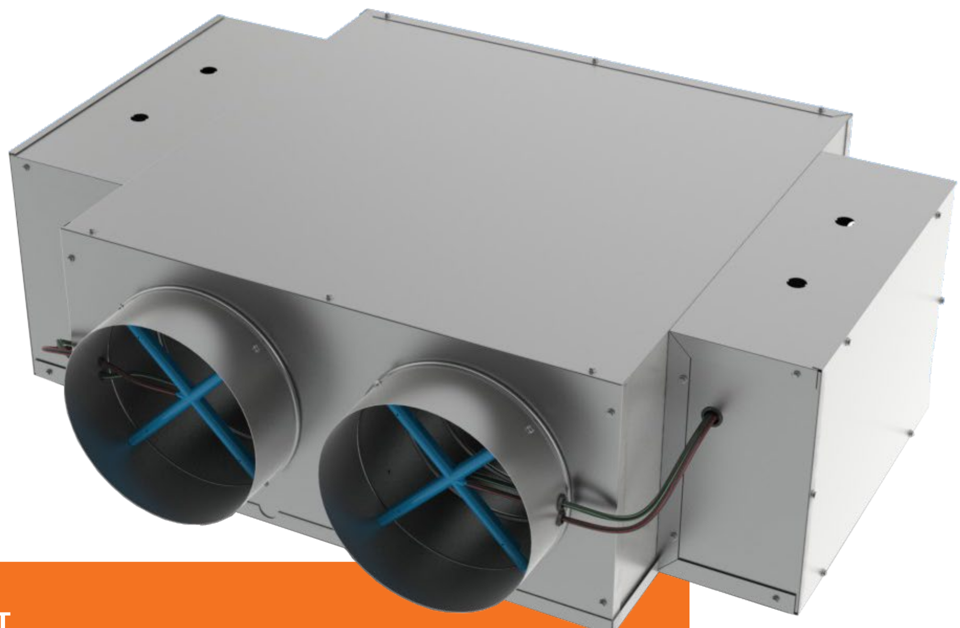
In healthcare facilities the goal is to maintain the pressure relationships required in each room. As you know, you can use room pressurization to keep things in or out of a space. For example, operating rooms require a positive pressurization in order to keep polluted air out of the area, but gas storage areas require a negative pressurization so that if gas were to leak, it does not get out of the room. In addition, there are areas that require no pressurization, such as in intensive care and burn units. Standard 170 goes over all these requirements, in addition to air distribution device requirements, as well as establishes ventilation, space and humidity level and filtration requirements for various areas within healthcare facilities.

How well a dual duct box mixes is described as its mixing ratio.

EXPERT INSIGHT
Mixing dual duct boxes are typically used in healthcare applications, whereas non-mixing are used when low temperature warm air is used. They are commonly used to bring ventilation air into the warm side while cooling and dehumidifying supply air is delivered by the cold side.

After leaving any of these VAV boxes, the air will travel through the discharge ductwork and enter the occupied space through a grille or diffuser – often referred to as GRDs.

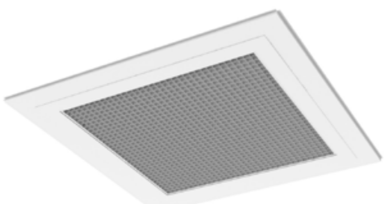
But before we get into that, we need to review some GRD basics, everything from identifying the differences between the three outlets to understanding and converting catalog data.



EXPERT INSIGHT
A 1:10 mixing box, the typical mixing ratio, means there's no more than one degree of temperature difference four feet off the discharge for every 10 degrees of difference in the two supply air temperatures. High mixing is considered 1:20. A 1:20 mixing box has no more than one degree of temperature difference four feet off the discharge for every twenty degrees of difference in supply air temperatures.

Grilles and diffusers:
There's more than meets the eye.

Grilles and diffusers have similar functions and are sometimes used interchangeably. They both allow air to pass through them into a space, either as supply air or return air, but they have important technical differences.



A grille consists of a frame and deflectors with a neck, or inlet side, and a face that are about the same size. Air travels straight through them.

A diffuser is an air device, as well, but the inlet is a different size than the discharge, and the airflow usually exits ninety degrees from the direction it entered.

Grilles are typically placed high on a wall, whereas diffusers are usually in the ceiling, but their function is the same – to mix supply and ventilation air into the room to provide comfort.

Let's pause for a moment to discuss comfort

If you ask multiple people what a comfortable room is, you'll probably get multiple answers.

