Form 130.30-EG1 (704)

AirFixture®
AIRWAY™ SYSTEM*

ENGINEERING GUIDE

DESIGN AND APPLICATION GUIDELINES

*Patent pending

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Foreword

The design and application of new technology is often considered risky and many choose to avoid change by staying with the same old thing. The risk, time and effort it takes to become proficient in applying new ideas and concepts acts as a hindrance.

The information compiled in this manual will make adoption and application of Airway™ System air distribution technology friendlier and less challenging. Reading this manual will help you learn about **AirFixture**® technology and how it can be applied to your projects to save time, effort, energy and money.

To make information easier to understand and use, the Airway system story has been divided into several documents. This booklet, *AirFixture Airway System Engineering Guide*, is just one in the series. Each booklet is intended to improve your understanding and supply information in a logical progression, beginning with an introduction and ending with specific construction details. Other booklets in the series provide information on:

- Applying AirFixture technology
- Frequently asked questions
- Airway controls application
- Codes and standards
- Construction issues
- LEED™ Green Building ratings

If you have a question about any of the information provided, find a mistake, or just want to send us a comment, please write us at *es.commercial@york.com* or call (800) 861-1001 and we will be happy to respond.

Airway Components

BASIC AIRWAY SYSTEM COMPONENTS

YORK and **AirFixture®** have assembled a variety of air distribution components to meet most commercial applications. **AirFixture** components are specifically designed for Airway system air distribution and for operation with pulse-modulated, variable-air-volume controls. Conventional diffusers, registers and grilles are not compatible with Single or Dual Airway system air distribution.

Physical design of the ceiling grid is the only limitation to the flexibility of Airway system components. However, this is not new; the ceiling grid has always been a limitation of HVAC design. System designers commonly locate diffusers and registers so that they do not intersect the beams (tees) of a ceiling suspension system—they are positioned to fall within the area occupied by a ceiling panel.

The physical dimensions of **AirFixture** components fit the traditional 24-inch (600-mm) spacing of the main lay-in ceiling tees. In many cases, supply and return terminals are nominally 24 inches by 24 inches (600 mm by 600 mm) to minimize the necessary number of custom cut ceiling tiles. In all cases, at least one dimension of an Airway terminal is nominally 24 inches (600 mm).

AirFixture Component Nomenclature

Tables 1A, 1B, 1C, 1D, 1E and 1F show the model numbers for AirFixture components.

TABLE 1A - AIRFIXTURE DIFFUSER AND FAN TERMINAL NOMENCLATURE

Typical Diffuser Model Number V S R - 2 * * *

Terminal Type
CRO = Constant Volume Return Only CSO = Constant Volume Supply Only CSR = Constant Volume Supply / Return HCD = Combination Heating (ducted) / Cooling / Return HCR = Combination Heating / Cooling / Return HSD = Heating Supply Only (ducted) VSO = Variable Volume Supply Only VSR = Variable Volume Supply / Return

Combination and Supply Only Terminals Supply Throw / Airflow	Return Only Terminals Airflow
1 = 1-way / 150 CFM (71 L/sec) 2 = 2-way / 300 CFM (142 L/sec) 3 = 3-way / 300 CFM (142 L/sec) 4 = 4-way / 300 CFM (142 L/sec)	1 = 680 CFM (321 L/sec)
Comb. Terminal Return Rating 400 CFM (189 L/sec)	

E = Eggcrate Metal Return
P = Perforated Metal Return

V = Vertical Throw

D = Manual Damper (CV units only)

Typical Fan Terminal Model Number F T E - 1 - 1 2 M

FT = Fan Terminal

Type of Heat
E = Electric

Unit Size
1 = 150 CFM (71 L/sec) Direct Connected

Voltage
12 = 120 V / 1 Ph / 60 Hz 24 = 240 V / 1 Ph / 60 Hz 27 = 277 V / 1 Ph / 60 Hz

Controller Type
M = Master S = Slave

Airway Components *(continued)*

TABLE 1B - AIRFIXTURE CEILING COMPONENT NOMENCLATURE

Model No.	Description	Gasket	Color	Size
ACB-1	Aesthetic Ceiling Brace	n/a	n/a	12 in.
ACH-1	Aesthetic Ceiling Hanger	n/a	n/a	12 in.
ACM-1	Aesthetic Ceiling Main Beam	Yes	White	12 feet
ACT-2B	Aesthetic Ceiling Tee, Butt	Yes	White	2 feet
ACT-2L	Aesthetic Ceiling Tee, Lap	Yes	White	2 feet
ACT-4B	Aesthetic Ceiling Tee, Butt	Yes	White	4 feet
ACT-4L	Aesthetic Ceiling Tee, Lap	Yes	White	4 feet
CTR-1	Ceiling Trim Ring	Yes	White	24 in. x 24 in.
CWA-1	Ceiling Wall Angle	Yes	White	10 feet
MCC-1	Median Ceiling Cross	Yes	White	12 feet
MCC-4	Median Ceiling Cross	Yes	White	4 feet
RAP-1	Return Air Passage	n/a	n/a	4" Dia. X 12 in.
SAB-1	Supply Airway Barrier, Uninsulated	n/a	n/a	4 feet
SAB-2	Supply Airway Barrier, Insulated	n/a	n/a	4 feet

TABLE 1C - AIRFIXTURE MISCELLANEOUS COMPONENT NOMENCLATURE

Model No.	Description	Airflow	Input Voltage	Size
BFP-1	Single Bypass Fan (with 24-voly AC power supply)	400 cfm	120 vac	24" x 24” panel
BFP-2	Dual Bypass Fan (with 24-volt AC power supply)	800 cfm (total)	120 vac	24" x 24” panel
BFP-3	Dual Bypass Fan (with 24-volt AC power supply)	800 cfm (total)	240/277 vac	24" x 24” panel

TABLE 1D - AIRFIXTURE CABLING COMPONENT NOMENCLATURE

Model No.	Description	No. Conductors	Gauge	Shielded	Size or Length	Cable End #1	Cable End #2	Color
EJB-1	Junction Box Panel	n/a	n/a	n/a	24" x 24”	n/a	n/a	n/a
EPS-1	Power Supply, 24 VAC, 90 VA	n/a	n/a	n/a	24" x 24”	n/a	n/a	n/a
HCS-1	Heating and Cooling Switch	4	18	No	n/a	Receptacle	Plug	n/a
PAP-1	General Purpose Cable	4	18	No	25 ft.	Receptacle	Receptacle	Blue
PAP-2	Whip Cable (for external devices)	4	18	No	50 ft.	Receptacle	Bare	Yellow
PAP-3	Extender Cable	4	18	No	25 ft.	Receptacle	Plug	Blue
PAP-5	Control Power (Only) Cable	2	18	No	25 ft.	Receptacle	Plug & Receptacle	Green
PAP-6	All-Purpose Jumper Cable	4	18	No	2 ft.	Receptacle	Plug & Receptacle	Black
PAP-7	Heating and Cooling Cable	3 pair	22	Yes	30 ft.	Receptacle	2 Plugs & Receptacle	White

TABLE 1E - AIRFIXTURE INTEGRATION AND COMMUNICATION COMPONENT NOMENCLATURE

Model No.	Description	Alarm Relays	Supply Pressure	Space Pressure	Supply Temp.	Space Temp.	Relative Humid.	RTU Staging	Local Display	TCD Network	Time-clock
IBX-1	Stand Alone Pressure Control	Yes	Yes	No	No	No	No	Yes	Yes	No	No
IBX-2	Modbus RTU Communication	No	No	No	No	No	No	No	No	Yes	No
IBX-3	BACNET Communication	No	No	No	No	No	No	No	No	Yes	No
IBX-4	Serial ASCII Communication	No	No	No	No	No	No	No	No	Yes	No

TABLE 1F - AIRFIXTURE TEMPERATURE CONTROL COMPONENT NOMENCLATURE

Model No.	Description	Color	Display	Setpoint	RS-485	Cooling Control	Heating Control	Switch-over	Rooftop Control	Time-clock
TCD-1	Wall-Mounted, Heating/Cooling	White	Yes	Buttons	Yes	Yes	Yes	No	No	No
TCD-2	Wall-Mounted, Cooling	White	Yes	Buttons	No	Yes	No	No	No	No
TCD-3	Rotary Dimmer Style, Cooling	White	No	Knob	No	Yes	No	No	No	No
TCD-4	Rotary Dimmer Style, Cooling / Heating	White	No	Knob	No	Yes	No	Yes	No	No

Supply Terminals

AirFixture supply terminals are available in constant-volume (CV) and variable-air-volume (VAV) models. Both types have one-, two-, three- and four-way throw options. Constant-volume terminals may be field-adjusted to set the air supply rate. Variable-air-volume terminals are self-balancing and do not require any field adjustment. All supply terminals for standard ceiling applications provide a nominal throw of 18 feet. Table 1A defines the supply and return terminal (diffuser) model nomenclature.

Controlling VAV terminals with pulse modulation eliminates complications in selecting supply diffusers or registers for specific airflow rates, throw performance and noise criteria. The airflow rate passing through an **AirFixture** VAV supply terminal is always constant for the period of time that air flows. Since the air valve control damper is either open or closed, the airflow rate is either the nominal rating or the minimum rating. (Air valve dampers do not seal in the OFF position and a minimum amount of air always passes through small gaps between the damper blades.) Pulse modulation controls alternate the duration and frequency of the ON and OFF pulses to meter the airflow necessary at a given load condition.

The air valve control damper actuates quickly allowing the opening transition to be very short from minimum flow to rated flow. Likewise, the closing transition from rated flow to minimum flow is also very short. This characteristic means that the supply terminal's exit velocity and throw performance remain substantially constant, even at part loads. Whenever the air valve control damper is in the ON position, air passes through the diffuser at the rated flow with the rated throw.

Constant-volume supply terminals

Basic constant-volume (CV) supply-only models have one-, two- and four-way throw characteristics as shown in Figure 1 (model CSO) on page 8. A model CSO-4 four-way terminal becomes a model CSO-3 three-way terminal by addition of an internal baffle. Throw characteristics of a model CSO-3 remains substantially unchanged from the nominal 18-feet throw of a model CSO-4.

Variable-air-volume supply terminals

Similar to constant-volume terminals, variable-air-volume (VAV) supply-only models have one-, two- and four-way throw characteristics as shown in Figure 2 (model VSO) on page 8. Likewise, a model VSO-4

