UNDERFLOOR VENTILATION

Raised-floor air distribution for office environments

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Having worked for many years in design, facilities management (owner), and, presently, as a division manager for one of the largest property management and real estate firms in the country, it has been my experience that new ideas and approaches are sometimes met with much skepticism and resistance.

Too often, when a "new" design approach is presented to ownership (and I have been on both sides of the table), the first question usually asked is "How much more will this cost me?" If the answer to that question is satisfactory to ownership, the next question will usually be, "Where else has this design approach been implemented?" Responses have ranged from, "This is not building standard," to, "Show us where else this system is installed and then maybe we will consider it." The best response I have ever heard, from a senior manager I was working for while in facilities management was: "Well, you seem to like it, so go ahead. But if it does not work, it's your neck." Needless to say, this alternative design was not installed.

With those responses, what designer, engineer, or facilities or property manager would want to put their "neck" on the line? If the innovators of the early 18th and 19th centuries had adopted this attitude and always had to worry about job security—as so many talented and innovative people of today must—the Industrial Revolution may never have occurred.

On the other hand, our counterpart, the architect, is always looking for something new, innovative, and groundbreaking. Usually, this is not only encouraged by the owner/client, but also funded by him or her. The reason for this is that the architect is encouraged to do something original and to leave their "signature on the landscape." Engineers, on the other hand, go with what has worked in the past.

"CONVENTIONAL" DUCTED SYSTEMS
Pros & Cons

ADVANTAGES:

- Supply and return air is distributed entirely through galvanized sheet-metal ductwork, making it a "cleaner" system.
- Complete zoned VAV control for both peripheral and internal areas.
- At the present time, this system is more familiar to both ownership and maintenance staffs.

DISADVANTAGES:

- Increase in quantity of ductwork needed, increasing material and labor installation costs.
- Since most ductwork will be larger, ceiling heights must be lower.
- Increased controls costs.
- Reduced flexibility in future retrofits resulting in additional future costs.

Refer to Figures 1 and 2 for a typical raised-floor and VAV ducted "conventional" system.

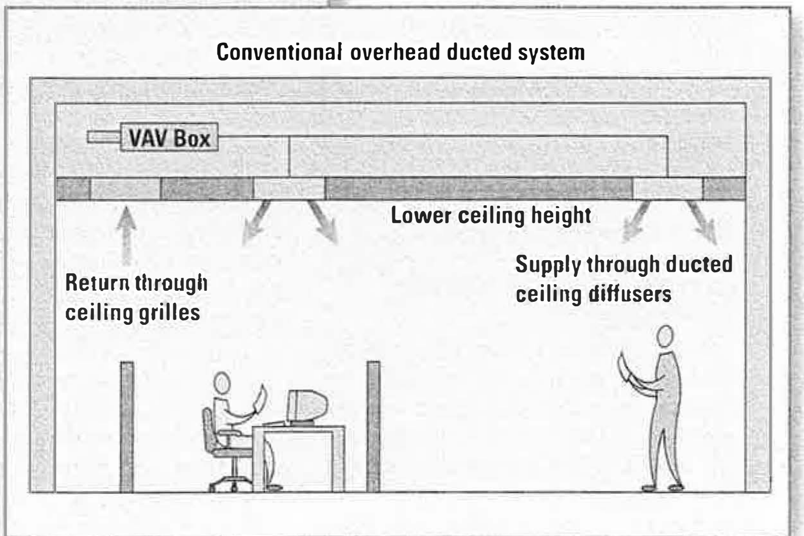


FIGURE 1. Elevation of typical overhead ducted air distribution system. Note the lower ceiling heights necessary for large ductwork, conduits, piping, etc. (Raised floors for power and data are not shown in this illustration).