Comfort is when your body's heat generation is equal to its heat dissipation. Dissipation happens through skin, which is a function of your surface area – if we were all circles, that would translate to our radius squared. The relationship between generation and dissipation varies with each individual's radius. In other words, people with larger radii generally generate more heat, making them warmer.

While that gives us a baseline understanding, we aren't circles, so that view is too simplistic. Luckily, ASHRAE Standard 55, Thermal Conditions for Human Occupancy, helps us define comfort for building design. It outlines six parameters for comfort – met, clo, air temperature, radiant temperature, air speed and humidity.

A person walking in a typical office would generate about 1.7 met, whereas someone sitting would generate 1.0 met. The clo measurement is less pronounced now because most offices are business casual, meaning most people are wearing roughly the same number of layers and weight of clothing. If we think about it in terms of a black-tie event, however, the clo's importance is more apparent. Those in suits are at about 1.0 clo whereas those in dresses are at 0.5 clo.

Since we can't control every occupant's radii, how much they're moving and what they're wearing, we have to focus on what we can control.

ASHRAE STANDARD TO KNOW

ASHRAE Standard 55: Thermal Conditions for Human Occupancy

With so much variation in what humans find comfortable, it can be hard for engineers to design a system in which everyone is the perfect temperature. Enter Standard 55. It outlines the requirements for thermal environmental conditions for human occupancy in various situations. It focuses on factors engineers can control – air temperature, radiant air temperature, air speed and humidity – rather than how much heat a person generates or their clothing's insulation, to help create the optimal environment.

Met: ASHRAE's measurement for energy generation.

Clo: ASHRAE's clothing measurement.

ASHRAE recommends we maintain the room at seventy-three to seventy-nine degrees Fahrenheit in the summer and sixty-eight to seventy-four degrees Fahrenheit in the winter. The room dew point temperature should not exceed sixty-two degrees Fahrenheit to help ensure a comfortable space. It also says that maximum average air speed is forty feet per minute (fpm). You can have higher air speeds with higher temperatures, however. Just keep in mind that for every additional 15 fpm, occupants will feel one-degree cooler.

You also need to consider the temperature difference between an occupant's ankles and neck. If they're sitting, it should be no more than 5.4 degrees Fahrenheit, and if they're standing, no more than 7.8 degrees Fahrenheit. Floor temperature should range between 66.2 and 84.2 degrees Fahrenheit.

Throw: Distance the air travels from the center of a grille or diffuser into the space.

Catalog data: Performance data for each type of grille or diffuser, provided by the manufacturer.

Isothermal conditions: Supply air is the same temperature as the room air.

Okay, back to grilles and diffusers

Before the airstream we're following is ready to enter the space, we have a few other design considerations to cover off.

Throw

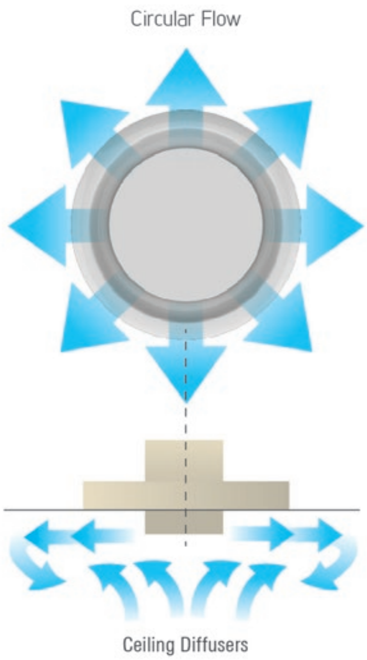
Each grille and diffuser has a cataloged (see catalog data definition) throw. Throw is measured in certain velocities and is typically cataloged at 150 fpm, 100 fpm and 50 fpm, represented by T_{150}, T_{100} and T_{50} respectively. Throw values demonstrate how far air will travel until it reaches terminal velocity. For example, if cataloged throw data is 5-7-13, that means velocities exceeding 150 fpm may be found within five feet, velocities 100 fpm or greater may extend to seven feet and no velocities over 50 fpm should be found 13 feet or more from the outlet. All catalog data is taken in isothermal conditions, enabling repeatable and comparable data, but that's not typically how HVAC systems operate. We'll get into understanding and converting catalog data in a bit.

T_{150} and higher is the same value (distance), regardless of the supply air temperature. Going back to our 5-7-13 example, that means seventy-five degrees Fahrenheit air, fifty-five degrees Fahrenheit air and ninety degrees Fahrenheit air will all have the same velocity (≥ 150 fpm) five feet from the middle of the diffuser.