Airway Components *(continued)*

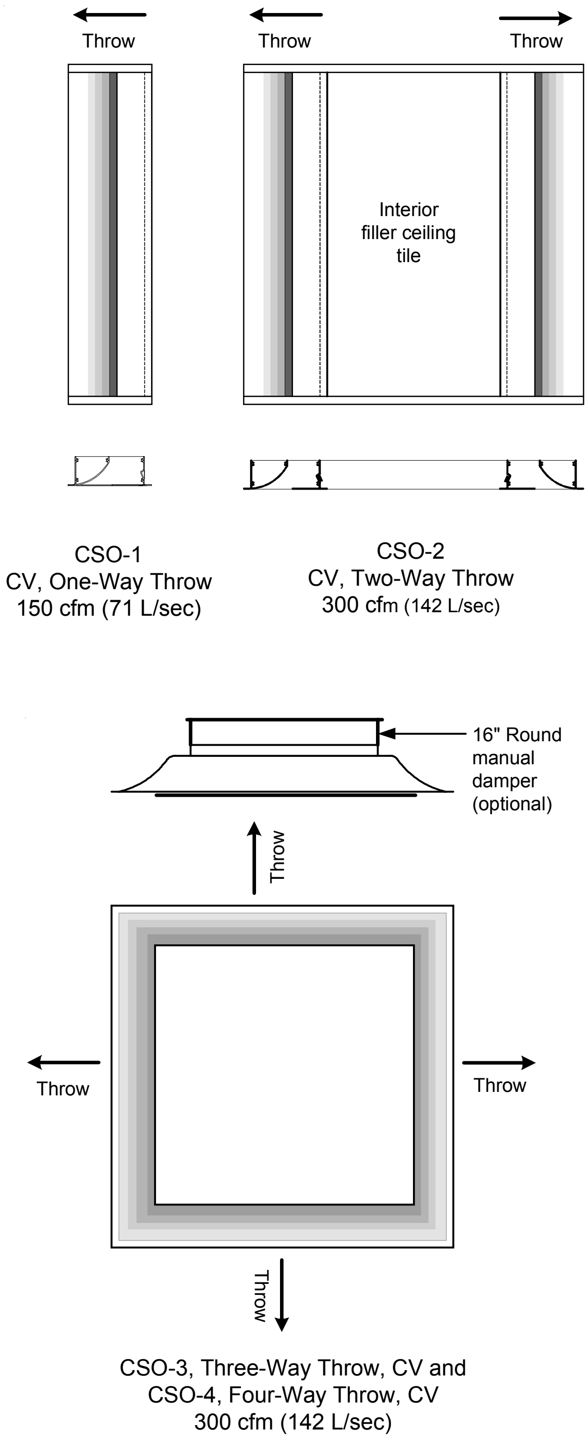

Fig. 1. Constant volume supply terminals

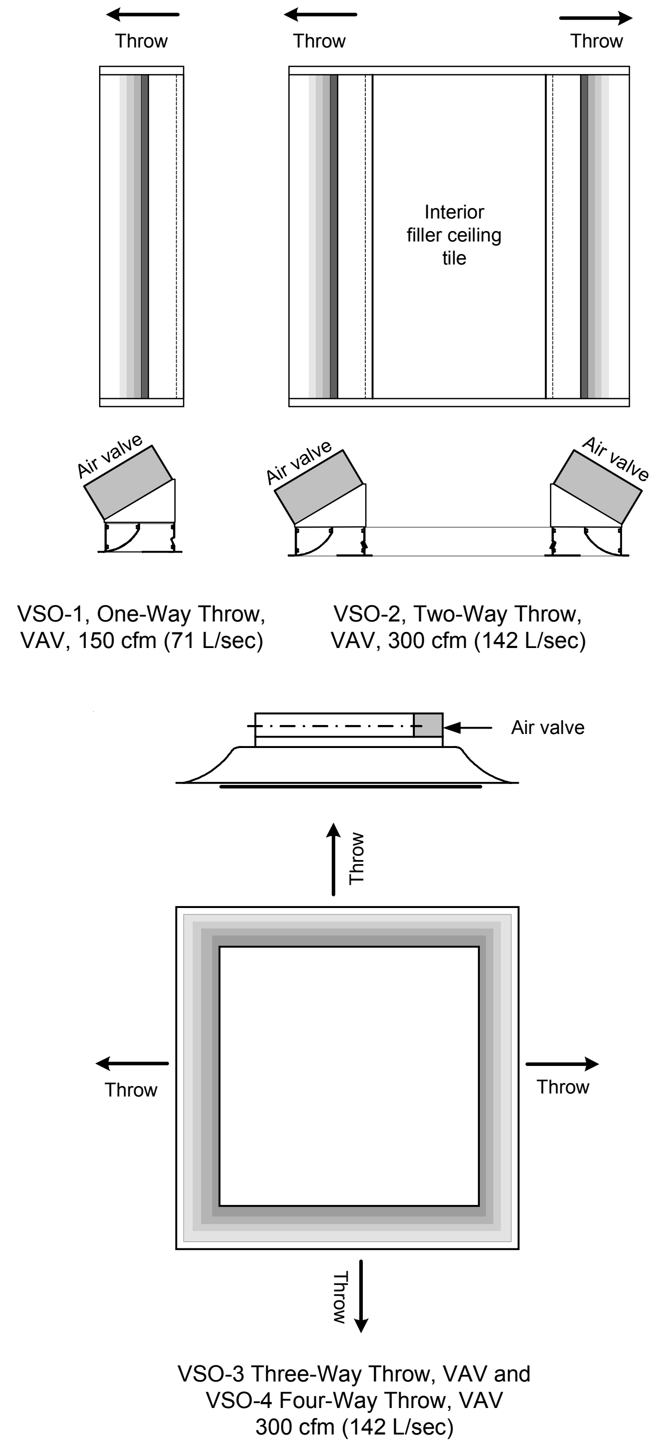

Fig. 2. Variable-air-volume supply terminals

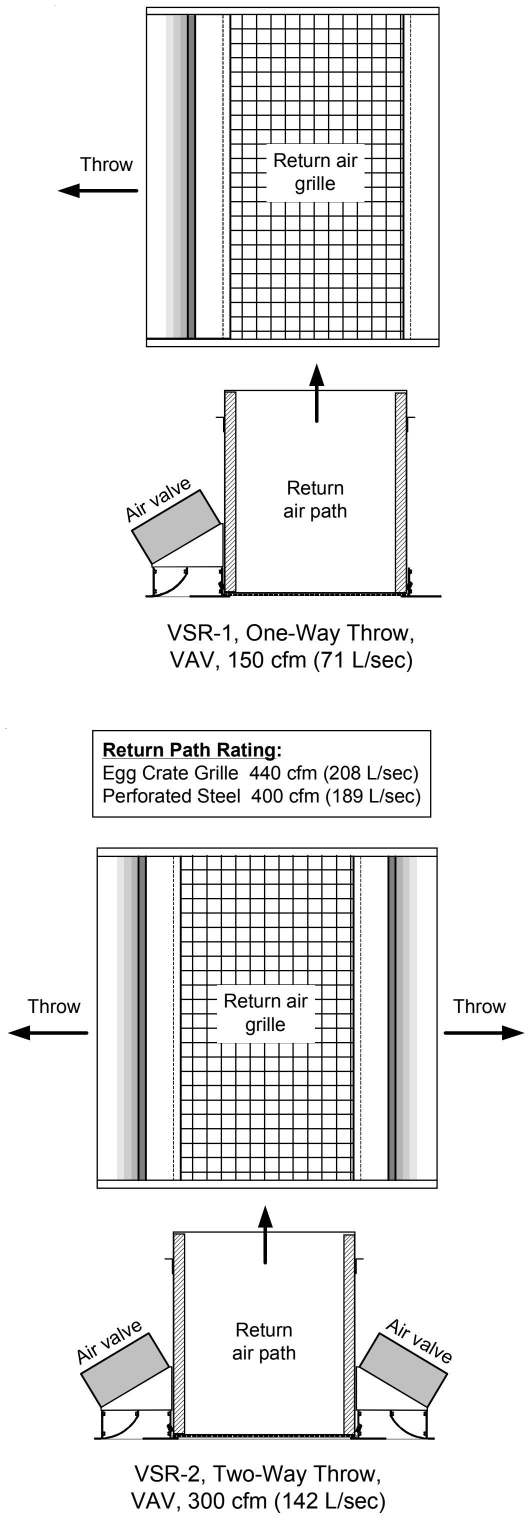

Fig. 3. Combination VAV supply and return terminals

four-way terminal becomes a model VSO-3 three-way terminal with substantially similar throw characteristics by addition of an internal baffle.

Combination supply and return terminals

AirFixture manufactures combination terminals with one-way and two-way throw patterns. Both CV and VAV models are available (models CSR and VSR respectively). The return grille and sheet metal transition (that passes between the aesthetic ceiling and the median ceiling) are included as part of the combination terminal assembly. Figure 3 shows the VSR-1 and -2 variable-air-volume models. Constant-volume models are identical in appearance and design except they do not have air valves for flow modulation.

Return Terminals

Return terminals in a Dual Airway distribution system must have a sheet metal extension (referred to as a core module) above the return grille that permits return air to pass through the supply Airway space to the return Airway space above the median ceiling. **AirFixture** Dual Airway return terminals (model CRO-1), as shown in Figure 4, ship from the factory as an assembled unit and have a nominal rating of 680 cfm at 0.02 inches w.g. (321 L/sec at 5 Pa).

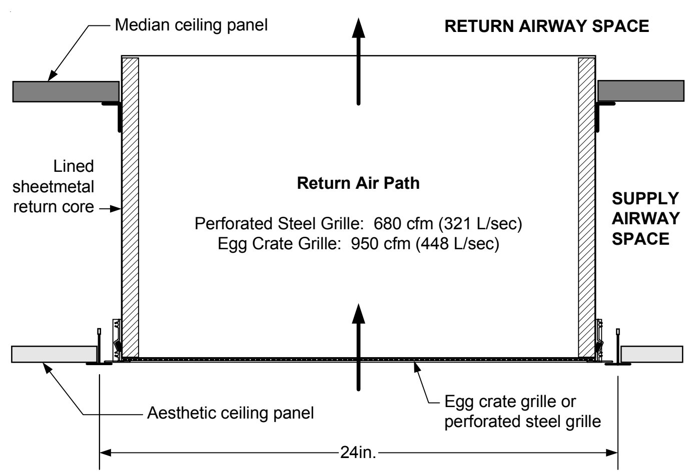

Fig. 4. Section through a model CRO-1 return air terminal

Airway Components *(continued)*

Bypass Fans

Bypass fans, as shown in Figure 5, are panel-mounted for easy installation in the median ceiling and are available in two models. The single fan unit (model BFP-1) fits into a nominal 24-inch by 24-inch (600-mm x 600-mm) ceiling grid and has a flow rating of 400 cfm at 0.05 inches w.g. (189 L/sec at 12.4 Pa). The fan is pre-wired to a 4-inch, dual-gang junction box. The dual fan unit (model BFP-2) supplies 800 cfm at 0.05 inches w.g. (378 L/sec at 12.4 Pa) and fits into a 24-inch by 24-inch (600-mm by 600-mm) ceiling grid. Both fans are pre-wired to a 4-inch, dual-gang junction box. BFP-1 operates from a 120-volt, 60 hertz, single-phase power supply. BFP-2 can be ordered suitable for operation from a 120-, 240- or 277-volt power source. The rated electrical consumption is 26 watts per fan. Each bypass fan assembly is supplied with a factory-wired, 24-volt ac control power supply. The fan motor leads and control transformer leads are pre-wired so that the field wiring attaches to single connection points.

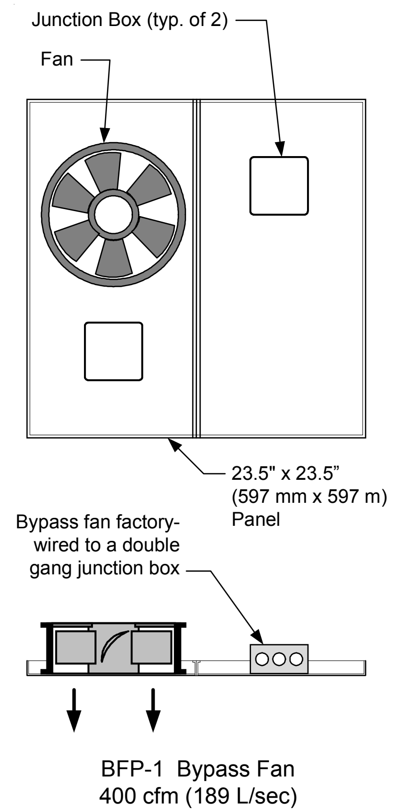

Fig. 5. Bypass fan model BFP-1

Combined Heating and Cooling Terminals

AirFixture manufacturers several terminal models that combine pulse-modulated, variable-air-volume cooling and constant-volume heating. Figure 6 shows models HCR-1 and -2 that direct connect to a fan terminal unit, model FTE-1. In the cooling mode, the supply terminals operate identically to standard **AirFixture** VAV supply terminals using pulse modulation control to regulate the proper airflow to the space. In the heating mode, the fan terminal unit draws air from the return Airway space, heats it with electric heating elements, and supplies it directly to the heating air outlet (with a vertical discharge). The model FTE fan terminal unit has three stages of electric heating: fan only, 50% heat and 100% heat. The maximum temperature rise is 36°F (20°C).

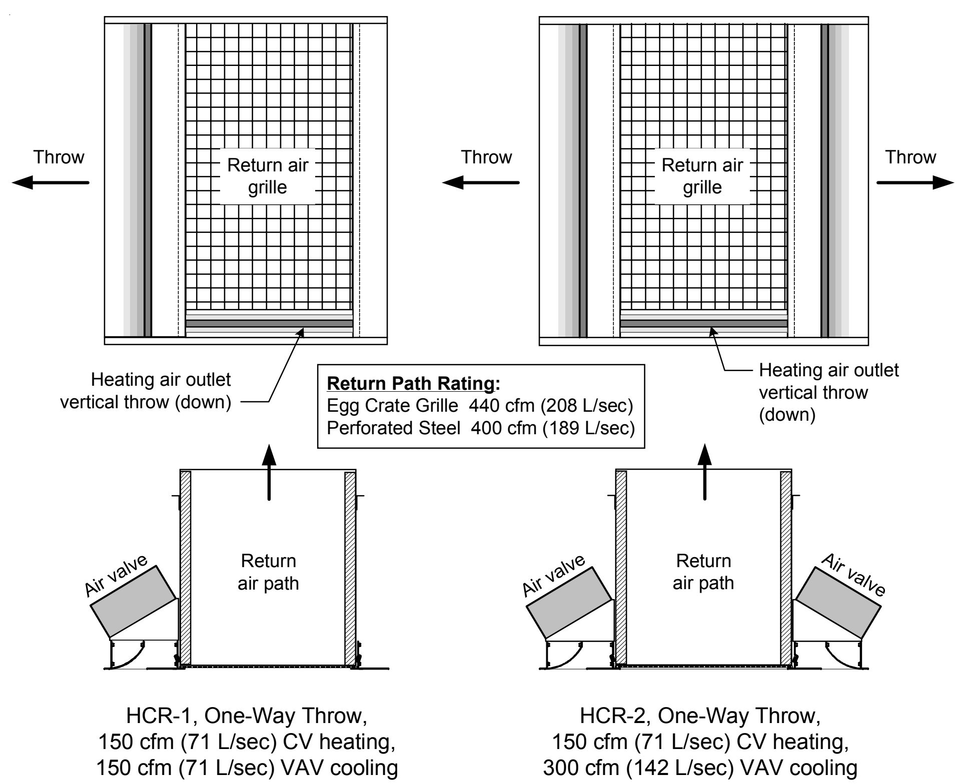

Fig. 6. Combined heating and cooling terminals

AirFixture models HCD-1 and -2 operate similarly to the HCR models except the heating air connection is ducted. This enables multiple HCD supply terminals to operate with one model MFT-B or MFT-C modular fan terminal unit. The MFT-B and -C fan terminal units draw air from the return Airway space. A short stub duct mounts on the discharge side of the fan terminal unit and the HCD supply terminals connect to it through short sections of flexible duct. MFT-B and -C fan terminal units have nominal airflow ratings of 300 cfm (142 L/sec) and 600 cfm (284 L/sec) respectively. They are available with either electric or hot water heating coils.

Heating Only Terminals

Perimeter heating zones should be fitted with **AirFixture** "heating only" terminals. Model HSD-1 is designed to function with model MFT-B and MFT-C modular fan terminal units. The HSD-1V installs in a manner similar to the HCD terminals described above. Short sections of flexible duct connect HSD-1V terminals to a short stub duct mounted on the discharge side of the fan terminal unit.

Model CSO-1V and CSO-2V supply only terminals are specifically designed for perimeter heating zones and have vertical discharges (designated by the V). The CSO-1V and CSO-2V are intended for operation in a heating supply Airway space supplied by a dedicated heating source such as model MFT-B and MFT-C modular fan terminal units.

Terminals

TERMINAL SIZING FUNDAMENTALS

There are many possible ways to supply air to a large zone or open area. Traditional designs often use just a few very large supply terminals. Ductwork material and installation costs are lower for systems using fewer terminals. Diffuser manufacturers offer a variety of terminal types and sizes to accommodate a wide range of space sizes.

The "bigger is better" approach for overhead diffuser design is not ideal for Airway system distribution. Test results confirm that an array of small diffusers will distribute air more uniformly than a few large units. When you consider induction, it becomes intuitive that uniform mixing of room air with supply air is easier using many small jets rather than one large one. Without ductwork, an Airway system has almost no cost penalty for having an array of terminals as compared to one large terminal.

AirFixture terminal sizes are standardized to simplify design and improve flexibility. The practical limit for low-pressure Airway technology is about 150 cfm (71 L/sec) for a single air jet and 300 cfm (142 L/sec) for a single supply terminal. If more than 300 cfm (142 L/sec) is necessary, use several terminals arranged in an array to distribute air uniformly. This is much simpler than selecting a different diffuser or register size for each zone.

For example, consider a variable-air-volume zone that requires 450 cfm (212 L/sec) at peak load. There are three **AirFixture** terminal possibilities:

- Install two 300-cfm (142-L/sec) terminals and let the pulse-modulated VAV controls modulate the correct volume
- Install one 300-cfm (142-L/sec) terminal and one 150-cfm (71-L/sec) terminal
- Install three (or more) 150-cfm (71-L/sec) terminals

Conversely, a constant-volume system, must have the terminals sized specifically to supply 450 cfm (212 L/sec), otherwise the system will overcool the zone. A traditional ducted VAV system may use used a single

Terminals *(continued)*

450-cfm (212 L/sec) diffuser or a combination of 150-cfm (71 L/sec) and 300-cfm (142 L/sec) diffusers, but part-load dumping becomes a consideration.