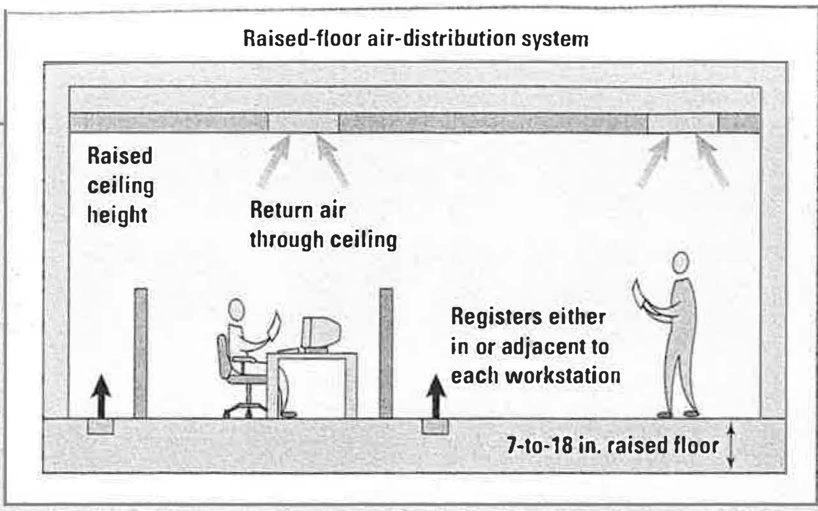


FIGURE 2. Elevation of a raised floor air distribution system. Note the strategic location of floor grilles, raised floor heights, and high ceiling heights.

RAISED-FLOOR SYSTEMS

Pros & Cons

ADVANTAGES:

- Early studies have shown that underfloor systems save energy. Since underfloor systems only need approximately 0.1 in. of external static pressure for proper floor-diffuser performance, overall external fan delivery static pressure can be reduced to approximately 0.5 in.(compared to 1.5 to 2 in. with overhead systems). This results in reduced fan horsepower and energy consumption, not to mention reduced first electrical and mechanical installation costs.
- Reduction of installation costs due to all work being performed at the floor level instead of above the ceiling.
- Increased safety for construction workers (less climbing, ladders, etc.).
- Reduced ductwork and duct sizes results in higher ceiling heights.
- VAV-box maintenance, repair, and controls are simplified.
- Each person has individual control over his or her own air supply.
- Due to the increased supply-air temperature (approximately 60 F to 67 F) hours of usage of an air-side economizer can be increased, reducing operating costs and extending the life of the central-plant equipment.
- Energy savings can be obtained at the central plant. The chilled-water temperature no longer will need to be distributed in the 44 F-to-49 F range. 50 F-to-54 F water is more than adequate to provide 60 F-supply air.
- Floor diffusers or grilles can be rearranged if the office layout changes. This is accomplished by moving the entire access floor panel with the diffuser to another location.
- Since air flow is from the floor to the ceiling, heat from lighting is removed before it enters the occupied zone by the ceiling-located return. This will result in better heat removal.
- The system is self-balancing, since the entire system, in theory, will operate at the same pressure.

DISADVANTAGES:

- Floor slab has to be kept clean at all times. Should be implemented as part of the building O&M program.
- Occupants may close off their register, resulting in increased supply-air flow through adjacent registers.
- Humidity problems due to the higher supply-air temperatures. Space humidity should be monitored through the BMS. To satisfy IAQ and as recommended by ASHRAE, an upper RH limit of 60 percent in summer should not be exceeded.
- Due to the higher supply air temperature, more supply-air may be necessary to satisfy the same space loads (delta T is less). It should be stated, though, that this has not been found to be a problem. Since the floor diffusers have a throw of approximately 6 or 7 ft, this will preserve the stratification layer at the ceiling. Testing has shown that there is 100-percent mixing in the occupied zone. The ceiling stratification results in supply and return temperatures of approximately 17 F to 20 F (delta T). This is the typical delta T found in "conventional" systems.

Breaking from this mold, the intent of this article is to offer a "design guide" to raised-floor air distribution within an office environment.

WHY CONSIDER RAISED-FLOOR AIR DISTRIBUTION?

Design criteria. Office buildings include both peripheral and interior spaces. The peripheral space can extend from 8, 10 or 12 ft from the exterior wall. This space is usually reserved for offices that are occupied by the corporate elite. Since the wall usually has a large glass area, these zones have variable loads that are dependent on the time of year, time of day, glass construction, shading coefficients, and weather. During the winter, heating is required in these spaces; during the spring and fall, one side of the building may require heating while the other side requires cooling; and in the summer, full cooling is the norm.