Throw is also influenced by whether the airstream will be a free jet or one that moves along a surface, like a ceiling or wall. The difference is that the free jet can induce air from both sides, but the jet along a surface can only entrain air from one side.

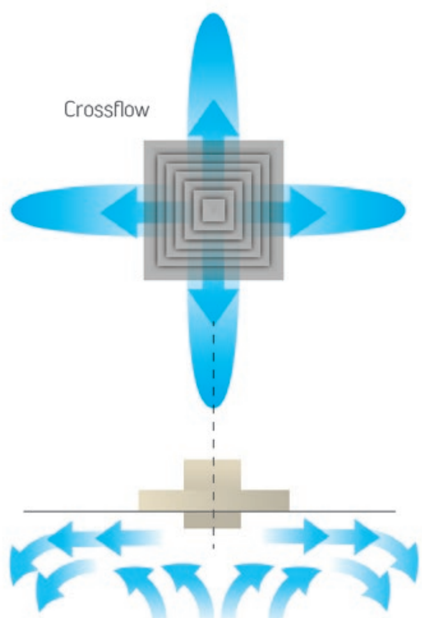
Air patterns

How air is thrown depends on the diffuser's or grille's air pattern. There are two types of air patterns: circular and crossflow.



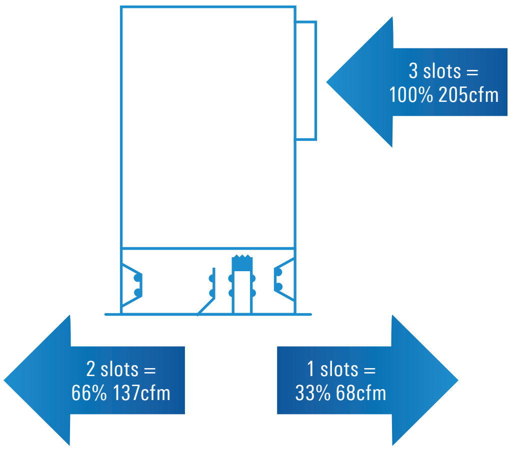
Circular Flow

Circular is exactly how it sounds – there's a 360-degree airflow from the diffuser. It doesn't necessarily require a round diffuser, the air just has to come out of the diffuser's entire perimeter. They aren't always recommended for heating because there's more entrainment and a shorter throw than crossflow, making it harder to get heat into the occupied zone.



Crossflow

Crossflow air patterns move air out in individual jets depending on the diffuser's specific pattern, *i.e.* two jets, three jets, etc. Some have a balanced configuration, with two or four slots facing in the same direction, and others are unbalanced with three slots. All have a higher drop than circular.



Understanding and converting catalog data

Catalog data isn't directly applicable to real-life scenarios and it sometimes only shows data for one discharge pattern. To get what you need, you have to do a little math. Make sure you have the catalog data ready for reference.

As an example, for linear diffusers with more than one slot, divide the total amount of air proportionately into the total number of slots. Then divide the total amount of air by the proportioned slot amounts and you get the total airflow amount for each direction. From there, find that data on the one-way data page and you'll know how the diffuser will perform.

EXPERT ADVICE

Remember when doing this to also take into account how the diffuser noise level will change. A diffuser with multiple slots will be louder than a diffuser with one slot. Use the NC values for cubic feet per minute (cfm) –per–foot for the total number of slots. Check out the section on acoustics to learn more about noise.

Diffusing the confusion around diffusers

One of the last design considerations left to discuss, before the airstream is ready to enter the room, is how many grilles or diffusers can be put on a single terminal box. While it can be a grille or diffuser, we'll use diffusers as our example here.

Diffusers cost less than a VAV box, so it's tempting to put more on a box, if possible. But it's not as easy as dividing the airflow by how many diffusers you want. It's really about zone layout.

If you're designing for one large zone, like a conference room, it's typical to have one 1,200 cfm VAV box supplying the space feeding six 200 cfm diffusers. If it's not one large zone and it's, say, six different offices with one thermostat, the same 1,200 cfm VAV box might supply all of them if all occupants are doing the same type of work (*i.e.* working on the computer). It would require six diffusers (one for each room), and the thermostat can be put in any office.