Turndown on conventional diffusers and registers is a problem and designers are cautious to avoid intentionally selecting oversized terminals. A major advantage of **AirFixture** terminals is that oversized supply terminals have no detrimental effect on comfort or air quality. An oversized terminal with pulse-modulated, variable-air-volume controls will provide good mixing, maintain its throw characteristics and not dump at part-load conditions.

In conventional systems, oversized and undersized VAV boxes are a problem. If you undersize a VAV box, the space will be short of air at peak load conditions and may create a distracting noise. An oversized VAV box has poor modulation and control characteristics, and may have a whistling damper at low volumes. With Airway systems and pulse-modulated, variable-air-volume controls, there are no VAV boxes.

In constant-volume systems, the supply terminals should not have a combined capacity greater that the supply fan capacity. For instance, if the supply fan provides 4,000 cfm (1,890 L/sec), the combined capacity of all supply terminals should not total more than 4,000 cfm (1,890 L/sec). Installing too many supply terminals prevents the supply Airway space from becoming properly pressurized. Likewise, variable-air-volume systems should not have an excessive allowance for diversity. The supply Airway space should operate at 0.05 inches w.g. (12.4 Pa). If the supply Airway space positive pressure is less than 0.03 inches w.g. (7.5 Pa) because of too many terminals, the system will not operate properly.

Summary:

AirFixture supply terminals in an Airway system with pulse-modulated, variable-air-volume controls eliminate most problems associated with sizing, selecting, installing and balancing VAV systems. Part-load dumping, noise and balancing issues common in conventional VAV systems are eliminated.

BYPASS AIRFLOW, AIRWAY LEAKAGE AND THEIR INFLUENCE ON TERMINAL SIZING

Bypass Airflow

The primary purpose of bypass airflow is to desaturate the air leaving the cooling coil and entering the supply Airway space. Bypass airflow should be a minimum of 20% of the airflow volume leaving the cooling coil. However, it is not critical to maintain an exact 20% ratio, so bypass fans sizes are standardized in 400-cfm (189-L/sec) increments.

Introducing an additional 20% air volume into the supply Airway space does *not* imply a requirement for 20% more supply terminals. The secondary purpose of bypass air is to replace airflow lost to leakage through the median and aesthetic ceilings. The supply airflow lost through leakage will be approximately equal to the bypass flow. Thus, bypass does not influence terminal sizing or selection.

Leakage

Designers seldom consider duct leakage. But, standard unsealed ductwork in low-cost, low-rise commercial buildings may leak up to 48 cfm per 100 square feet of duct at a pressure differential of 1.0 inch water gauge (2.4 L/sec/m^2 at 249 Pa) (SMACNA 1989). Extrapolating that leakage rate over an entire building can be shown to result in total leakage of about 0.20 cfm per square foot (1.0 L/sec/m^2) of floor space, based on a supply rate of 1.0 cfm per square foot (5.1 L/sec/m^2) and an average branch duct pressure of 0.75 inches w.g. (187 Pa). Recent field measurements of installed ductwork in 70 low-rise commercial buildings indicate that actual [localized] leakage rates may be as much as 10 times the SMACNA value (Cummings et al. 1996). Recognizing the problem, ASHRAE recommends sealing all ducts (Harriman et al. 2001).

Airway systems, operating at 0.05 inches w.g. (12.4 Pa), also leak. However, Airway system leakage is *controlled* leakage that functions in the building in specific, positive ways. The fact that Airway ceilings do leak is not a distinguishing negative characteristic that should influence comparisons between Airway systems and conventional ducted systems. Dual Airway systems leak about the same as unsealed ductwork; designers have just become more at ease with duct leakage.

In a Dual Airway system, about half of the supply Airway space leakage goes through the median ceiling to the return Airway space, and about half goes through the aesthetic ceiling into the occupied space. It is necessary to limit leakage through both ceilings, but aesthetic ceiling leakage should receive greater attention and care during design and construction. Aesthetic ceiling leakage must be:

- Sufficiently small so as to not influence temperature control in the zone
- Less than the minimum airflow requirement to the zone
- Restricted to allow pressurization of the supply Airway space to 0.05 inches w.g. (12.4 Pa).

When sizing and selecting supply terminals, the designer should estimate the ceiling leakage rate and deduct that from the combined supply and bypass airflow entering the supply Airway space. Generally, it will be found that leakage offsets bypass airflow and has no resulting influence on supply terminals sizes or quantities.

The total airflow entering the supply Airway space is the sum of the air-handling unit (or rooftop unit) flow plus the bypass flow from the return Airway space. As the combined airflow passes through the supply Airway space, air leaks through both the median and aesthetic ceilings. On average, both the median and aesthetic ceilings, with 2-foot by 4-foot tiles (600-mm by 1200-mm), leaks about 0.10 cfm per square foot of ceiling (0.51 L/sec/m^2) each. Total leakage of 0.20 cfm per square foot (1.0 L/sec/m^2) is coincidentally the same as the documented leakage for unsealed ductwork. Leakage represents approximately 20% of the air delivered from the supply fan, assuming an average air delivery rate of 1.0 cfm per square foot (5.1 L/sec/m^2) of floor space. It is no coincidence then that the recommended nominal bypass rate is 20% of the supply fan rate.

Other ceiling-mounted devices may also leak air from the supply Airway to the conditioned space. Light fixtures, sprinkler heads, occupancy sensors, smoke detectors and other devices with unsealed penetrations permit air to flow into the conditioned space. Table 2 lists average leakage rates for typical ceilings and ceiling-mounted light fixtures.

Table 2
Typical Leakage Rates for Ceilings and Light Fixtures

Item	Approximate Leakage Rate at 0.05 in. w.g. (12.4 Pa) differential
Median ceiling (2 ft x 4 ft panels)	0.10 cfm/ft^2 (0.51 L/sec/m^2)
Aesthetic ceiling (2 ft x 4 ft panels)	0.10 cfm/ft^2 (0.51 L/sec/m^2)
Aesthetic ceiling (2 ft x 2 ft panels)	0.13 cfm/ft^2 (0.66 L/sec/m^2)
Untreated fluorescent light troffer 2 ft x 4 ft	40-45 cfm (18.9-21.2 L/sec)
Untreated fluorescent light troffer 2 ft x 2 ft	20-23 cfm (9.4-10.9 L/sec)
Treated fluorescent light troffer 2 ft x 4 ft (Note 1)	5-15 cfm (2.4-7.1 L/sec)
Treated fluorescent light troffer 2 ft x 2 ft (Note 1)	3-10 cfm (1.4-4.7 L/sec)

Notes:
1. Treated fixtures have openings and penetrations sealed similar to "Chicago Plenum Construction" to minimize airflow through the light fixture.

The *maximum* airflow to a zone (to satisfy the peak load) includes: the supply terminal volume plus leakage through the aesthetic ceiling plus leakage through other ceiling-mounted devices. When calculating the *minimum* supply volume to a zone, leakage is constant and will be the same at peak load and minimum load (since the supply Airway pressure is constant). The only variable flow to a zone is the controlled flow through the supply terminals.

The airflow that must be distributed by supply air terminals is equal to the supply fan airflow plus bypass airflow minus leakage.

Consider a simple example of a single zone within a larger system:

Zone size: 500 ft^2 (46.5 m^2)
Supply fan airflow: 500 cfm (236 L/sec)
Bypass airflow: 100 cfm (47.2 L/sec)
Light fixtures: Four 2 ft x 4 ft recessed troffers
Median ceiling leakage:
500 ft^2 x 0.1 cfm/ft^2 = 50 cfm (23.6 L/sec)
Aesthetic ceiling leakage:
Ceiling: 500 ft^2 x 0.1 cfm/ft^2 = 50 cfm (23.6 L/sec)
Lights: 4 x 10 cfm each = 40 cfm (18.9 L/sec)

Terminals *(continued)*

Total leakage: 50 + 50+ 40 = 140 cfm (66 L/sec)
Air distributed by supply terminals:
(500 + 100) – 140 = 460 cfm (217 L/sec)

LOCATING SUPPLY AND RETURN TERMINALS

Many criteria play a role in locating supply and return terminals: the zone load, the shape of the zone, zone location (interior or exterior), terminal air volume ratings, terminal throw characteristics, obstructions in the space, and aesthetics. In a conventional, ducted supply system, supply diffusers influence room air movement, not the return. For this reason, system designers typically take more care locating and specifying supply terminals than they do with return terminals. Air distribution concerns in an Airway system are basically the same, but with a few distinguishing characteristics.

Supply Terminals

In most applications, supply terminal devices (diffusers) provide a high-induction flow of air at the ceiling that spreads horizontally by means of the Coanda effect. The diffuser discharge pattern remains at a relatively high velocity above the occupied zone to entrain and mix with room air over a large area.

Supply terminals in Dual Airway systems should be located using the same criteria that would be applied in a conventional ducted system. The designer should select the type, quantity and location of supply terminals based on:

- The airflow requirement and the throw rating of the terminals
- The ceiling height
- To uniformly distribute air in the room or zone (e.g., interior zones)
- To distribute the air in proportion to the heat gain or loss in different areas of the room or zone (e.g., exterior zones)

AirFixture terminals are available with one-, two-, three- and four-way throw patterns, and have a throw rating of about 18 feet (5.5 m) with a terminal velocity of 50 ft/min (0.25 m/sec). The maximum supply rate for a single fixture is 300 cfm (142 L/sec). Installing an optional factory-engineered damper in constant-volume fixtures adjusts the delivery rate to achieve lower flows, for example 250, 200, 150, 100, and 50 cfm (118, 94.4, 70.8, 47.2 and 23.6 L/sec), without field balancing.

Because of the relatively low supply pressure of 0.05 inches w.g. (12.4 Pa), the imposed 300-cfm (142-L/sec) limitation assures good mixing of supply air with room air. The use of several smaller terminals provides better mixing and control than one large terminal with the same total capacity. In addition, a modular approach is more practical with lay-in fixtures that can be easily moved, added or changed as needed.

AirFixture supply air terminals installed in ceilings higher than 13 feet above the floor must be specified for this service. High-ceiling installations should use supply air fixtures with a vertical-down discharge, for example, VSO-1V (see **AirFixture** Diffuser Nomenclature, Table 1A, on page 5).

When designing supply terminal arrangements in a Dual Airway VAV system, the designer need not worry about airflow characteristics at part-load conditions. Pulse-modulated controls enable AirFixture terminals to retain their throw characteristics at all load conditions.

Return Terminals

While there is a wealth of reference information available to size and locate supply terminals, there is very little guidance available to size and locate return terminals. In an Airway system, the location and size of the return terminal is just as important as the supply terminal.

Uncontrolled building pressurization is a leading cause of moisture migration through exterior walls, which supports mold and mildew growth in a building. For this reason, proper pressurization control is very important in any building regardless of the air distribution system. *The New ASHRAE Design Guide for Humidity Control in Commercial Buildings* (Harriman et al. 2001) addresses this problem. Although the book is based on studies of conventional building systems and construction, some of the information applies to Airway systems.

Dual and Single Airway system designs must address building pressurization on every project. Building pressurization extends beyond the occupied space and includes interstitial spaces below floors and above ceilings. The ASHRAE design guide recommends keeping the pressure of all building spaces at least 0.008 inches w.g. (2 Pa) higher than the outside atmosphere to prevent moisture from becoming a problem. The Dual Airway system satisfies that criteria without expensive return ductwork.

The return system pressure drop influences building pressurization; therefore, the return Airway space must have a very low resistance to airflow. In many conventional systems, especially plenum return systems, the pressure loss from the occupied space to the rooftop unit (or to the air-handling unit intake) is not considered except to calculate the fan external static pressure. Too often, inadequate quantities of return air terminals, insufficient return area or improper return location, results in undesirable negative plenum pressure. In an Airway system, the overall pressure drop through the return Airway space should not exceed 0.02 inches w.g. (5 Pa). This allows both the occupied space and return Airway to remain at a positive pressure, relative to the outside ambient, without over-pressurizing the occupied space.

The amount of air that can be *supplied* to a space is a function of the *return* path resistance. With zero resistance, the theoretical amount of air that can be supplied to a space is infinite. Conversely, if there is no return path, the airflow supply that can be delivered to a space is zero. In real life, when the return area is too small or the return resistance too high, supply airflow becomes limited and may be inadequate to condition the space. Having the correct return is especially important when the supply air static pressure for air delivery is only 0.05 inches w.g. (12.4 Pa). A few extra hundredths of an inch (Pascals) in return resistance can cut the supply air delivery by a third or more.

Summary:

The pressure of all building spaces should be at least 0.008 inches w.g. (2 Pa) higher than the outside atmosphere to help prevent moisture from becoming a problem. The return Airway space pressure drop should not exceed 0.02 inches w.g. (5 Pa).

Combination Terminals

Combining the return and supply into a single factory-assembled and tested terminal automatically assures correct return sizing and placement. Since a combination unit is factory-designed with a very low return pressure drop, it avoids negative building pressures that can induce moisture migration through the building exterior.

In Figure 7, a one-way throw, combination fixture (model CSR-1) joins the supply and return into a single terminal that throws air across the ceiling above the occupied zone. With the return opening located on the backside of the supply jet, the induction action helps draw room air into the return. The combination terminal design assures adequate return area and placement relative to the supply. Also, a single combination terminal uses less ceiling space and requires less labor to install than separate supply and return terminals. Constant-volume combination terminals CSR-1 and CSR-2, and variable-air-volume terminals VSR-1 and VSR-2, all provide this important feature. Combination terminals are the recommended standard unless there is an aesthetic objection, or if separate supply and return devices are necessary for another reason.