The interior zones will most likely have a steady cooling load year round. These loads are usually due to lighting, equipment, and people. Typical values used for cooling-load calculations are 1 to 2 w per sq ft for lighting, 1 to 3 w per sq ft for equipment (depending on use), and a population density of one person per 100 sq ft (assuming 8-by-8-ft workstations).

As stated in the "ASHRAE 1999 Applications Handbook," the general indoor design criteria used for office spaces is 70 to 74 F in winter (at 20-to-30-percent RH) and 74 to 78 F in summer (at 50-to-60-percent RH).

SYSTEM COMPARISONS

As with all types of systems, there are bound to be advantages as well as disadvantages. It's up to the design engineer and owner, after weighing these advantages and disadvantages, to decide which type of system to implement. The advantages and disadvantages of both systems can be found in the sidebars "Raised-Floor Systems: Pros & Cons," and "Conventional Ducted Systems: Pros & Cons."

GENERAL DESIGN CONSIDERATIONS

Architectural. The first item to coordinate with the architect is the location of the AC units, which will distribute the supply air to the raised-floor plenum space. I have seen these AC units ducted until the duct reaches beyond the "core" or center area of the floor. I've also seen these units simply supplying air directly to the raised-floor plenum, with no ductwork. Depending on the floor area and the location of the core, either the middle of the core or the end of the core is the ideal location. With this method, AC-unit quantities usually are in multiples of two.

Second, a raised-floor height must be established. Published test data performed by the Center for the Built Environment (a University of California at Berkeley collaborative with industry manufacturers that is sponsored by the National Science Foundation) recommend a minimum raised-floor height of 7 in. with 3 in. clear of any obstructions (cables, conduits, etc.) for ideal system performance and distribution. However, typical raised-floor heights are usually 12 to 18 in.

The third item that must be determined are the type of floor grilles to be used, and the coordination of their specific locations. On the market today are speciality access floor products specifically designed for raised-floor distribution. These grilles are heavy duty to withstand foot traffic. They can come with an actuator and damper that can modulate depending on space conditions, and can be either ducted or non-ducted. Additionally, there are fan powered boxes that are available with either electric or hot-water reheat. To avoid any confusion during construction, it is recommended to sit down with the architect or interior designer and mark up a furniture plan to show where all registers are to be located.

Code issues. The code requirements when designing either a raised-floor or a ducted system are quite similar. For example, whether the ceiling is being used as a return plenum or the floor cavity is being used as a supply plenum, certain code requirements must be adhered to. Minimum outside air requirements for that state or city must be followed (ANSI/ASHRAE Standard 62-1999, *Ventilation for Acceptable Indoor Air Quality* is a guideline, not a code). Other items to address are duct construction standards, duct supports, and fire and life safety.

The one difference between the two design approaches regarding code is one that is often overlooked by the engineer or designer. As discussed, we are going to be supplying air through our raised-floor system. Per Article 100 of the *National Electric Code* (NEC), the definition of a plenum is a device "to which one or more air ducts are connected and which forms part of the air distribution system". Section 300-22 of the NEC addresses power wiring requirements in a plenum (this article basically states that other than that of specific types of cables [MI and MC],

Cost Analysis

An example analysis was performed to help illustrate the costs associated with a "standard" VAV chilled water system (Scheme A) versus an underfloor distribution system with fan coil units serving the peripheral areas (Scheme B). A layout for each scheme was completed (refer to Figures 1 and 2). Each floor space under consideration is approximately 5,000 sq ft (usable) and located in New York City. The estimated construction costs associated with Scheme A and Scheme B are as follows:

Note: Comparing budget costs for both Scheme A and B, Scheme A is $33,800, or 17 percent greater than Scheme B. It should be noted that each design is conceptual in nature and the prices below are budget prices obtained from various mechanical contractors who were not in a competitive bid. Equipment substitutions, for example, an inlet vane damper for a variable-frequency drive; layout; controls (substitute pneumatic instead of using DDC) could all occur, reducing the project's cost.