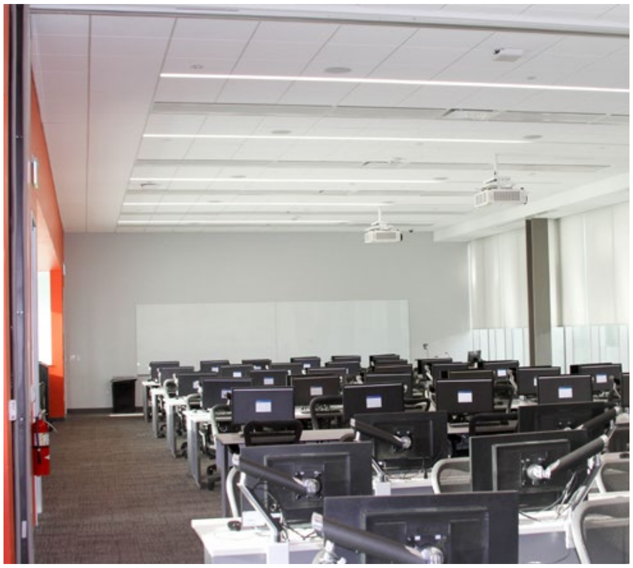
Life typically isn't that cut and dry, so let's make it a little more complicated.

Let's say these six offices are split up into two banks – three interior offices on one side and three perimeter offices on the other. There's still only one VAV box with a diffuser in each office. The thermostat is on the interior bank. And it's winter.

It's cold in the morning, so the heat clicks on. Once the office with the thermostat gets to the setpoint (it's now comfortable), the heat turns off. The problem is that the entire bank of offices on the perimeter will only get colder.

If we move the thermostat into a perimeter office, the heat will stay on until that office reaches a comfortable temperature, and occupants in the interior bank will be too hot.

In this case, you're better off having one VAV box serving the perimeter side and another serving the interior. That way occupants in each zone are able to control their own thermostats.



VAV diffusers

Another work-around is incorporating VAV diffusers into the design. As with VAV boxes, VAV diffusers vary the airflow into the space, but they do it at the diffuser, thanks to a damper that modulates the diffuser's supply airflow rate. The diffuser still has to know the setpoint and the space temperature to know how much air to supply to the space.

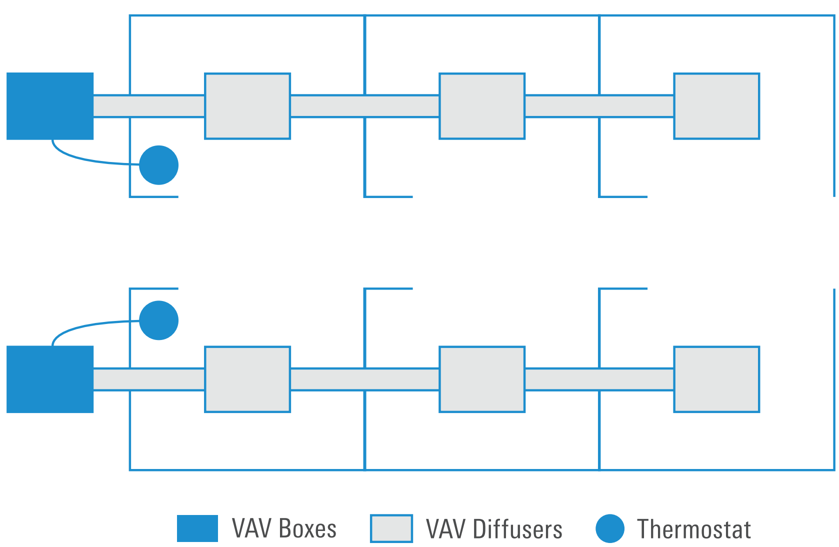
EXPERT ADVICE

Some VAV diffusers will still require a thermostat while others will require the setpoint to be set on the diffuser. If it's the latter, make sure the diffuser is set to calibrate appropriately for a ceiling location, so the space temperature doesn't get wonky. Another cool thing to note is that some diffusers' air patterns will change as the damper modulates, like with Titus' Helios. The variable geometry allows the diffuser to maintain its jet velocity as the airflow is reduced, increasing the mix at lower airflow volumes and maintaining occupant comfort.

Back to our example of one bank of offices being too cold and the other bank, too hot. VAV diffusers allow the occupants of the too-cold side to change their own temperature without influencing the rest of the system. When an occupant gets too cold, they could bump up to seventy-six degrees Fahrenheit so the damper will modulate to close and keep the space at the desired temp.

It is possible to do an entire building with VAV diffusers. We haven't seen much of it in the U.S., but it's fairly common in other countries. With studies linking indoor air quality and comfort to occupant productivity, its application is bound to increase.