In addition to simplified return sizing and location, combination terminals have another important feature: it is impossible to bypass supply air directly to the return. Sometimes, a design ceiling arrangement improperly directs a supply diffuser discharge at a return. This happens for many reasons. For instance,

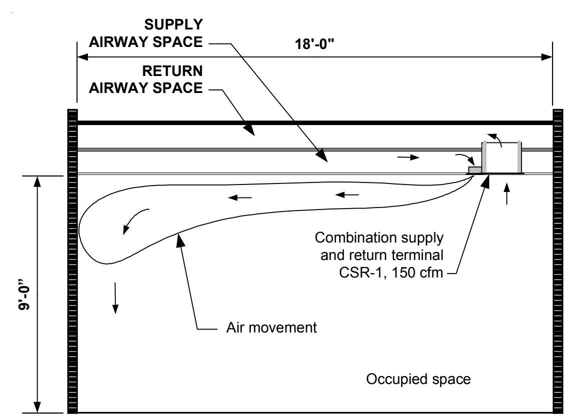

Fig. 7. Section view through a small office with a 150-cfm combination terminal CSR-1

Terminals *(continued)*

other ceiling-mounted devices (i.e., light troffers, sprinkler heads, sound speakers and other devices) can crowd the ceiling of a small room and create obstructions to preferred diffuser and return arrangements. Sometimes, it is just poor planning. For whatever reason, the inadvertent short-circuiting of supply air to the return reduces system performance and efficiency. It affects both indoor air quality and temperature control by reducing the fresh air percentage in the occupied zone and by reducing the amount of heat removed from the space. **AirFixture** combination supply and return terminals for use in Airways have been designed and tested to assure this will not happen.

Adjustments to Terminal Locations

One final question: "What happens if a terminal is incorrectly located or a larger supply volume is necessary?" In a conventional system, the ductwork must be modified (at substantial additional cost) or an excessively long flexible duct is substituted to reach to the new location. Too often designers and contractors simply accept the wrong location. Even removing a section of flexible duct and adding a longer section is time consuming. The situation is worse if a larger VAV box is necessary or the system must be rebalanced. To solve this problem in an Airway system, all that must be done is to move the terminal (just like you would move a ceiling tile) and the terminal's modular control wiring. To get more air, add another terminal. Because there is no ductwork, there are no resizing, relocation or rebalancing issues to add cost.

FIXTURES FOR SMALL ZONES

Small offices and other small rooms, such as medical exam rooms in a doctor's office, can be an air distribution challenge. Too often, a small amount of air "dumps" from a large supply diffuser or register at a very low velocity. This typically happens because the terminal is oversized, especially at part-load conditions. Oversized terminals lack good induction characteristics at low flow rates.

Figures 8 and 9 show a small interior space served with a single-throw, 150-cfm (71-L/sec), **AirFixture** supply terminal. In this example, a one-way, CSO-1 supply terminal throws the air across the ceiling above the occupied zone. Between the supply terminal and the wall, a single CRO-1 return terminal passes air to the return Airway space.

Summary:

The location and sizing of supply and return terminals is greatly simplified with the pre-engineered and tested approach offered by AirFixture combination terminals. Engineers and owners especially appreciate the flexible benefits of AirFixture terminals if it becomes necessary to change the system.

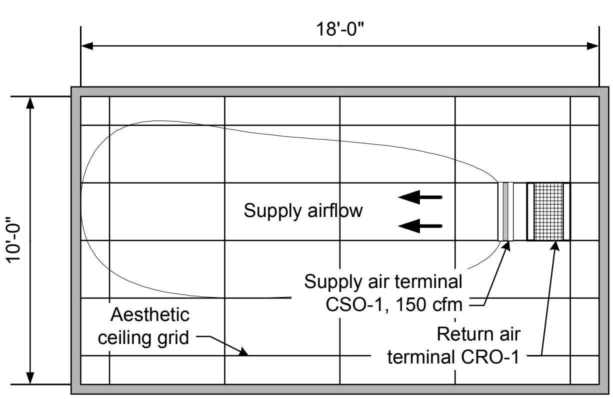

Fig. 8. Plan view of a small interior office with models CSO-1 and CRO-1 terminals

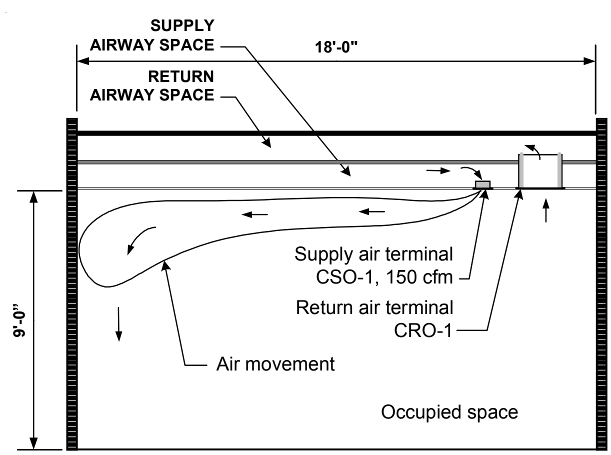

Fig. 9. Section view of small interior office with 150 cfm (71 L/sec) CSO-1 and CRO-1

TERMINAL EXAMPLE

Figure 10 illustrates a typical mechanical plan of an interior zone with a bay size of 35 feet by 35 feet (10.7 m by 10.7 m). The calculated airflow requirement is 1,250 cfm (590 L/sec) and the zone uses a single, cooling-only VAV box with four, square, four-way diffusers. For simplicity, the layout does not show any other ceiling features or obstructions such as: sprinkler heads, beams, conduits, roof drains or light fixtures.

As a comparison, Figure 11 shows the same space with a Dual Airway system reflected ceiling plan using combination terminals and pulse-modulated VAV controls. With 20% bypass, the combined airflow delivered to the zone through the Airway space is 1,500 cfm (708 L/sec).

The aesthetic ceiling in the Dual Airway system leaks air to the conditioned space at the controlled rate of about 0.10 cfm per square foot (0.5 L/sec/m²) or about 123 cfm (58 L/sec). In addition, the space has nine light fixtures (2 ft by 4 ft troffers) that leak about 10 cfm (4.7 L/sec) each, delivering another 90 cfm (42 L/sec) to the space. Median ceiling leakage is also about 0.10 cfm per square foot (0.5 L/sec/m²). Total leakage is about 336 cfm (159 L/sec). The total airflow distributed by the supply terminals is found by subtracting the estimated leakage from the calculated total airflow delivered through the Airway space. The result is 1,164 cfm (549 L/sec). Total airflow delivered to the zone is the sum of the terminal airflow and aesthetic ceiling leakage, which is 1,377 cfm (650 L/sec).

Supply fan airflow: 1,250 cfm (590 L/sec)
Bypass airflow: 250 cfm (47.2 L/sec)
Light fixtures: Nine 2 ft x 4 ft recessed troffers
Median ceiling leakage:
  1,225 ft² x 0.1 cfm/ft² = 123 cfm (58 L/sec)
Aesthetic ceiling leakage:
  Ceiling: 1,225 ft² x 0.1 cfm/ft² = 123 cfm (58 L/sec)
  Lights: 9 x 10 cfm each = 90 cfm (42 L/sec)
Total leakage: 123 + 123 + 90 = 336 cfm (159 L/sec)
Air distributed by supply terminals:
  (1,250+ 250) – 336 = 1,164 cfm (549 L/sec)
Total air delivered to the occupied space:
  1,164 + 123 + 90 = 1,377 cfm (650 L/sec)

The four terminals indicated in Figure 11 are **AirFixture** VSR-2 terminals rated at 300 cfm (142 L/sec) supply and 400 cfm (189 L/sec) return each. Note that the

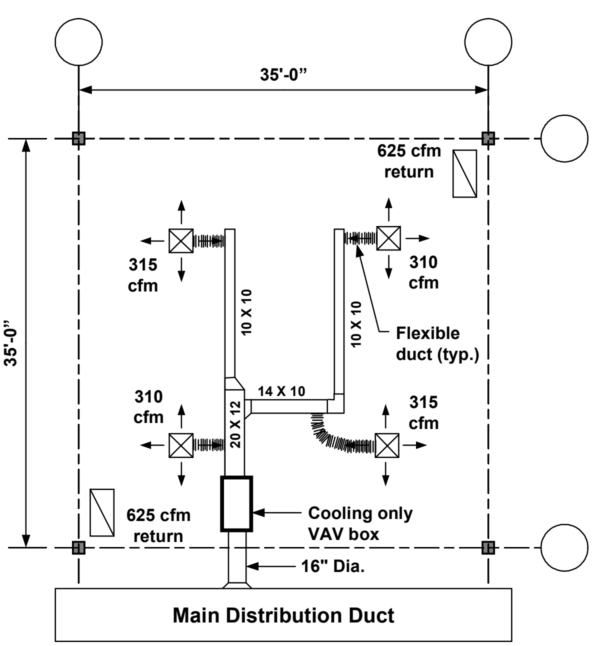

Fig. 10. Conventional, ducted variable-air-volume interior zone supplying 1,250 cfm (590 L/sec) to an area of 1,225 sq. ft. (113.8 m²)

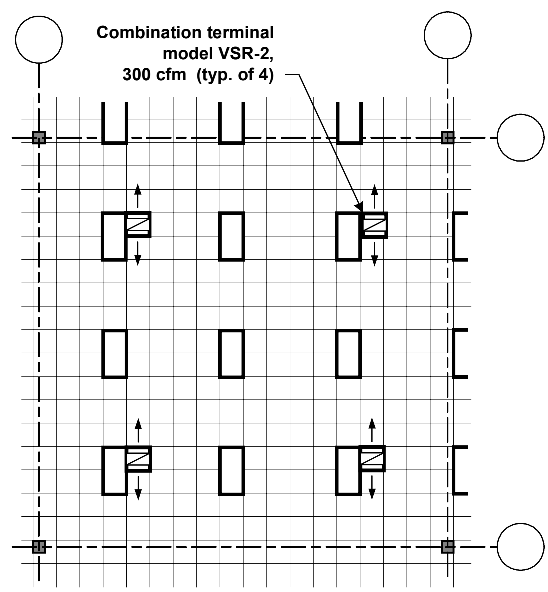

Fig. 11. Reflected ceiling plan showing four AirFixture VSR-2 combination supply and return terminals, rated at 300-cfm (142 L/sec) each, supplying 1,164 cfm (549L/sec) to the same interior zone shown in Figure 10

Terminals *(continued)*

Airway supply fixtures in Figure 11 total 1,200 cfm (566 L/sec) rather than 1,164 cfm (549 L/sec). Because Airway VAV systems use pulse-modulated control, the fixtures will automatically throttle the airflow rate to the proper volume based on the zone thermostat control signal.

In the off position, the minimum terminal airflow rate is 20 cfm (9.4 L/sec). Because the supply Airway space is at a constant pressure, aesthetic ceiling and light fixture leakage rates are constant at 123 cfm (58 L/sec) and 90 cfm (42 L/sec) respectively. The total minimum airflow to the conditioned space is 293 cfm (138 L/sec). Thus, the supply volume (plus leakage) can modulate from 293 to 1,377 cfm (138 to 650 L/sec), or in percentage terms from 23% to 110% of the calculated peak requirement.

Keep in mind that at the minimum condition (23% airflow) the supply air temperature reset characteristic will have taken effect (see Bypass Fan section beginning on page 19). While the system minimum flow to the conditioned space may be 23%, recirculation of the bypass fan reduces the temperature difference between the supply air and the conditioned space and reduces the effective cooling minimum load. At the hypothetical minimum flow condition described for the zone, 250 cfm (118 L/sec) of the 293 cfm (138 L/sec) total is bypass airflow, leaving only 43 cfm (20 L/sec), about 3% of the full load rate, to come from the air-handling unit. Please note that this example is for a zone only. The air-handling unit fan will not be expected, in most commercial installations, to throttle to such a low flow rate for the entire facility.

Summary:

There are three supply air sources:

1. **Supply terminal flow**
2. **Aesthetic ceiling leakage to the space**
3. **Leakage through non-HVAC, ceiling-mounted fixtures**

Leakage rates are constant. Terminal flow rates vary in response to the pulse-modulated VAV controls. All three combine to meet both the minimum load and the peak load requirements.

OVER-PRESSURIZATION

In variable-air-volume (VAV) and variable-volume/variable temperature (VVT) systems, the designer should include provisions to guard against over-pressurization of the supply Airway space if the minimum flow from the air-handling unit (supply) fan is greater than the minimum airflow required to satisfy space conditioning requirements. The preferred solution is to use multiple supply fans so that one or more fans may be stopped during very low load periods. An alternative is to install a counter-balanced relief damper or pressure control damper in the median ceiling to relieve supply air directly to the return Airway space. The relief damper should be set to relieve at 0.10 inches w.g. (25 Pa).

UNDER-PRESSURIZATION

When an Airway system design has too many supply terminals, the supply Airway space cannot be properly pressurized. Constant-volume systems should have enough supply terminals so that their combined capacity equals the supply fan capacity. Unlike variable-air-volume system, constant-volume systems should not use a diversity factor when selecting the size and quantity of supply terminals.

A variable-air-volume system design should apply diversity just as it would in any ducted system. The building load calculations determine the cooling requirements in each zone and for the building overall (block load). The block load airflow and cooling requirement will be smaller than the sum of the peak loads for each zone. Supply terminals should be sized and selected just as they are for ducted systems. Likewise, the supply fan, whether it is a central air-handling unit or a packaged rooftop unit, should be sized just as it would be for a ducted system. The engineer should review the load calculation results to verify that the applied diversity is not excessive, and that the supply Airway space can achieve properly pressurization.

Bypass Fans

BYPASS FAN APPLICATION

Dual Airway systems can be applied in a wide variety of climates. In regions conducive to microbial growth where moisture control is important, a bypass fan or some other form of relative humidity control must be used to limit supply air relative humidity. Very often, the supply air leaving a cooling coil is nearly saturated with a relative humidity between 90% and 95%. However, to limit opportunities for microbial growth, the relative humidity of air passing through a supply Airway space should not exceed 80%.

A simple way to limit supply air relative humidity is to subcool the air and then reheat it to the desired dry bulb temperature for delivery to the space. Of course, this is an inefficient and costly option that is prohibited by many codes. To achieve reheat at practically no cost, **AirFixture** developed the concept of a bypass fan mounted in the median ceiling of a Dual Airway system.

The bypass fan injects relatively warm return air into the air stream entering the supply Airway space from the air-handling unit or rooftop unit. The turbulent action created by introducing return air perpendicular to the direction of supply airflow mixes the two air streams quickly and efficiently.

BYPASS FAN SIZING

In most applications, a bypass airflow rate equal to 20% to 25% of the supply fan airflow will lower the relative humidity of the combined air stream to less than 80%. Bypass airflow up to 35% of the supply fan flow is not detrimental to system performance; however, bypass flows greater than 35% are excessive and serve no benefit. As a rule of thumb, the minimum bypass rate should be 20%.

Given the range of 20% to 35% bypass, there is no determining criterion that defines an optimum percentage. The simple objective is to get the combined supply air stream relative humidity somewhere below 80%. For this reason, **AirFixture** standardized bypass fans into two modular sizes: 400 cfm and 800 cfm (189 L/sec and 378 L/sec).

