



Steven T. Taylor

Return Air Systems

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Most HVAC systems at least partially recirculate air to increase cooling or heating capacity to conditioned spaces while avoiding the energy and first cost impact of conditioning outdoor air. These systems generally take one of the following forms:

- Return air is conveyed entirely in ductwork from the conditioned space back to the air-handling unit;
- Return air is conveyed entirely using architectural plenums such as ceiling cavities, drywall shafts, and mechanical rooms; or
- A combination of ductwork and architectural plenums.

Using architectural plenums is prohibited in some applications. For instance, most model mechanical codes do not allow conveying air in plenums exposed to materials that do not meet certain flame spread and smoke generation limits, such as wood beams or trusses. Most health-care codes also prohibit the use of architectural plenums for critical medical spaces because of concern about asepsis. But for most commercial and residential applications, architectural plenums can be used.

Benefits of Architectural Return Air Plenums

The benefits of using architectural plenums vs. ductwork include:

- Reduced HVAC system costs of about \$3 to \$5 per square foot (\$32 to \$54 per square meter), about 10% to 20% of the total HVAC system cost.
- Reduced costs to other trades to accommodate the congestion caused by the added return air ductwork, such as raising the floor-to-floor height or adding additional offsets in plumbing and sprinkler piping.
- Reduced fan energy costs of about 20% to 30% due to the much lower pressure drop of the plenum return system.
- Reduced fan energy in systems with outdoor air economizers due to the ability to use non-powered relief

or relief fans in lieu of less efficient return fans, which are generally required when return air is fully ducted.^{1,2}

- Little or no balancing costs for the return air system and, for VAV systems, balance is better maintained as supply airflow rate varies as loads vary. Ducted return systems can only be balanced at one condition, generally at design airflow rates, and are inherently unbalanced at other conditions, possibly leading to overly positive or negative space pressurization.

- Reduced noise transfer between rooms. Sheet metal ducts, if unlined, are very adept at channeling crosstalk from room to room,* much more so than a large ceiling plenum where noise can dissipate.

Disadvantages of Architectural Return Air Plenums

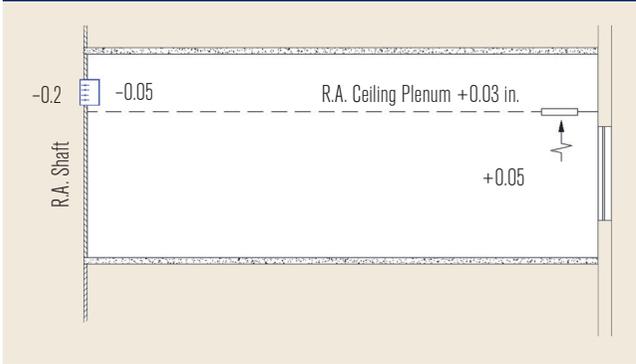
On the other hand, using architectural plenums has some potential disadvantages:

- There is the possibility of indoor air quality problems in humid climates if the architectural plenum is negatively pressurized to the outdoors.³ Humid outdoor air can be drawn into the architectural plenum and cooled below the dew point, causing condensation and subsequent mold and mildew problems within the structure. This potential problem can be avoided by simply not allowing the architectural plenums to become negatively pressurized relative to outdoors. For example, a return air plenum can be easily designed and controlled to be positively pressured. First, the building can be controlled to be pressurized to about 0.05 in. w.c. (12.5 Pa),⁴ and ceiling return air grilles can be selected to have a pressure drop of only about 0.02 in. w.c. (5 Pa). The ceiling plenum will thus be positive 0.03 in.w.c. (7.5

*The author experienced this firsthand with a home that was custom built for the previous owner who required that the furnace be fully ducted to each room with unlined sheet metal ducts. My teenage children entertained themselves for hours spying on each other by listening through the return air grilles. The first modification my wife and I made to the house was to blank off the return air grille to our bedroom...

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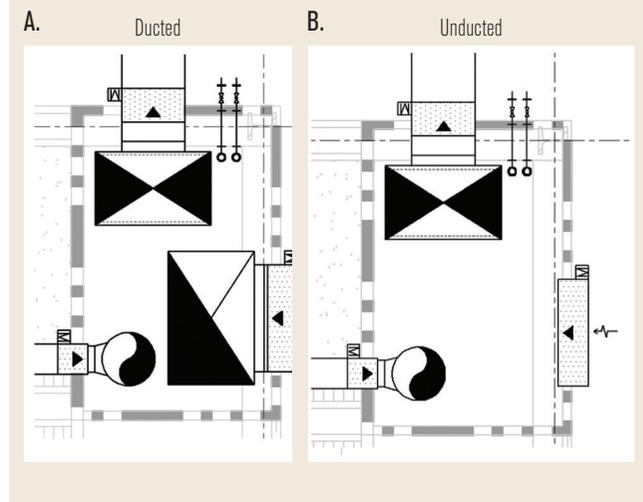
FIGURE 1 Typical pressures: Plenum return.