Bank of diffusers in office environment.



Thermal displacement diffusers

The airstream we're following could also go through a displacement diffuser. While displacement ventilation requires its own discussion, we should quickly touch on displacement diffusers. The size and placement of them, unlike conventional ceiling diffusers, need early coordination with architectural professionals to be successful.

How they work

Typically located in a low sidewall or floor mounted, displacement diffusers discharge cool air at low velocities and rely on negative buoyancy to cause the discharge airstream to drop to the floor and move away from the outlet (think: liquid spilling). If a displacement diffuser is located in the floor, it still uses negative buoyancy to stay along the floor. A return outlet is located several feet above the occupied zone. When occupants are in the space, they give off heat, forming heat plumes which rise until they reach the ceiling or other equally warm air. The rising warm air pulls the cooler supply air, near the floor, up with it to condition the space's occupants and remove respiratory contaminants. This also results in minimal local velocities outside the heat plumes, which contribute to vertical space temperature stratification.

When they're used

Ideal applications are classrooms and open spaces with tall ceilings, such as theaters, meeting rooms, malls and airport terminals.

When they're not recommended

Displacement diffusers are well-suited for a wide variety of applications. However, they should not be used in spaces with ceiling heights lower than nine feet as contaminants are likely to be reintroduced into the occupied space, negating the advantages of displacement ventilation. Other applications, such as chemical laboratories, may involve contaminants heavier or colder than the occupied zone air and are not recommended.

Adjacent zone: The area around the diffuser discharge where the velocity exceeds 50 fpm at the ankle.

Design and performance considerations

Select displacement diffusers with an average face velocity between 40 and 70 fpm. Supply air temperature should be between sixty and sixty-five degrees Fahrenheit since air is discharged in the occupied zone. But, be sure the temperature difference between an occupant's ankles and neck is no more than 5.4 degrees Fahrenheit when seated and 7.2 degrees Fahrenheit when standing. This will help determine the supply airflow requirement. Return air inlets must be located well above the occupants' breathing area and be amply sized. We recommend a maximum face velocity of 80 fpm (based on the return inlet free area) to allow contaminated air easy passage. The assigned coverage area of a displacement diffuser should not exceed a radius of thirty to thirty-five feet from the outlet's discharge.

The most critical performance parameter, however, is the size of a displacement diffuser's adjacent zone. Stationary occupants should not be located here because as the cool air drops from a sidewall diffuser exceeding 50 fpm and travels across the floor, occupants will be able to feel it.

The airstream can now enter the space, bringing to life your thoughtfully designed system, to keep occupants comfortable.

EXPERT ADVICE

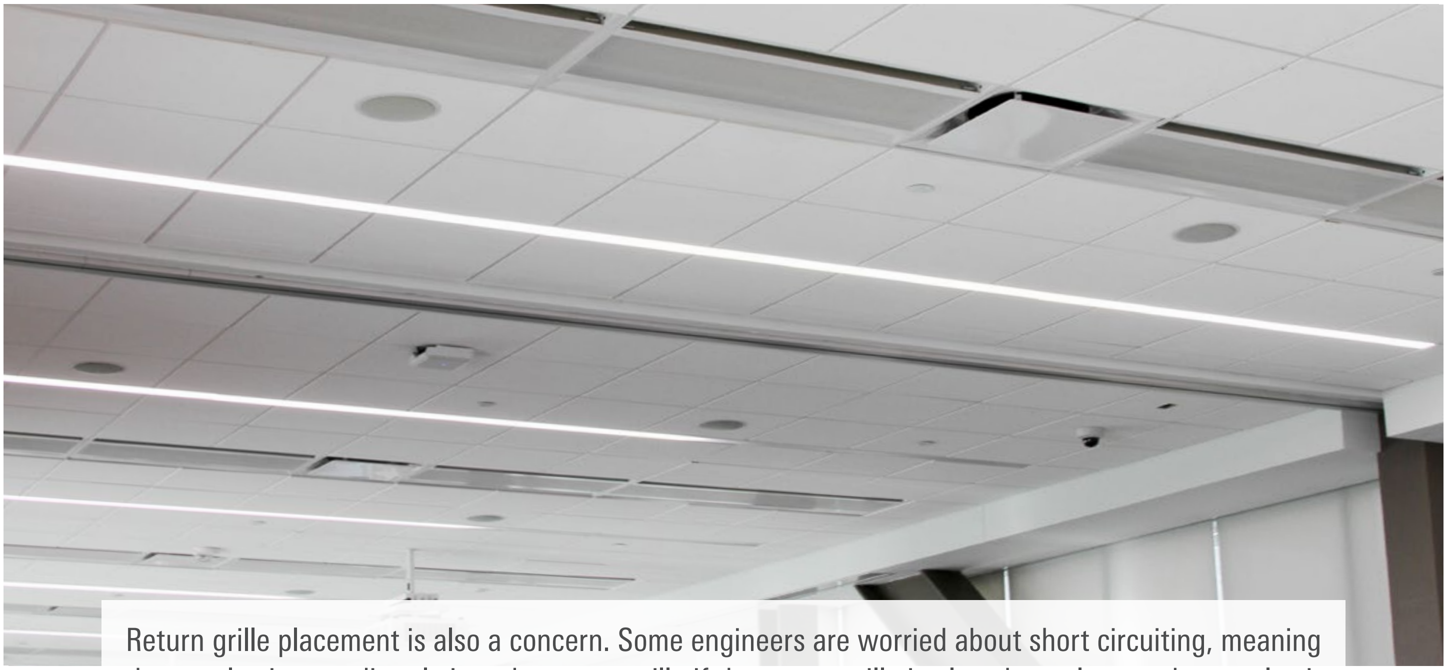
If you are using a plenum return, take note if the building has slab-to-slab walls or if there are noise concerns. You'll need to use an air transfer boot to allow air to move between the spaces.