SCHEME A

Item	Cost
20-ton AC unit with variable-frequency drive w/ vibration isolation (materials)	$39,500
Ductwork and acoustic lining (material and labor)	$39,000
VAV boxes (materials and labor)	$18,000
Linear diffusers (plenums, materials, and labor)	$10,000
Diffusers and return grilles	$2,500
AC-unit installation (labor only)	$8,000
Gauges	$1,000
DDC controls (materials)	$45,000
Piping (materials and labor)	$8,600
Duct and pipe insulation (materials and labor)	$ 9,500
Balancing (air and water)	$ 5,000
Startup and supervision	$ 6,000
Electrical (control and power)	$38,000
TOTAL	**$230,100**

SCHEME B

Item	Cost
Two 5-ton downblast AC units	$20,000
Ductwork and acoustic lining (material and labor)	$18,000
Fan-coil units w/vibration isolators (materials)	$12,600
Fan-coil unit installation	$ 6,000
Linear diffusers (plenums, materials and labor)	$10,000
AC-unit installation (materials and labor)	$11,400
Controls (materials)	$14,700
Piping (materials and labor)	$34,400
Duct and pipe insulation (materials and labor)	$12,000
Balancing (air and water)	$3,500
Startup and supervision	$5,000
Electrical (control and power)	$21,700
Raised-floor VAV-type grilles	$27,000
TOTAL	**$196,300**