Standardization simplifies bypass fan sizing. One or more bypass fans are installed according to the air delivery volume from the supply fan so that the total bypass flow is equal to at least 20% of the supply fan airflow. The designer must also verify that the bypass flow adjacent to each supply outlet (directing air into the Airway space) is approximately 20% of the outlet airflow.

Bypass fan selection should be made from Tables 3 and 4 on page 20. Table 3 applies to most built-up systems using an air-handling unit, and is based on a nominal airflow of 350 cfm per ton (47 L/sec/kW). Table 4 applies to most rooftop systems and is based on a nominal airflow of 400 cfm per ton (54 L/sec/kW).

BYPASS FAN ADDITION TO SENSIBLE HEAT LOAD

The sensible heat load from a bypass fans is negligible. The electrical input to a 400-cfm (189-L/sec) fan operating against a 0.05 inch w.g. (12.4 Pa) differential is only 26 watts. The temperature rise in the bypass air stream is about 0.20°F (0.11°C). Remembering that the bypass flow is 20% to 35% of the supply fan airflow, the temperature rise in the combined supply air will only be in the range of 0.03°F to 0.05°F (0.02°C to 0.03°C).

Summary:

Dual Airway systems should use bypass fans to limit the combined supply air stream relative humidity to 80%. Failure to do so could lead to microbial growth problems. The sensible heat gain from bypass fans is negligible. The minimum bypass rate should be equal to 20% of the supply fan flow rate.

Bypass Fan *(continued)*

MULTIPLE BYPASS FANS

AirFixture standardized on a relatively small bypass fan size to modularize the system and to have multiple injection points on larger systems. Multiple fans:

- Reduce stratification by providing turbulent mixing at multiple supply air discharge ducts feeding into the supply Airway space
- Simplify service because they are not customized for a particular facility or building, and are manufactured with standardized dimensions
- Are easily mounted in the median ceiling
- Add reliability by minimizing the effect of any one bypass fan failure in an array of fans

In addition, the noise generated by an array of small fans and the space required for installation are much less than that for a single large fan.

SUPPLY AIR TEMPERATURE RESET

Constant-volume bypass fans operating in a variable-air-volume supply system have the implicit characteristic of resetting the supply air temperature at part-load conditions. Just as the bypass airflow dilutes the supply air relative humidity, it also dilutes the supply air temperature. For instance, consider a Dual Airway system operating with 20% bypass airflow at full load. Assuming a supply air temperature of 54°F (12.2°C) leaving the air handling unit (and entering the supply Airway space) and a return temperature of 78°F (25.6°C), the combined air temperature delivered to the supply Airway space will be 58.0°F (14.4°C). At part-load conditions, when the required supply air volume (from the air-handling unit) is 75% of that required at full load, the blended air temperature in the supply Airway space will be 59.1°F (15.1°C). If decreasing loads reduce the required air-handling unit airflow drops to 50% of full load rate, the blended air temperature in the supply Airway space will rise to 60.9°F (16.1°C).

BYPASS FAN NOISE

Bypass fans are relatively quiet, rated at a free area sound level of 52 SIL (average Lp in 500-2000 Hz). When placed in the median ceiling of a Dual Airway system, the sound perceived in the room will vary depending on the aesthetic ceiling tile selected, but will not be obtrusive for general office applications. Actually, since they run continuously, bypass fans provide a degree of "white noise" that is useful in masking other typical office sounds and noise.

Table 3
BYPASS FAN SELECTION (Main airflow at 325 cfm/ton)

System Cooling Capacity (tons)	System Fan Capacity (cfm)	No. of Bypass Fans	Bypass Airflow (cfm)	Total Airflow (cfm)
4	1,300	1	400	1,700
5	1,625	1	400	2,025
6	1,950	2	800	2,750
7	2,275	2	800	3,075
8	2,600	2	800	3,400
9	2,925	2	800	3,725
10	3,250	2	800	4,050
12	3,900	3	1,200	5,100
15	4,875	3	1,200	6,075
20	6,500	4	1,600	8,100
25	8,125	5	2,000	10,125
30	9,750	6	2,400	12,150
35	11,375	7	2,800	14,175
40	13,000	8	3,200	16,200
45	14,625	9	3,600	18,225
50	16,250	10	4,000	20,250
60	19,500	12	4,800	24,300
70	22,750	14	5,600	28,350

Table 4
BYPASS FAN SELECTION (Main airflow at 400 cfm/ton)

System Cooling Capacity (tons)	System Fan Capacity (cfm)	No. of Bypass Fans	Bypass Airflow (cfm)	Total Airflow (cfm)
4	1,600	1	400	2,000
5	2,000	1	400	2,400
6	2,400	2	800	3,200
7	2,800	2	800	3,600
8	3,200	2	800	4,000
9	3,600	2	800	4,400
10	4,000	2	800	4,800
12	4,800	3	1,200	6,000
15	6,000	3	1,200	7,200
20	8,000	4	1,600	9,600
25	10,000	5	2,000	12,000
30	12,000	6	2,400	14,400
35	14,000	7	2,800	16,800
40	16,000	8	3,200	19,200
45	18,000	9	3,600	21,600
50	20,000	10	4,000	24,000
60	24,000	12	4,800	28,800
70	28,000	14	5,600	33,600

BYPASS FAN ENERGY EFFICIENCY COMPLIANCE

There are two issues regarding compliance with ASHRAE Standard 90.1 – *Energy Standard for Buildings Except Low-Rise Residential Buildings* (ASHRAE 2001): fan system power limits and reheat source.

Fan System Power

Paragraph 6.3.3.1 of the standard describes the fan power limitations for systems having a total system power in excess of 5 horsepower (3.7 kW). The standard defines *fan system power* as: "the sum of the nominal power demand (nameplate horsepower) of motors of all fans that are required to operate at design conditions to supply air from the heating or cooling source to the conditioned space(s) and return it to the source or exhaust it to the outdoors." Since the bypass fans must operate continuously as part of the air delivery system, they must be considered when determining compliance with this requirement.

Table 6.3.3.1 indicates the most stringent requirement is for a constant-volume system with a capacity greater than or equal to 20,000 cfm (9,439 L/sec). The standard allows 1.1 hp per 1,000 cfm (1.74 kW per 1,000 L/sec).

Each 400-cfm (189 L/sec) bypass fan adds 26 watts to the fan system power consumption. This is equivalent to 0.035 horsepower. In a system where bypass is 20% to 35% of the supply fan airflow, the net addition to fan system power is between 13 and 23 watts, or 0.017 to 0.031 horsepower per 1,000 cfm (472 L/sec) of supply fan airflow. Thus, under the most stringent conditions, bypass fan operation uses about 1.5% to 2.8% of the allowable fan system power.

Reheat Source

Paragraph 6.3.2.3 of the standard forbids any means of simultaneous heating and cooling for humidity control with certain exceptions. Exception (e) states that reheating is permissible if, "At least 75% of the energy for reheating or for providing warm air in mixing systems is provided from a *site-recovered*…source." Since the **AirFixture** bypass fans use return air for reheat, fully 100% of the reheat energy is recovered from a site source. Therefore, reheat using small bypass fans to inject return air to the supply air stream is permissible.

Summary:

Bypass fans in Dual Airway systems are permissible under ASHRAE Standard 90.1. Bypass fans add about 0.017 to 0.031 horsepower (13 to 23 watts) per 1,000 cfm (472 L/sec) of supply fan airflow to the fan system power.

BYPASS FAN CONTROL

Bypass fans are constant-volume fans and should operate continuously whenever the air-handling unit or rooftop unit supply fan operates. This is true for both constant-volume and variable-air-volume systems.

Since bypass fans are constant-volume fans, the proportion of bypass air increases as the main VAV supply fan volume decreases at part loads. This serves to provide an automatic temperature reset function that warms the supply air as load decreases.

Typical wiring for a bypass fan uses either a normally open auxiliary contact on the supply fan contactor, or a

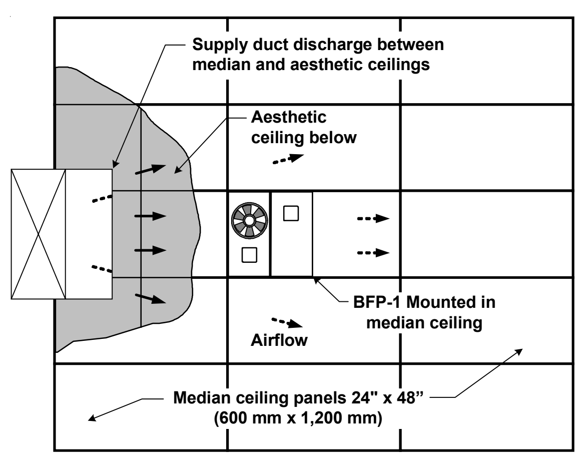

Fig. 12. Plan view of a typical arrangement for a single bypass fan operating with a single supply discharge

Bypass Fan *(continued)*

separate relay that energizes and provides 120 volt, single-phase power to the bypass fan whenever the supply fan is running. No other control wiring or sequences are required.

BYPASS FAN LOCATION

Bypass fans should be installed in the median ceiling adjacent to the supply fan discharge point. They must be located close to the main air stream to ensure good induction and mixing. The designer must consider the different conditions on each project that affect placement, but the objective is to mix return air in the supply air stream as thoroughly and quickly as possible. Figures 12 through 16 show several typical bypass fan placement recommendations.

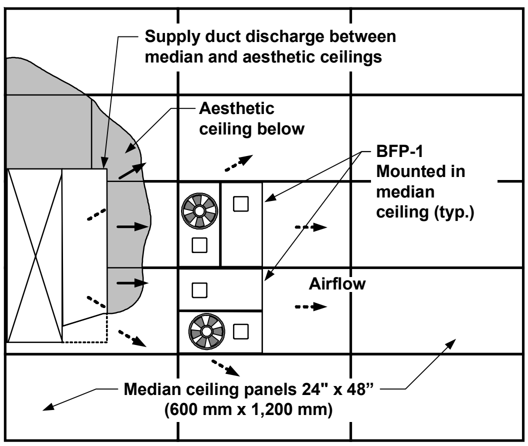

Fig. 13. Plan view of a typical arrangement for two bypass fans operating with a single supply discharge

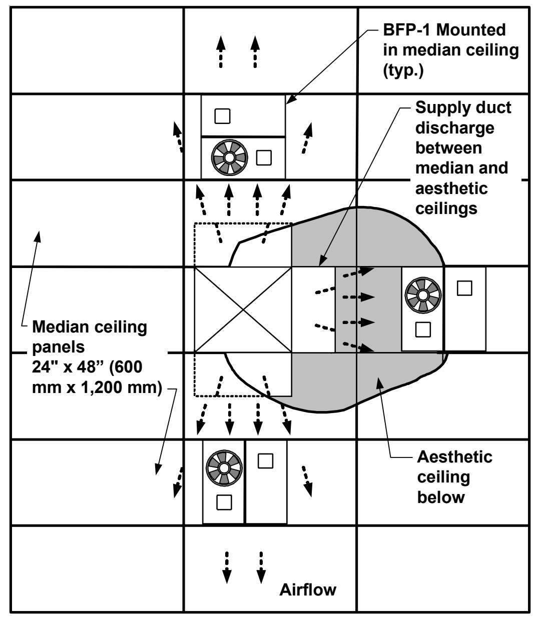

Fig. 15. Plan view of a typical arrangement for three bypass fans operating with a three-way supply discharge

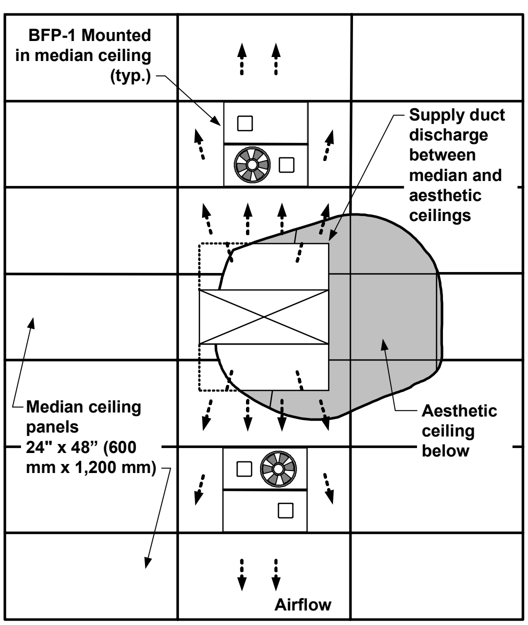

Fig. 14. Plan view of a typical arrangement for two bypass fans operating with a two-way supply discharge

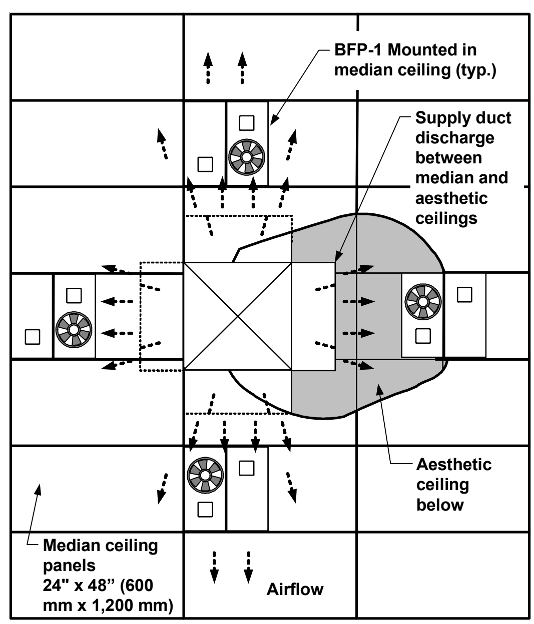

Fig. 16. Plan view of a typical arrangement for four bypass fans operating with a four-way supply discharge

Humidity Control

CONTROLLING HUMIDITY AND PREVENTING MOLD AND MILDEW

A current trend in the insurance industry is to limit coverage for fungi and mold-related damages to a specified maximum amount that also includes the cost of testing and remediation. Insurance companies have dropped coverage in some states for mold-related damage due to rising litigation costs. Almost every state in the union has a school that was closed due to mold. The subjects of mold and indoor air quality are prominent in HVAC trade journals and are justified causes for concern among many design professionals, contractors, and owners. As in all HVAC systems, addressing mold control is an important issue in Dual and Single Airway systems.

Summary:

Single and Dual Airway systems offer excellent protection from mold and fungi. AirFixture has worked for years developing solutions that address mold-related concerns.