Return of the air

Once the supply air leaves a GRD, it directs the airflow for good mixing, around in the space, mixing with room air and is warmed (or cooled) in the process. It ultimately makes its way to the return grilles.

Spaces can either have a ducted return (or exhaust) – where the return air is directly ducted to the air handler – or a plenum return, where return air just goes into the open plenum ceiling cavity.

Plenum returns involve less ductwork (resulting in lower install and material costs), less balancing and a lower pressure drop (resulting in lower energy costs). There are associated IAQ and mold concerns if potentially harmful particles or humidity in the plenum get into the return air and back into the air handler. Some buildings, like hospitals and healthcare clinics, limit or prohibit plenum return usage for these reasons.



Return grille placement is also a concern. Some engineers are worried about short circuiting, meaning the supply air goes directly into the return grille if the return grille is placed too close to the supply air outlet. It's a valid concern because of the waste in energy. You'd essentially be cooling or heating air to the desired temperature then sending it directly into the return.

We'll let you in on a little secret.

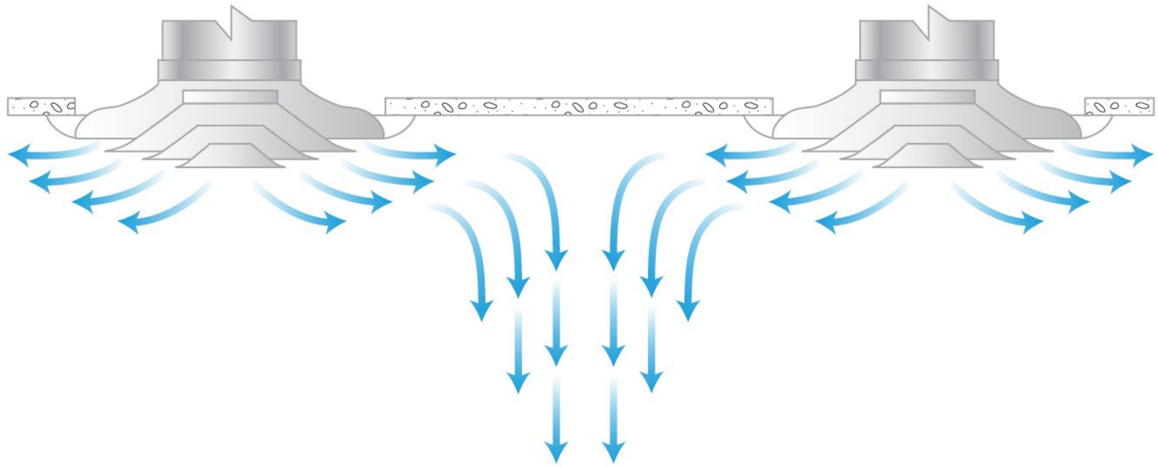
Unless the supply outlet is super close to the return, the return won't have any effect on the supply airflow. That's because you can't suck out a lit match, you can only blow it out. It might be a geeky air distribution saying, but it's true. However, it is always good practice to locate the return outside of supply jet velocities that exceed 100 fpm.