Pa) relative to the outdoors (Figure 1; note that all pressures shown are relative to outdoors). Of course, wind pressure and stack effect can overwhelm these small-positive pressures, but that is true of both plenum and ducted return air systems.

- Figure 1 shows that while the ceiling return air plenum is positive to the outdoors, the shaft is not. It is generally not practical for the shaft to be designed to be positive to the outdoors without overpressurizing the space. In humid climates, it is critical that the architectural return shaft be completely disconnected from the exterior walls; if the structure is built so this negative pressure is seen at the exterior wall, moisture and mold problems can result. This disconnect is generally not an issue for steel and concrete structures, but may be for wood construction typical of residential buildings. In the latter case, ducting the return air riser (Figure 2a) is a good idea versus unducted (Figure 2b). It may also be required by code if the return air system is being used for smoke exhaust such as in a high-rise building. But many engineers duct the return air riser even when leakage into the riser is simply return air from the conditioned space, not from the outdoors. Shaft leakage does not matter in this case – the air leaked into the shaft is the same air that is drawn into the return air duct. Ducting the riser in this case adds to first costs, energy costs, and space requirements and can cause imbalances in airflow between floors as supply air and return air rates vary in VAV systems. If the shaft is unducted and sized for low velocity (less than 1000 fpm [5 m/s] through the free area at the top of the shaft), airflow pressure drop from top to bottom is small, making the shaft nearly self-balancing. Again, stack effect may also cause imbalances, but that is true both ducted and unducted risers.

FIGURE 2 Return air risers.

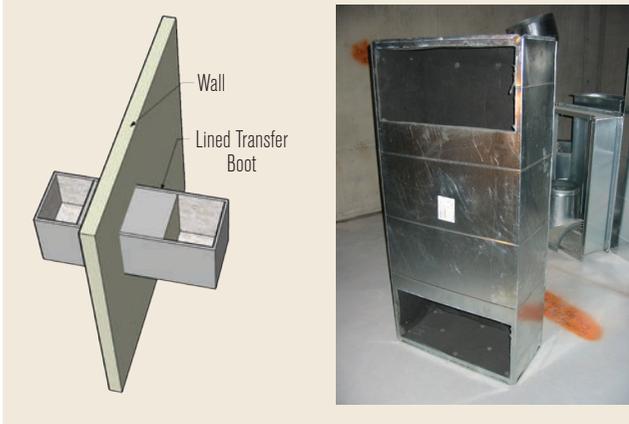


- Some indoor air quality specialists point out that even dry architectural plenums can be potential sources of indoor air quality pollutants such as particles. A ceiling return air plenum that has been used for a few years could have substantial dust accumulation on plenum surfaces. But return air ducts could have a similar or even thicker layer of dust. The dust “challenge” for both are particles drawn from the conditioned space and the source strength of these particles is the same whether the return air is ducted or an architectural plenum. In both cases, the air will be filtered at the air handler before the recirculated air is supplied to the space, so in both cases, this is generally a non-issue from an indoor air quality perspective. Particle challenges from outdoor ventilation air are usually much greater.

- It is common for full height (slab-to-slab) walls to be provided as acoustical barriers for noise sensitive spaces, such as conference rooms. An acoustic return air transfer “boot” must be provided at these spaces to allow return air to transfer from them to the ceiling plenum or to the adjacent space. Figure 3 shows an inexpensive sound boot: it is composed of a standard 5 ft (1.5 m) duct section that can be produced from a typical “coil line” duct making machine, which reduces its cost relative to a hand fabricated zee-shaped duct or elbow although acoustic performance of the latter may be better. Rules of thumb for sizing various return air transfer assemblies are shown in Table 1.

- Maintaining a low pressure drop return air path from conditioned spaces to the air handler can be a challenge using architectural plenums when spaces are divided by

FIGURE 3 Inexpensive return air sound boot.



many floor-to-floor partitions, such as acoustical partitions, tenant separation walls, and rated corridor walls. Where there are multiple partitions between the air handler or return air shaft and the most remote rooms, return air transfer openings and sound boots must be sized for even lower velocities and get progressively larger (Figure 4) to ensure that the overall pressure drop remains low to

TABLE 1 Rule-of-thumb design velocities for transfer assemblies.

NO.	INLET LOCATION	DISCHARGE LOCATION	APPLICATION	DUCT SIZING RULE OF THUMB
				FPM
1	Return Air Plenum	Return Air Plenum	Lined 5 ft Boot (Figure 3)	800
2	Return Air Plenum	Return Air Plenum	Flex Duct Both Sides	750
3	Return Air Plenum	Return Air Plenum	Single Elbow (No Turning Vanes)	700
4	Return Air Plenum	Return Air Plenum	Double Elbow Both Sides (No Turning Vanes)	575
5	Ceiling Grille	Return Air Plenum	Flex Duct to Perforated Face Grille	500
6	Ceiling Grille	Ceiling Grille	Flex Duct to Perforated Face Grilles	350
7	Return Air Plenum	Ceiling Grille	Toilet Makeup. Flex Duct to Perforated Face	325

The velocities are intended to result in a 0.08 in.w.c. (20 Pa) pressure drop across the transfer assembly including pressure drop of entrance, exit, duct, and grilles. Return air plenum is assumed to be 0.02 in. w.c. (5 Pa) relative to the space for Application 5 and 0.05 in. w.c. (12 Pa) for Application 7. Note that these are for a single return air transfer – for multiple boots in series (e.g., cascading from one room to another before it gets to the shaft), velocities must be even lower so the total pressure drop does not exceed 0.08 in. from furthest room to shaft or fan room to ensure exterior plenum walls are positively pressurized relative to the outdoors.