Microbial Growth

Microbial growth can occur anywhere in a building or an HVAC system that it is consistently wet and supplies a source of food. Mold does not prefer the material or surface it calls home, all it needs is moisture and food. In a conventional HVAC system, mold is likely to grow on sheet metal, duct liner, cooling coils and drain pans. In buildings, mold grows inside walls, under carpeting, under wallpaper or any other space where there is a source of moisture and food.

A primary source of nutrients supporting microbial growth in HVAC systems is the fine dirt and dust particles that deposit on system components. Other organic building materials, such as paper, cardboard and wallpaper paste are also food sources. In a well-designed and maintained HVAC system, air filters capture most (but not all) particle contaminants. The system cooling coil, when active (wet), also acts to filter particulates from the air stream. Over time though, dust and dirt will migrate downstream and deposit on the inside surfaces of fans, housings, ductwork and other components. Likewise, dust and dirt accumulates in all parts of a building, whether open or enclosed. In fact, many enclosed areas simply retain the dust and dirt that was deposited there during construction.

Both prerequisites, food and moisture, are necessary. Eliminating one or the other will control microbial growth. In a building or an HVAC system, combating microbial growth comes down to controlling moisture.

Moisture Control

In a buildings operating with rooftop units (RTUs) or air-handling units (AHUs), the primary sources of moisture are leaks, outdoor air, occupants and other internal sources (e.g., coffee pots). Moisture control in the building comes down to two important criteria: maintaining a positive building pressure relative to the outdoors and controlling the space relative humidity to a maximum of 40 to 60%. In the circulated air streams, cooling coils condense a portion of the entrained moisture, but in absolute terms a large amount of moisture remains in the air. Traditional moisture control methods in HVAC systems include:

- Cooling coils sized with face velocities slower than 500 to 550 feet per minute (2.5 to 2.8 m/sec) to prevent air entrainment of droplets
- Adequately sized and sloped drain pans that are large enough to collect draining condensate and droplets falling from the downstream edge of coil fins
- Properly sized and installed condensate drain pipes
- Using steam humidifiers rather than water-spray humidifiers
- Properly sized and selected outdoor air louvers (or hooded intakes) to prevent penetration by entrained droplets
- Properly installed and maintained rooftop units with weather-tight seams and joints
- Periodic cleaning of ductwork and equipment housing interiors
- Relative humidity in the occupied space controlled to between 40% and 60%

Humidity Control *(continued)*

Moisture Control Problems

In spite of all the good moisture-control features that can be built into an HVAC system, consider the following extraordinary events that are, at the same time, all too common:

- An RTU has a fan operating continuously. The refrigeration compressor cycles on and off to maintain space temperature. The outside air damper remains open when the compressor cycles off. When the compressor stops, water on the coil evaporates into the air stream, and at the same time, the supply air stream temperature rises above the cooling supply temperature that was established when the compressor was running. Warmer, more humid air now comes into in contact with duct (or duct liner) surfaces that may be below the dew point temperature of the current supply air stream. Condensation occurs, providing a moisture source.
- An AHU chilled water coil discharges air at 55°F (12.8°C) and about 95% relative humidity. If the discharge controller hunts its control point or the chilled water temperature varies, the supply air temperature will vary. If the cold supply duct that had been at 55°F suddenly sees air with a dew point above 55°F, moisture will condense on the duct and AHU housing surfaces.
- An AHU with chilled water coil is working well, delivering air at 55°F (12.8°C) and 95% RH. A thunderstorm occurs causing a brief power outage. When system operation is restored, the AHU restarts immediately, but the restart time on the chiller is slower. For a time the AHU will circulate warm, moist air that will condense on cold duct surfaces.
- The AHU or RTU in a system does not maintain positive pressure in the building, allowing moisture and microbes to infiltrate. Water condenses on any surface with a temperature below the air dew point temperature.
- The building owner or the building automation system turns off the air-conditioning system at night, on holidays and on weekends. With the air conditioning systems off, moisture infiltrates which raises the building's humidity and creates an opportunity for moisture to condense on building surfaces.
- To save energy, the building automation controls raise chilled water temperature to limit electrical demand. Raising the chilled water temperature reduces dehumidification capacity of cooling coils. With internal moisture sources or humid outdoor air, the space relative humidity may rise in spite of maintaining the dry bulb set point.

Moisture Control in an Airway System

The engineering standard of care used in designing ducted air-conditioning systems applies equally to air-conditioning systems designed with Airway distribution. In addition, the Airway system should be designed and constructed with the following features:

- Limit the cooling coil discharge temperature to a maximum of 54°F (before fan heat)
- Provide reheat to raise the supply air relative humidity
- Minimize ductwork

In an Airway system, the length of supply air ductwork from an RTU or an AHU can be held to a minimum. This short length of relatively large duct should be installed in such a way that is accessible to inspect and clean.

Dual Airway systems function with continuously operating, constant-volume bypass fans that reduce the degree of saturation in the supply Airway. Bypass fans provide reheat by diluting the near-saturated supply air with relatively dry return air. The reheat action drops the supply air relative humidity from about 95% to about 80% and helps reduce the possibility of microbial growth. When a building uses recessed, ceiling-mounted light fixtures, the supply Airway relative humidity drops further because supply air captures 50% to 75% of the lighting load before it is released to the conditioned space.

Summary:

Dual Airway systems distribute air with the relative humidity at or below 80% to control microbial growth. The short length of main duct necessary for an Airway system should be easily accessible for inspection and cleaning.

Depending on the building arrangement, lighting design, and supply air discharge design in the Airway space, the supply air relative humidity may decrease below 80%.

The ceilings in a Dual Airway system are readily accessible and easy to inspect. If for some reason contaminated tiles are found (e.g., from a roof leak), then it is easy to remove the tiles and replace them. As a point of comparison, consider the cost of replacing ceiling tiles with the cost of cleaning, relining or replacing a contaminated duct system. Easy inspection and low remediation cost is a definite advantage for the Dual Airway system.

Many under-floor systems have, for some time, used an air-handling system that purposely delivers air at or below 80% relative humidity. They achieve this by a return air bypass in the air-handling unit.

Pressure in the Return Airway Space

Because a building's envelope is never perfectly sealed, moisture migrates through cracks and penetrations in the wall and roof. Even with return ductwork, moisture will continue to migrate inward due to wind pressure and roof leaks. However, return ductwork isolates the ceiling space from circulated air. If (and when) moisture infiltrates into the ceiling space, stagnant air conditions become charged with humidity, creating an incubation zone for microbial growth. Mold accumulation will be difficult to detect and remove. The only way to minimize moisture infiltration, with or without return ductwork, is to positively pressurize the building.

Figure 17 (on page 26) shows a section through a typical building with ducted supply and plenum return. ASHRAE indicates that keeping the building cavities slightly positive, as little as 0.004 inches w.g. (1.0 Pa), will help solve the moisture problem. Of course, there will be times when high wind pressure exceeds the building pressure in certain parts of the building. But, continuous, positive building pressurization has been shown to be more important than transient wind effects.

Building pressurization controls generally regulate the room pressure relative to the outdoor air pressure by modulating the outdoor air and relief air dampers. The secret to maintaining a positive pressure in the return Airway space is to limit the pressure drop across the return terminals so that the Airway space remains positive relative to outdoors. When an Airway system is installed with an adequate number of return terminals, the pressure drop between the room and the return Airway space is 0.02 inches w.g. (5 Pa) or less.

Figure 18 (on page 26) shows a Dual Airway system with pressurization control. **AirFixture** pressurization control IBX-1 controls the supply Airway space pressure relative to the occupied space pressure. The primary air-handling device and/or the building automation system must control the overall building pressurization.

Summary:

When designing a Dual Airway system, keep the supply Airway space at 0.05 inches w.g. (12.4 Pa) higher than the occupied room, and the return Airway space at a positive pressure relative to the exterior average. Single and Dual Airway systems can provide continuous pressurization control over the average outdoor pressure to limit moisture infiltration.

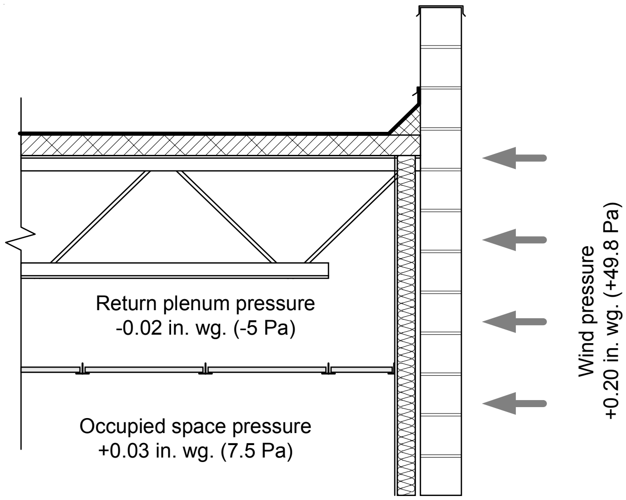

Fig. 17. Typical building construction with a ducted supply and plenum return

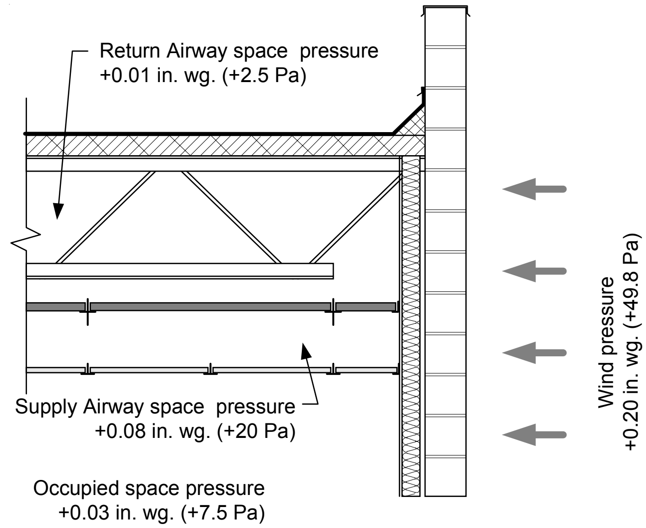

Fig. 18. Maintaining a positive pressure in return Airway space

Heating and Perimeter Systems

DUAL AIRWAY HEATING AND PERIMETER SYSTEM OPTIONS

Dual Airway overhead air distribution systems have four recommended heating options: 1) a switchover system, 2) a dedicated heating system, 3) combination heating and cooling terminals used at the building perimeter, and 4) a separate perimeter supply Airway space. Each of these options has both ducted and unducted versions, giving the system designer at least eight variations to choose from. The best choice must be evaluated by considering specific project requirements and conditions. Significant decision criteria include: the source of heat, the building layout, anticipated heating loads, and budgets (e.g., electric heat offers low first cost whereas hot water heating may provide lower operating cost at somewhat higher first cost). Airway systems may also be combined with traditional baseboard radiation or hydronic radiant-floor heating systems.

The Switchover Option

The switchover option is a common operating scheme for most small systems. It uses a single rooftop unit or air-handling unit that provides both cooling and heating (although not simultaneously). A conventional thermostat with auto-changeover capability controls the system and switches from cooling to heating (or heating to cooling) as may be necessary.

In a Dual Airway system, a heating-cooling switch (model HCS-1) detects the air-conditioning unit's automatic change from cooling to heating by sensing the supply Airway space temperature. The switch then reverses the pulse-modulated air valve control action at the supply terminals. In each zone, a wall-mounted AirSwitch thermostat (model TCD-1 or TCD-2) is necessary to provide a modulating control signal to the supply terminal(s) to maintain the set point under both cooling and heating conditions.

In larger buildings, a switchover system may be designed as a perimeter zone separate from the building's interior zones. A positive barrier is necessary in this case to create separate supply Airway spaces. The barrier may be formed by extending the interior walls through the supply Airway space or by installation of supply Airway barriers (model SAB-1) as shown in Figure 19. Whether using walls or barriers, leakage between the zones is not significant because adjacent supply Airway spaces operate at the same positive pressure (0.05 inches w.g., 12.4 Pa).

A drawback to the switchover system is that locating supply terminals is a compromise between the throw characteristics of a terminal at different temperature airflows. The buoyant character of warm air tends to reduce effective throw of a diffuser, especially when the throw measurement includes the distance down a vertical wall. An offsetting benefit is that the warm air in the supply Airway space has a positive radiant heating effect. This combines with warm air leaking through the aesthetic ceiling and the warm air distributed through the terminals to provide an overall level of comfort in the room.

The Dedicated Heating System

Typical ceiling supply terminals do not throw air vertically downward across exterior exposures as should be done when heating. A solution to this problem is to use small, heating-only terminals at the building perimeter to offset radiant and transmission heat losses through the cold exterior wall (or window) and to intercept convective drafts that fall downward from cold surfaces. Mixing heated air with cool convective airflow offsets the cooling effect and can maintain comfort.