EXPERT ADVICE
ASHRAE's Handbook on HVAC applications is another resource to use on return grille location.

Return grille placement should be decided based on the system and application. For instance, a good location for a typical office would be so it returns the warmest air during cooling season. And of course, make sure your supply airstream isn't short circuited directly into the return grille.

Diffusers can also be used as a return. It's more visually appealing to use the same inlet and outlet, but there are a couple of performance characteristics to keep in mind. Return diffusers will be louder than what catalog data shows for that diffuser in supply. A good rule of thumb is that it'll be about four noise criteria (NC) louder. In addition, the total pressure cataloged is going to be equal to the negative static pressure.

Once through the return, air goes back to the air handler where it's either exhausted or mixed with supply air and the process starts all over again.



Acoustics in air distribution

If you're currently sitting in a commercial building, take a moment to listen to the space. Tune out the chatting and pitter-patter of typing. What do you hear? Depending on how your building's HVAC system was designed, you ideally should hear a nice white noise. Not too loud, not too soft. A constant sound that helps create conversational privacy without being distracting.

That perfect white noise didn't just happen. Engineers like you designed it that way.

While you likely aren't involved in this part of the system design yet, we wanted to arm you with some of the basics to get you thinking about (and listening to) the acoustics of moving air.

Air terminals are among the most noise sensitive HVAC components and their selection and sizing are critical to designing an acoustically sound space. Made up of two types – those that control the amount of airflow to a temperature zone (air control units, ACUs, or more commonly referred to as "boxes") and those that distribute or collect the flow of air (grilles and diffusers) – air terminals are closest to the building's occupants and the final components in many build-up air delivery systems.

There are two important measurements when designing an acoustically sound space – noise criteria (NC) and room criteria (RC).

NC curves were developed to represent lines of equal hearing perception in all bands and at varying sound levels. While an improvement over previous single-number ratings, it gives little indication of sound quality. Enter in RC – a more comprehensive analysis tool. RC helps identify certain frequencies within a space that affect conversation privacy and impairment (a big concern in open offices), as well as the ones that can cause major discomfort to occupants. This measurement is based on ASHRAE-sponsored studies investigating speech preference and requirements in a space and ratings for acoustical quality.

Hungry to learn more?

Here's how through good design practice you can minimize air terminal sound contributions to an occupied space.

- When possible, terminals should be located over areas where sound doesn't matter as much, such as in corridors, copy rooms and storage rooms.
- Use lined ductwork or manufacturers' attenuators downstream of air terminals to help reduce higher frequency discharge sound.
- When appropriate, fan speed controllers are used to reduce fan RPM, as opposed to using mechanical devices to restrict airflow, sound will also reduce.
- Separate the air terminal and return grilles as far as possible. This helps limit the radiated sound entering the space.
- Design systems to operate at a low supply air static pressure to reduce sound level. It will also provide more energy efficient operation and allow the central fan to be downsized.
- Minimize sharp edges and transitions in the duct design to reduce turbulent airflow and its resulting sound contribution.

AHRI STANDARD TO KNOW

AHRI Standard 885, Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminal and Air Outlets

That's the standard of note here. It's the basis most air terminal manufacturers use to convert sound power to a predicted room sound pressure level. Refer to it for guidance on environmental adjustment factors, acceptable total sound in a space and the maximum sound power levels for manufacturers' data.

The latest in air distribution

While you're still getting your arms around the basics, we'd be remiss if we didn't touch upon innovations and trends driving air distribution. We're not talking just product innovation, but also how new technology platforms – think virtual reality and augmented reality – are being incorporated into training programs.

These new technologies transport engineers into any building space to test how products and systems perform in simulated applications prior to installation. Cool, right? We can tell you from firsthand experience, it is.

This type of innovation is spawning a whole new ability to understand a system's potential, limitations and inner workings before it's even built. It's convenient and portable, making it a more engaging, interactive and economical way to experience training. And, let's not overlook the obvious, it's just plain fun!

Then there's the intriguing world of the Internet of Things (IoT), interconnecting building systems and HVAC devices to the internet to collect and share data. Imagine an HVAC and lighting system that automatically adjusts to accommodate weather conditions or that proactively sends maintenance alerts. Harnessed at maximum potential, it could even improve energy efficiency and sustainably. Until then, IoT's use in the HVAC industry is still being defined.