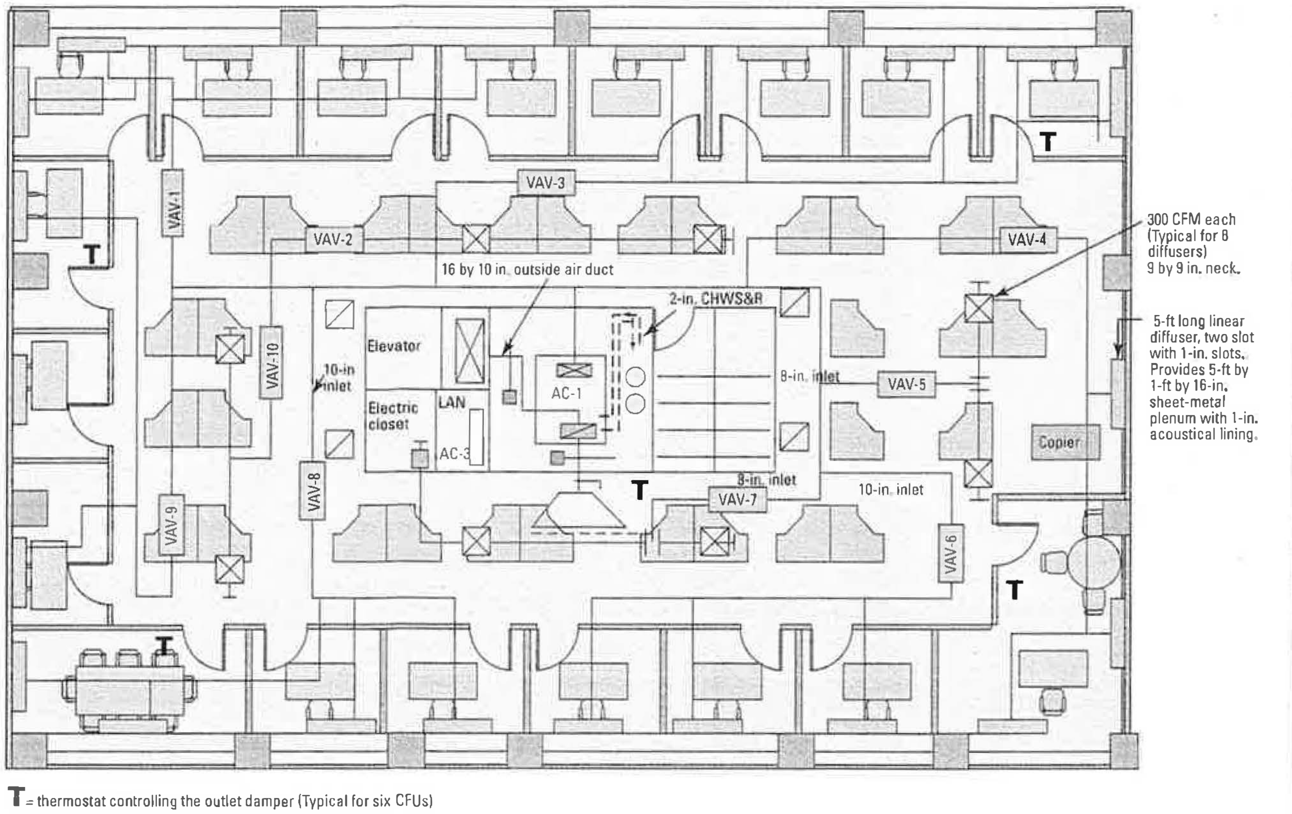


FIGURE 3. Plan view of a "conventional" overhead, ducted air-distribution system.

all other cabling must be in conduit or flexible metal conduit).

Article 800-53 (a) of the NEC addresses specific requirements for communications cabling in a plenum (must be type CMP). Fiber optic cabling, which is becoming more common, but still is basically used as a backbone or a vertical riser, (not out to workstations through the raised-floor) must also comply with Article 300-22 of the NEC.

This article only touches on some of the code issues. Depending on which part of the country your project is located in, UBC, UMC, BOCA, and NFPA are all relevant codes and guidelines which must be followed. Always remember, the authority having jurisdiction always has the final word.

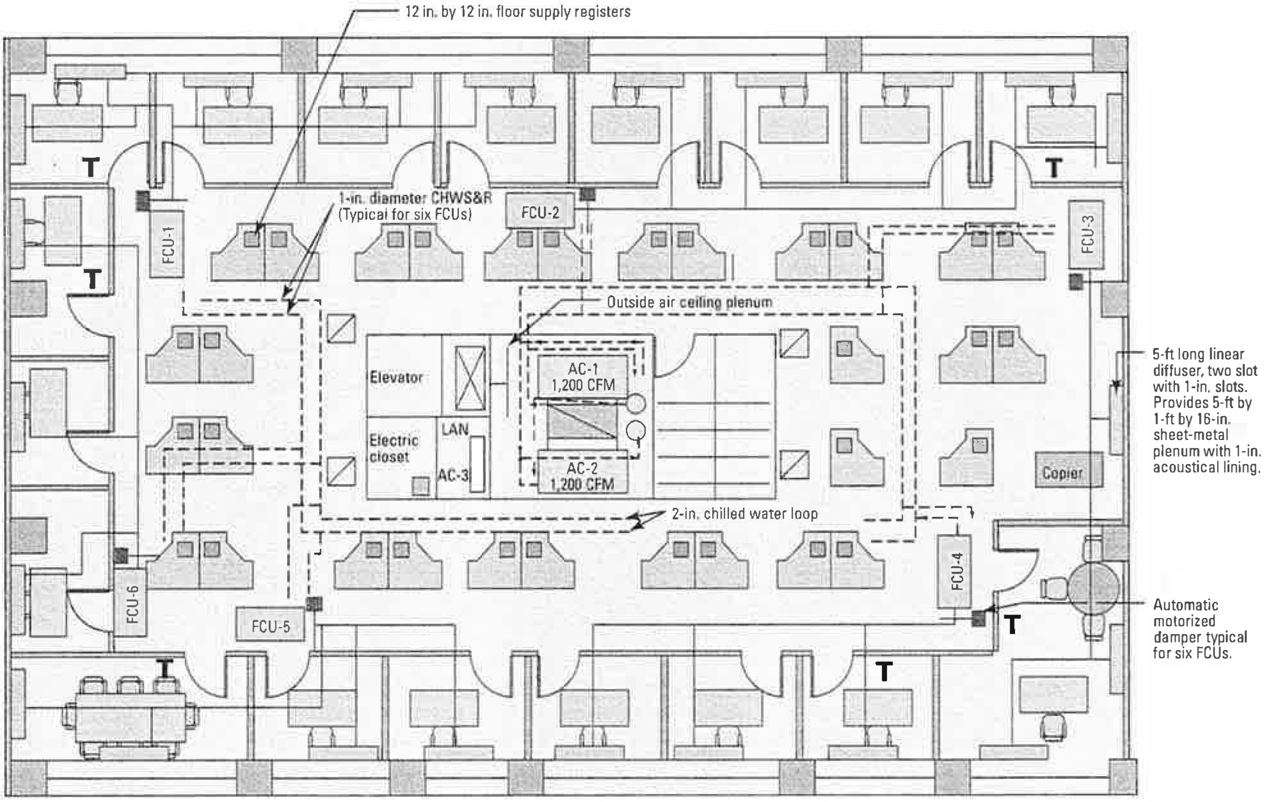
Equipment. Discussing briefly the equipment used when implementing a raised-floor system, please note that there are different approaches that can work well. I recently saw ducted fan power boxes below the raised floor to provide perimeter office cooling (or heating if fin-tube radiation is not an option). This allows for a complete underfloor-distribution type system.