Figure 20 illustrates a model MFT-C fan-powered terminal installed above the median ceiling and discharging into a short "stub" duct. Short round ducts extend from the rectangular stub duct downward

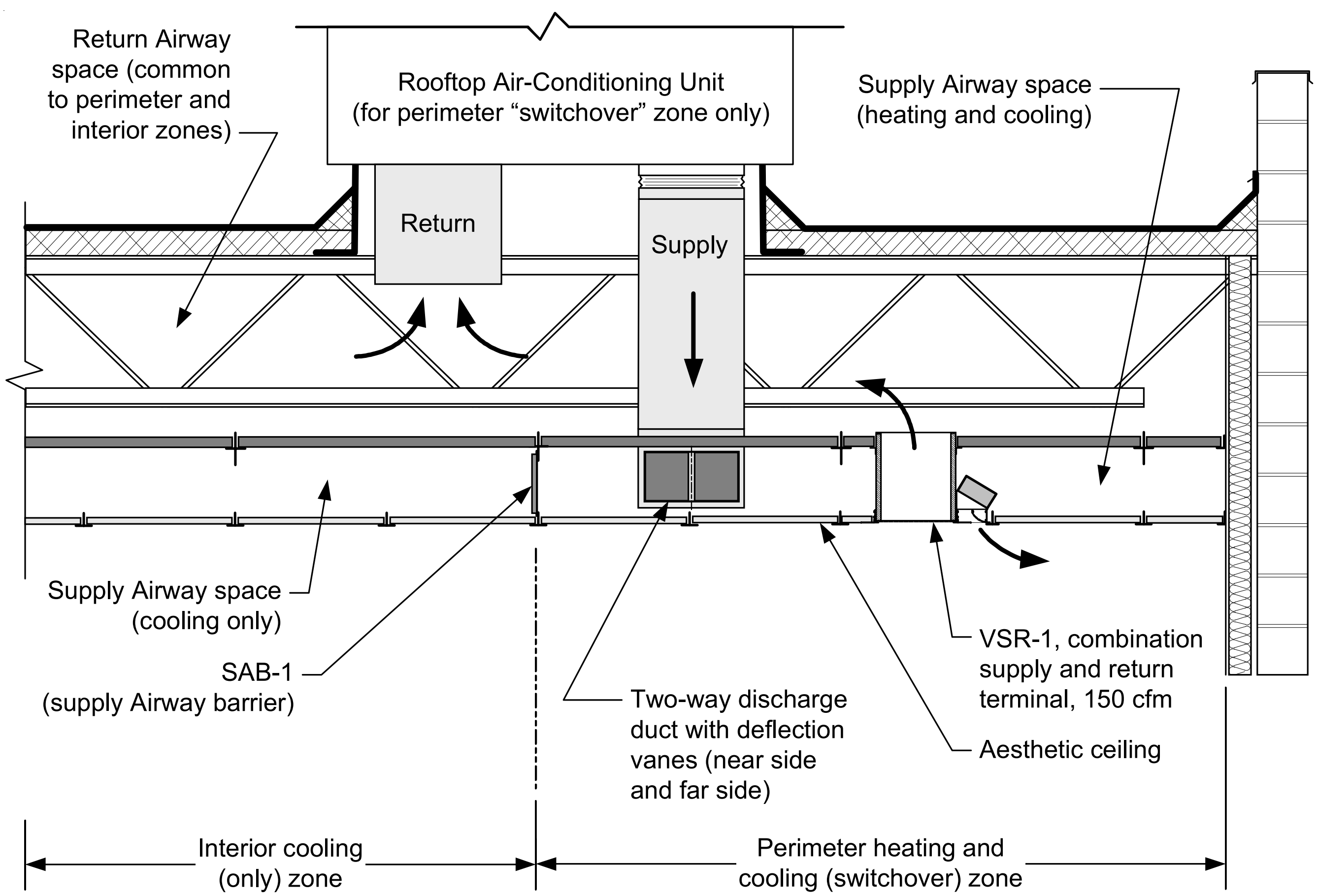

Fig. 19. Separation of the supply Airway spaces for a perimeter heating/cooling (switchover) zone and an interior cooling-only zone using supply Airway barrier model SAB-1

Heating and Perimeter Systems *(continued)*

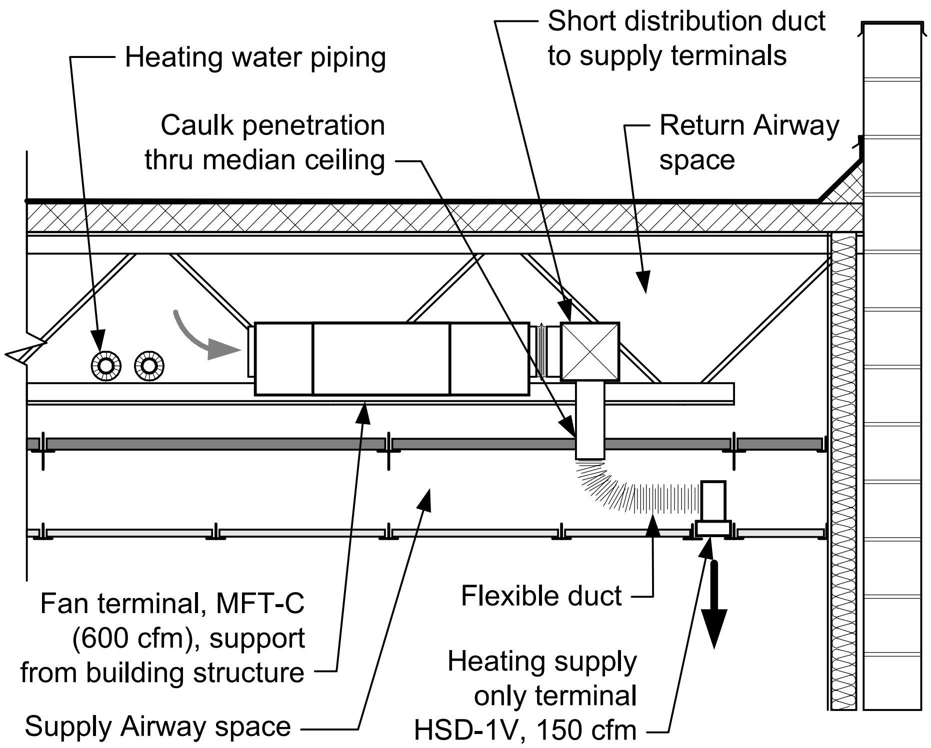

Fig. 20. Perimeter heating system using a model MFT-C fan-powered terminal with hot water coil and a dedicated supply air terminal

through the median ceiling; a flexible duct connects each heating supply terminal. The fan-powered terminal draws air from the return Airway space, heats it using a hot water coil (or an electric element), and discharges through the supply terminals installed in the aesthetic ceiling. Since this is a dedicated heating system, the air discharges vertically downward across the exterior wall. A single fan-powered box can serve multiple terminals, which is attractive for hot water heating applications because it reduces the number of piping connections and valves.

Combination Heating and Cooling Terminals

There are two perimeter heating alternatives using **AirFixture** combination heating-cooling terminals (model HCD-1, HCD-2, HCR-1 and HCR-2). Combination heating-cooling terminals combine both the cooling, heating and return functions in a single 24-inch by 24-inch (600-mm by 600-mm) panel. Separate air valves regulate the variable cooling airflow from the supply Airway space, a dedicated constant-volume diffuser projects heating air vertical downward, and return air passes from the occupied space through an insulated boot to the return Airway space.

Figure 21 illustrates the first option where HCR-2 combination heating-cooling terminals are individually equipped with a model FTE-1, direct-connected, fan-powered heating section. This option eliminates all piping and ductwork in the perimeter system. Combination heating-cooling terminals are available with nominal unit ratings of 150 cfm (71 L/sec) or 300 cfm (142 L/sec) cooling airflow, 400 cfm (189 L/sec) return airflow, and 150 cfm (71 L/sec) constant-volume heating airflow.

The second option uses model MFT-C modular, fan terminal units in a manner similar to that shown in Figure 20. Instead of using heating-only terminals (as shown in Figure 20), this option combines the MFT-C fan terminal unit with multiple model HCD-1 or -2 combination terminals. The HCD series terminals are similar to the HCR series terminals except that the heating portion of the terminal has a ducted supply connection. The FTE fan terminal cannot be used with model HCD combination terminals. Like the HCR terminals, model HCD terminals are available with nominal unit ratings of 150 cfm (71 L/sec) or 300 cfm (142 L/sec) cooling airflow, 400 cfm (189 L/sec) return

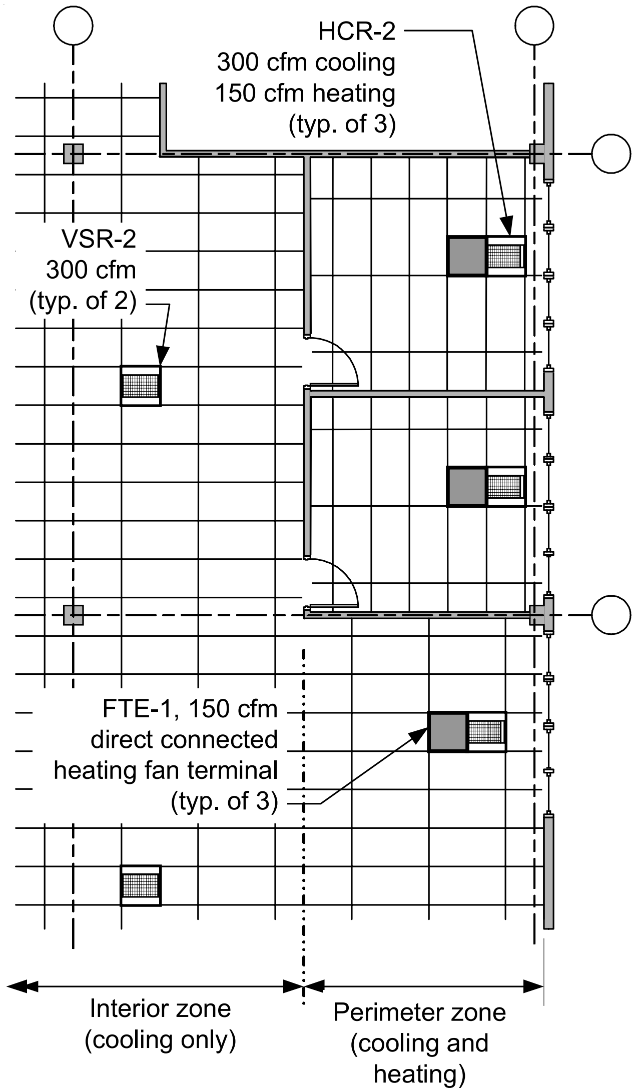

Fig. 21. Excerpt of a building plan showing a perimeter heating system using combination heating and cooling terminals

airflow, and 150 cfm (71 L/sec) constant-volume heating airflow.

Perimeter Supply Airway Space

Figure 19 (on page 27) shows a perimeter Airway space combined with a separate rooftop air-conditioning unit that serves only the perimeter zone. It is not necessary in all cases to install a separate unit dedicated to the perimeter zone. A perimeter zone may be a decoupled heating system using fan-powered terminals as shown in Figure 23 (on page 30).

Insulated supply Airway barriers (model SAB-2) form a perimeter zone in the supply Airway space. YORK model MFT-C modular fan terminal units, Figure 22, draw air from the return Airway space and deliver it to the perimeter supply Airway space. During cooling operation, the MFT-C fan terminal units are off. During the heating season, the MFT-C units recirculate return air as the first stage of heating supply. Hot water or electric coils provide a second stage of heating by elevating the temperature of return air recirculated to the perimeter zone.

The SAB-2 supply Airway barriers should be located so that the perimeter supply Airway space (heating zone) is about 4 feet wide. Some variation is permissible so that the supply Airway space is no less than 2 feet and no larger than 6 feet wide.

The advantage of a perimeter Airway space combined with YORK model MFT-C units is that multiple supply air terminals operate with a minimum of hot water piping connections, or power connections (for electric heating). No ductwork (flexible or rigid) is necessary to connect the fan-powered unit with supply air terminals. Each model MFT-C unit delivers 600 cfm of airflow.

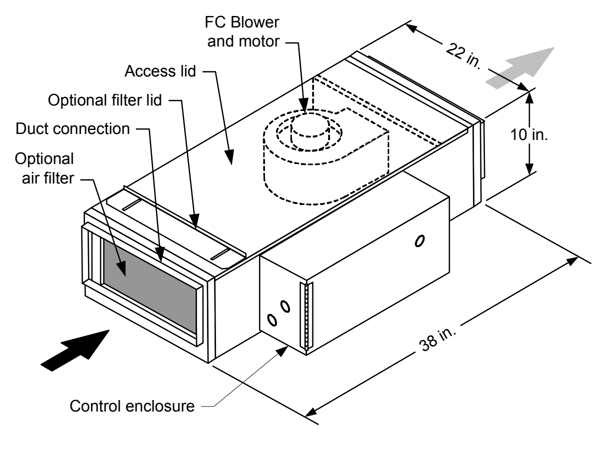

Fig. 22. York model MFT-C, 600-cfm modular fan terminal unit

Heating and Perimeter Systems *(continued)*

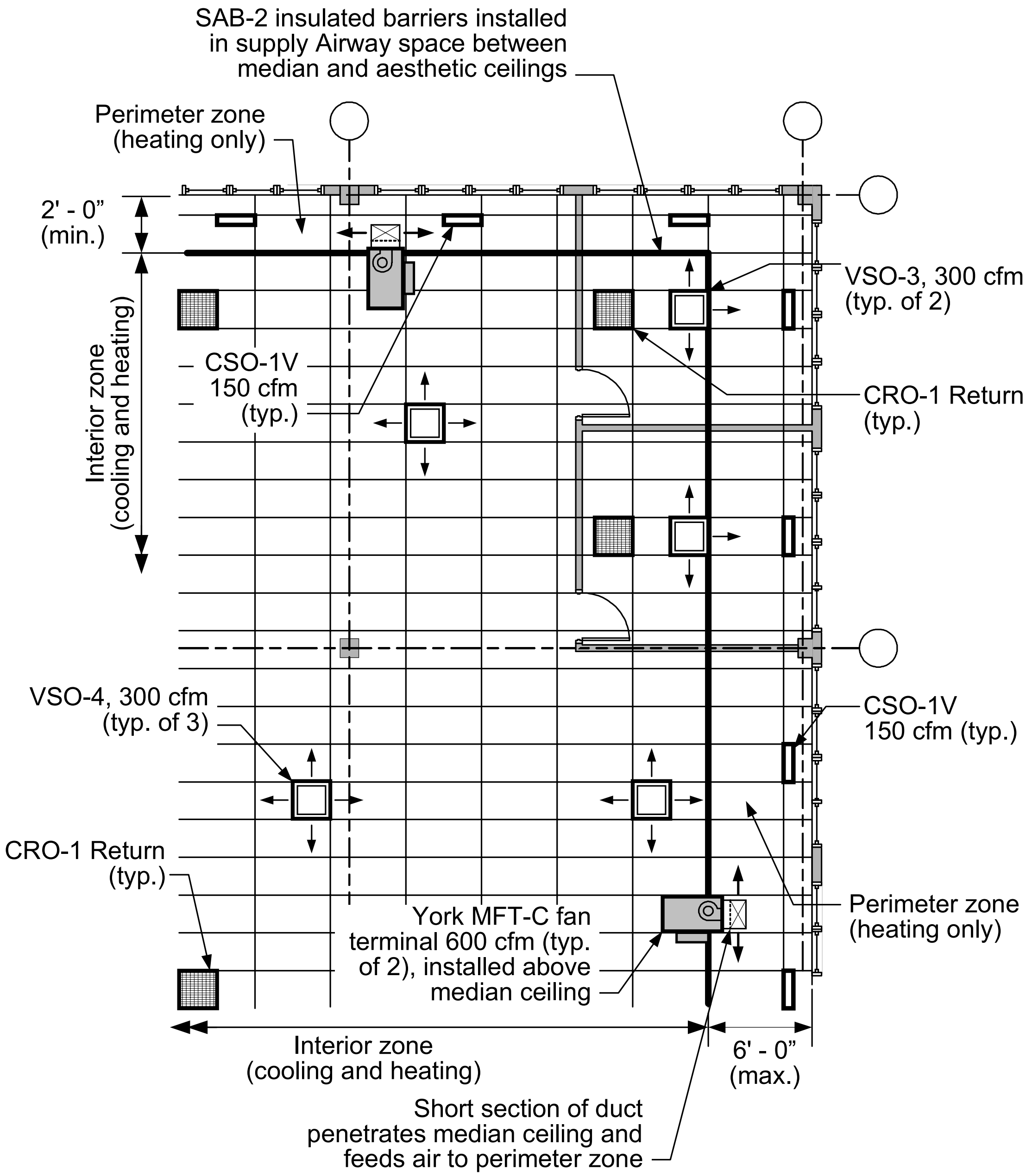

Fig. 23. Excerpt of a building plan showing a perimeter supply Airway space using York MFT-C modular fan terminal units