While we could write an entire book on product innovations as they relate to grilles and diffusers, we'll spare you. Regardless, here are a few examples to snack on. To start, maybe you won't be surprised to learn office workers are tired of battling over control for the thermostat. Well, that's a war today's VAV diffusers are ending. The diffusers are becoming more sophisticated with individualized controls for personalized comfort and increased energy efficiency because they self-power with ambient light. Another trend on the rise is the design of symbiotic systems. Don't let the fancy verbiage confuse you – we're talking about integrating products that serve multiple functions. Example: combining the efficiencies of chilled beams and LED lighting. Yes! An energy efficient light that also effectively heats or cools, because not everyone thinks that these very necessary grilles and diffusers look as sexy as we do. Go figure.

Hopefully by now, you're starting to form a better picture of exactly what the HVAC and air distribution industry holds. There's never been a more exciting time to understand what's possible and push the boundaries in designing optimal systems.

Additional resources to check out

While you now have a pretty good start to your HVAC engineering journey, there is always more to learn. Below are some helpful resources to tap into.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
ASHRAE's goal is to advance human well-being through sustainable technology for the built environment. Members focus on building systems, energy efficiency, indoor air quality and sustainability within the industry.

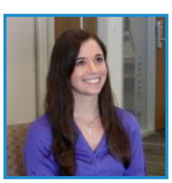
We recommend becoming a member of ASHRAE (if you're not already) in order to stay on top of the latest trends and standards. It has a ton of technical resources, as well as professional development classes, groups and conferences. Look into joining the Young Engineers in ASHRAE (YEA) group to connect with your peers.

Social groups
Use social media to connect with other engineers, see what questions are being asked and stay up-to-date on the latest trends.

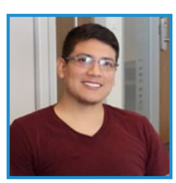
Explore Reddit, specifically the /r/engineering subreddit, to see what other engineers are talking about. You can narrow your search to "manufacturing" or "HVAC," to see discussions most relevant to your work.

LinkedIn has a variety of engineering groups you can request to join that share other informational resources. And it's a great way to build your network. Whether you choose to join Young Engineers in ASHRAE or not, you can still join the YEA LinkedIn group.

Titus University
Titus University is a leading training environment for the HVAC industry. We offer classes, webinars and training videos. Classes at our facility provide hands-on learning experiences, discussing a variety of topics engineers working in HVAC will need to know, regardless of what stage of their career they're in. Engineers receive certification completion that most states recognize as continuing education hours for their PE license.



"You learn about stuff in the classroom and you know about it from a design aspect, but actually being able to see it and learn how they test it is so much more hands-on. It makes it easier to remember."
Reagan Long
Project Engineer
RTM Engineering



"When you look at performance data, you only know so much about it. Titus University will help me get a better understanding of it."
Manuel Ascencio
Mechanical Engineer
Jordan & Skala Engineers

Consulting-Specifying Engineer

Consulting-Specifying Engineer is a magazine for professional engineers involved in the design, specification and product selection of integrated mechanical, electrical and electronic systems for new and retrofit building projects. While there are a number of trade publications that are fantastic resources for HVAC news, *Consulting-Specifying Engineer* has a focus on educating its readers. It offers online webinars through its CFE Edu portal and frequently has articles focused on education in its "Back to basics" feature.

Titus catalog

The Titus Product Catalog contains an in-depth "Engineering Guidelines" section on grilles and diffusers, terminal units, fan coils, acoustics, chilled beams, displacement ventilation and underfloor air distribution, including a lot of diagrams and graphs.

Tools to look for from manufacturers

Some manufacturers will offer a selection software to help save time reviewing which of their products will be a fit for your project. Titus offers TEAMS, an engineering design tool allowing application-based selection of grilles, diffusers, VAV terminals, chilled beams and fan coils for commercial HVAC systems. The TEAMS installation includes all of the Titus air distribution selection software suite of products. TEAMS calculates a range of products that will operate at user-specified conditions, allowing the design engineer to pick the best fit for the application.

In addition, most manufacturers offer visual tools to help understand their products. Always be sure to check their website for or ask about the latest REVIT and CAD drawings.

Concluding thoughts

While often overlooked, air distribution affects everyone's day-to-day lives. As an HVAC engineer, you'll have a bit of control over the comfort level of every person that steps into a building.

We hope you now have a good foundation on how to optimize airflow, and you feel more confident going into your career. We know how overwhelming starting out can be – use this guide to help find your comfort zone in the industry.

If you'd like to learn more, sign up for Titus University. You'll be able to dig deeper into energy solutions, ASHRAE Standards and other air distribution principles, as well as how to apply them into current projects. We'd love to see you there!

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