INTERIOR AREAS

As previously discussed under design criteria, the interior area of the office space will usually have steady loads with little or no variations. Therefore, using a non-modulating floor grille instead of the modulating VAV type will, in most situations, do the job. Regarding the AC units, there are two basic approaches that can be implemented. Either the units can be "data or computer room" type units (or packaged), or a "standard type" (i.e., non-computer room type units). The standard unit will discharge within a ducted system below the raised floor. In this outline, it is preferable to use units designed specifically for underfloor distribution. These units are of a downblast configuration, come packaged with their own controls, and can be either chilled water, water cooled, or split-system air cooled. Regarding the control package, since an office area does not possess the same critical nature (i.e., tight temperature and humidity control) as that of a data center or computer room, it is my opinion that specifying a high end control option is not necessary.

EXTERIOR OR PERIPHERAL AREAS

As previously discussed under design criteria, the peripheral areas have varying loads. Two approaches can be used to serve these areas. One is to use induction units located in each office. I find this approach costly and not very efficient. The second approach is to use a ducted fan-coil unit. Each fan coil should serve approximately three offices. A motorized damper should be placed in the ductwork at the fan discharge. When a drop in room temperature occurs, the thermostat should modulate the chilled-water control valve to the closed position. If the space temperature is still not satisfied, the



T = thermostat controlling the outlet damper (Typical for six CFUs)

FIGURE 4. Plan view of an underfloor air-distribution system. (Note that in this illustration, fan-coil units are shown serving the perimeter areas. A different approach could be taken using underfloor, fan-powered boxes.)

thermostat should modulate the discharge damper, decreasing the amount of supply air. This method gives two means of controlling temperature within an office space compared to a VAV box, which can only modulate between a maximum or minimum position (Figures 3 and 4 show typical layouts for conventional ducted and underfloor systems).

Heating can be accomplished in many different ways. A four-pipe-fan coil unit or a two-pipe unit with a summer-winter changeover can be used. This method is not preferred by most design engineers. The reason being, as we all know, is that heat rises, so "forcing it down" along the interior skin does not always do the job. The better way, in my opinion, is to provide hot water fin-tube radiation with either a reset schedule (based on outside air temperature) or one with thermostatic controls. It is preferable to have one thermostat control for both the fan-coil cooling/supply air and the fin-tube radiation (with both the fan coil and fin tube in the same zone). This approach prevents the possibility of simultaneously heating and cooling the same office space(s).

CONCLUSION

When we think of a raised supply-air system, what do we think of first? Distributed data centers and computer rooms, of course. If we trust cooling our vital equipment with this method, the lifeblood of our corporations ("AC for Computer and Telecommunications Rooms," November 1998), why don't we trust this method for our office areas?

Within this article, design criteria, design considerations, and a comparison of a raised-floor system and a "standard" ducted system were discussed. All of the equipment discussed has been used with excellent results. What is different has been the application in which this equipment was used.

In summary, if the design outline discussed is followed, than a raised-floor air-distribution system will be a success. Before deciding on any system, an evaluation must occur before implementation to see if the approach being considered is the correct one. In the end, complete client satisfaction is what the design engineer must strive for. If user satisfaction can be achieved at a minimal cost, then the engineer has met and exceeded his or her responsibilities as a professional.

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