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avoid negative plenum pressures relative to the outdoors around the building perimeter. There are applications where this necessitates such large return air boots that ducting the return air may be the right choice. But this is seldom or never true when the ceiling is not divided by full height walls. Many engineers partially duct return air into ceiling plenums to “within no more than 30 ft” (or other rule-of-thumb) of return air grilles believing that this improves return air performance. In the author’s opinion, there is no value to these duct extensions and they add to first costs and energy costs. If there is room in the ceiling for the return air duct, there is even more room in the return air plenum without the duct, so velocity and pressure drop will be lower if the duct is eliminated.

Diagnosing Return Air Problems

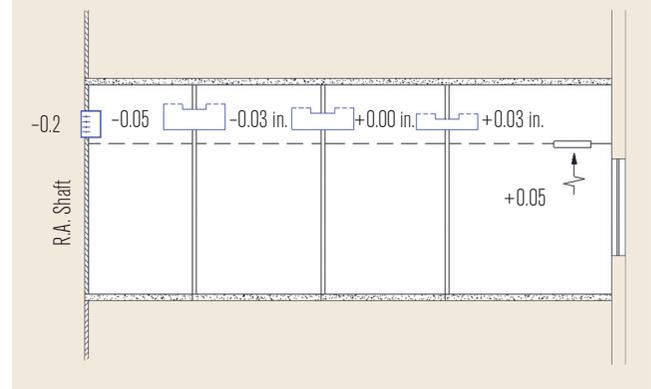
A common misdiagnosis is that a room is undercooled “because it has no return air path—the air is trapped.” However, this is almost never the case with ducted supply air systems such as VAV systems. This is because the walls and ceiling enclosing a typical room are not so airtight that they can cause enough backpressure to prevent air from the supply air fan from being supplied to the room.[†] If supply airflow to a room is verified by a flow hood, VAV box airflow sensor, or other airflow measuring device, the room is being conditioned even if there is no obvious return air path; air is simply leaving the room through leaks in walls, ceilings, doors, etc. To verify this, simply compare the measured supply airflow rate with the doors to the room open and then closed.

So a constricted return air path will seldom cause temperature control problems. But they can create differential pressure problems resulting in doors being pushed closed or open and audible airflow noise at leakage points such as around doors.

If the air handler has an airside economizer, these same symptoms can also be caused by an ineffective relief air path, such as an undersized non-powered relief (barometric) damper or undersized relief fan (powered exhaust). To determine which path, return or relief, is the cause, perform this simple test:

1. Configure the economizer dampers for zero outdoor air, zero exhaust air, and 100% return air.
2. If the system has a relief fan, turn it off. If it has a return fan that is controlled by airflow tracking,⁴ control

FIGURE 4 Return air boots in series.



the fan with zero offset. If the return fan has direct building pressure control, disable this control so the relief damper is closed.

3. Open VAV boxes as required to simulate full design conditions.

4. Run the supply air fan under normal control.

If the building or room pressures are excessive during this test, the return air path is constricted. If not, the relief system is the source of the problem. This could be verified by configuring the system in 100% outdoor air, 100% exhaust mode.

Once the constricted path is identified, the pinch point or points can be identified by measuring static pressure along the path looking for excessive pressure drops.

Conclusions and Recommendations

The benefits of using architectural plenums for return air are substantial, including much lower first costs and lower energy costs. In most cases, the design is also easy: just ensure that each space has a low pressure return air path back to the air handler. But where there are many full height walls and other constrictions, care must be taken to ensure that the low velocity return air path is maintained by properly sizing transfer ducts and sound boots.

References

1. Taylor, S. 2000. “Comparing economizer relief systems.” *ASHRAE Journal* (9).
2. Kettler, J. 2004. “Return fans or relief fans.” *ASHRAE Journal* (4).
3. Lstiburek, J. 2009. “Fundamental changes in the last 50 years.” *ASHRAE Journal* (7).
4. Taylor, S. 2014. “Controlling return air fans in VAV systems.” *ASHRAE Journal* (10). ■

[†] This rule is generally not true of low pressure unducted systems such as underfloor air distribution (UFAD) systems. The floor pressure is generally very low, less than 0.1 in. w.c. (25 Pa), so backpressure caused by a restricted return air path from a room can restrict supply airflow and thus cause temperature control problems.