Air-Conditioning Units

MULTIPLE SUPPLY UNITS SERVING A SINGLE AIRWAY SYSTEM

A single supply Airway may distribute air from multiple rooftop units or air-handling units and provide several practical advantages:

- Using multiple, smaller units provides improved reliability since the loss of a single unit will have less effect on the overall system performance.
- It offers the ability to stage units to meet the building load. For example, a 10-ton rooftop unit may only have one stage of cooling. However, if two 5-ton units replace the 10-ton unit, they can be sequenced so that one 5-ton unit runs continuously and the second unit cycles to meet the changing building load. Staged units do not have to be the same size.
- With multiple units, outdoor air may be conditioned separately. An example would be to use a 10-ton and a 30-ton unit for a 40-ton load. The smaller unit may run continuously to meet outdoor air requirements, and the second unit may modulate to meet changing indoor sensible cooling requirements.
- Using multiple, odd-sized units may help fast-track projects. In this situation, the availability of the units may be more important than the size. For example, to serve a 20-ton load, the designer may use: two 10-ton units, or a single 10-ton unit with two 5-ton units, or four 5-ton units, or any combination of available units. Cost may be a factor in this selection process also (i.e., it may be more attractive to select an array of low cost units rather than a single costly unit).
- An Airway system permits combining units on retrofit projects. An existing undersized system could be improved by adding a small unit to boost performance.
- Very high reliability is possible by mixing DX and chilled water units to serve the same space. If one system fails, the other available.
- Airway systems support equipment standardization. A building owner may choose to standardize around a single unit model. For example, if the standard unit is a 10-ton rooftop unit, then a facility with a 20-ton load is served by two units, a 30-ton facility by three, and so on.
- Using multiple, smaller rooftop units creates a natural low profile and avoids the cost of architectural screening that may be necessary with a single large unit. Also, since an Airway system is not ductwork dependent, rooftop units may be positioned almost anywhere as necessary to improve aesthetics.

RECOMMENDATIONS FOR AIR-CONDITIONING UNIT LOCATION

The location of air-conditioning equipment has little effect on either Single or Dual Airway systems (either overhead or under floor). Air-conditioning units for under floor air distribution need not be floor-mounted, computer room type units. Likewise, overhead Dual Airway systems are not more suited to rooftop unit applications. Regardless of the air distribution scheme, Airway systems work equally well with packaged unitary rooftop units or built-up air-handling units. Experience has shown that the choice of unit does not matter. In all cases, the recommendation is to select a unit location, or locations that permit minimization of the necessary ductwork.

OTHER RECOMMENDATIONS

The following are general recommendations to help assure an efficient and reliable Single or Dual Airway air distribution system.

- The choice of cooling, either direct-expansion (DX) or chilled water, has no effect on supply or return Airway design. Design engineers may apply either type of cooling as a matter of preference or project requirements.
- Never use a return fan.
- Never use a mixed air bypass—use a return air bypass mounted in the median ceiling.
- Always consider dehumidification in humid climates.
- Always consider using demand-controlled ventilation or performance ventilation with carbon dioxide sensors.

Air-conditioning Units *(continued)*

- When using multiple air-conditioning units with a common supply Airway space, backdraft dampers may be necessary to prevent reverse airflow through a stopped unit(s).
- Do not use multiple thermostats to control multiple air-conditioning units serving a common supply Airway space. Use an IBX-1 controller, which has up to 6 stages of control.
- Always provide a reliable means of building pressure control.
- With riser systems in multi-floor buildings, use a control strategy that automatically optimizes the down duct static to the lowest possible level.
- Use decoupled outside air when it makes sense.
- Use both volume and temperature control reset for supply optimized to load.
- Avoid using booster fans in the Airway system.
- Use static pressure night setback instead of temperature setback.

References

ASHRAE. 2001. *Energy Standard for Buildings Except Low-Rise Residential Buildings*. ANSI/ASHRAE/IESNA Standard 90.1.

Cummings, J. B., C. B. Withers, N. Moyer, P. Fairey, and B. McKendry. 1996. "Uncontrolled Air Flow in Non-Residential Buildings." Final Repot of project FSEC-CR-878-96, Florida Solar Energy Center, Cocoa, Florida.

Harriman, L.G., G.W. Brundrett, and R. Kittler. 2001. *The New ASHRAE Design Guide for Humidity Control in Commercial Buildings.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia.

SMACNA. 1989. *HVAC Duct Inspection Guide.* Sheet Metal and Air Conditioning Contractors' National Association, Vienna, Virginia 22182.

Guide Specifications

INTRODUCTION

These guide specifications are provided for reference purposes. Several of the unique, important features of Dual Airway ceiling construction are: the median ceiling, the airtight nature of ceiling construction, sealing the grid system, and airtight (non-porous) requirements of the ceiling panels.

Some of these guide specifications are recommendations of information to be added to the designer's standard specifications, others are complete sections. The intent is to assist the designer in modifying his or her project specifications to address important and unique features of Dual and Single Airway components and systems, and pulse-modulated controls.

SECTION 09515 – DUAL AIRWAY CEILING

PART 1 - GENERAL

1.01 Summary

A. Section Includes:

1. Median ceiling panels
2. Median ceiling suspension system
3. Aesthetic ceiling panels
4. Aesthetic ceiling suspension system
5. Wire hangers, fasteners, wall angle molding, gasket, and accessories

B. Related Sections:

1. Section 09250 - Gypsum Board
2. Section 09120 - Suspension System Framing and Furring for Plaster and Gypsum Board Assemblies
3. Division 15 - Mechanical
4. Division 16 - Electrical

C. Substitutions:

1. Substitutions for the materials or equipment described in the Contract documents will not be permitted unless a written request has been submitted to and received by the Architect no later than ten (10) working days prior to the date established for receipt of bids. Verbal requests will not be considered.
2. The acceptability of a substitution is contingent upon the Architect's and/or Engineer's review and approval of the proposed products. Approved substitutions will be set forth in an addendum. Approval shall not be considered official unless and until such time as it is set forth in an addendum. Bidders shall refrain from including substitutions in their bid that have not been confirmed by written addenda.
3. Bidder's shall submit separate requests for each proposed substitution. Each request shall include the name of the material or equipment for which it is to be substituted, drawings, catalog data, photographs, performance and test data, and any other information that will permit an appropriate and thorough evaluation. Each proposed substitution must meet all of the requirements of these specifications.

1.02 References

A. American Society for Testing and Materials (ASTM):

1. A641 – Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire.
2. A653 – Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process.
3. C423 – Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method.
4. C635 – Standard Specification for Metal Suspension Systems for Acoustical Tile and Lay-in Panel Ceilings.
5. C636 – Recommended Practice for Installation of Metal Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels.
6. E84 – Standard Test Method for Surface Burning Characteristics of Building Materials.

Guide Specifications *(continued)*

7. E1111 – Standard Test Method for Measuring the Interzone Attenuation of Ceilings Systems.
8. E1414 – Standard Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum.
9. E1264 – Classification for Acoustical Ceiling Products.
10. E1477 – Standard Test Method for Luminous Reflectance Factor of Acoustical Materials by Use of Integrating-Sphere Reflectometers.

1.03 Submittals

A. Product Data: Submit manufacturer's technical data for each type of median and aesthetic ceiling panel and suspension system required.

B. Samples: Minimum 6-inch by 6-inch (150-mm x 150-mm) samples of specified acoustical panel; 8-inch (200-mm) long samples of exposed wall molding and suspension system, including structural cross, main runner and cross tees.

C. Shop Drawings: Layout and details of acoustical ceilings. Show locations of items that are to be coordinated with, or supported by the ceilings.

D. Certifications: Manufacturer's certifications that products comply with specified requirements, including laboratory reports showing compliance with specified tests and standards. For acoustical performance, each carton of material must carry an approved independent laboratory classification of NRC, CAC, and AC.

E. If the ceiling materials supplied do not have an Underwriter's Laboratory classification of acoustical performance on every carton, subcontractor shall be required to send material from every production run appearing on the job to an independent or NVLAP approved laboratory for testing, at the Architect's or Owner's discretion. All products not conforming to manufacturer's current published values must be removed, disposed of and replaced with complying product at the expense of the Contractor performing the work.

F. The air leakage performance of each panel type and suspension member shall be identified in writing as compliant with this specification, without exception.

1.04 Quality Assurance

A. Single-Source Responsibility: Provide ceiling panels and suspension system components by a single manufacturer.

B. Fire Performance Characteristics: Identify acoustical ceiling components with appropriate markings of applicable testing and inspecting organization.

1. Surface Burning Characteristics: Shall be as indicated below, tested per ASTM E84, and complying with ASTM E1264 for Class A products.
   a. Flame Spread: 25 or less.
   b. Smoke Developed: 50 or less.

C. Coordination of Work: Coordinate median and aesthetic ceiling work with installers of related work including, but not limited to building insulation, gypsum board, light fixtures, mechanical systems, electrical systems, and fire sprinklers.

1.05 Delivery, Storage, and Handling

A. Deliver ceiling materials to project site in original, unopened packages and store them in a fully enclosed space where they will be protected against damage from moisture, direct sunlight, surface contamination, and other causes.

B. Before installing ceiling units, permit them to reach room temperature and a stabilized moisture content.

C. Handle ceiling materials carefully to avoid chipping edges or damaged units in any way.

1.06 Project Conditions

A. Space Enclosure:

1. Building areas to receive ceilings shall be free of construction dust and debris.
2. Panels and steel suspension systems can be installed at temperatures up to 120°F (49°C) and in spaces before the building is enclosed, where HVAC systems are cycled or not operating.
3. Panels and suspension systems cannot be used in exterior applications, where standing water is present, or where moisture will come in direct contact with the components.

1.07 Warranty

A. Aesthetic and Median Panels: Submit a written warranty executed by the manufacturer, agreeing to repair or replace panels that fail within the warranty period. Failures include, but are not limited to:

1. Panels: Sagging, warping and air leakage.
2. Support system: Rusting, air leakage and manufacturer's defects.

B. Warranty Period:

1. Median and Aesthetic panels: Ten (10) years from date of Substantial Completion. Note Project Conditions requirements above.
2. Suspension System and Grid: Ten (10) years from date of Substantial Completion.

C. The Warranty shall not deprive the Owner of other rights the Owner may have under other provisions of the Contract Documents, and will be in addition to and run concurrent with other warranties made by the Contractor under the requirements of the Contract Documents.

1.08 Maintenance

A. Extra Materials: Furnish extra median and aesthetic ceiling materials identical to the products installed. Extra materials shall be packaged with protective coverings for storage, and identified with appropriate labels.

1. Median and Aesthetic Ceiling Panels: Furnish additional full-size panels equal to [4%] [___%] of quantity installed.
2. Median and Aesthetic Suspension System Components: Furnish additional whole lengths of tees, crosses, wall angles, and additional quantities of hardware accessories equal to [1%] [___%] of the quantity installed.
3. Deliver extra materials to Owner.

Part 2-PRODUCTS

2.01 Manufacturers

A. Median Ceiling Suspension System Components:

1. Armstrong World Industries, Inc. (see paragraph 2.01.E below).
2. AirFixture, LLC.

B. Median Ceiling Panels:

1. Armstrong World Industries, Inc. (see paragraph 2.01.E below).
2. AirFixture, LLC.

C. Aesthetic Ceiling Suspension System Components:

1. Armstrong World Industries, Inc. (see paragraph 2.01.E below).
2. AirFixture, LLC.

D. Aesthetic Ceiling Panels:

1. [by Architect]

E. Armstrong and AirFixture products for Airway systems are available through:

Wagner Interior Supply Co.
1000 East 11th Street
Kansas City, Missouri
(816) 472-6622

2.02 Median Ceiling Suspension System

A. Model Numbers:

1. **MCC-1**: Median ceiling cross, 12 ft. (3.7 m) long.
2. **MCC-4**: Median ceiling cross, 4 ft. (1.2 m) long.
3. **CWA-1**: Ceiling wall angle, 10 ft. (3 m) long.

B. Components: All structural crosses (main beams) and cross tees shall be commercial quality hot-dipped galvanized steel as per ASTM A653. Structural crosses and cross tees shall be double-web steel construction with type exposed flange design.

1. Structural Classification: ASTM C635 Heavy Duty.
2. Finish: bare galvanized, unless noted otherwise.
3. Cross Tee Acceptable Product: Armstrong World Industries, Inc., Prelude XL 15/16" Exposed Tee.

C. High Humidity Finish: Comply with ASTM C635 requirements for Coating Classification for Severe Environment Performance where high humidity finishes are indicated.

Guide Specifications *(continued)*

1. Structural Classification: ASTM C635 duty class.
2. Color: White.

D. Attachment Devices: Size for five times design load indicated in ASTM C635, Table 1, Direct Hung unless otherwise indicated.

E. Wire for Hangers and Ties: ASTM A641, Class 1 zinc coating, soft temper, pre-stretched, with a yield stress load of at least three times design load, but not less than 12 gauge.

F. Wall Angles, Edge Moldings and Trim: Galvanized steel sheet metal or extruded aluminum of types and profiles indicated or, if not indicated, manufacturer's standard moldings for edges and penetrations that fit the type of edge detail and suspension system indicated. Provide wall angles and moldings with exposed flange of the same width as exposed main beams and tees.

G. Gasket: Factory-applied, closed-cell, self-adhesive, on the upper flange surface of all main beam flanges, cross tee flanges, wall angles and edge moldings to provide an airtight joint at the point the panels rest on the flange.

H. Caulking: Acrylic, 25-year warranty, conforming to the requirements of Section 07920 – Joint Sealants.

2.03 Aesthetic Suspension System

A. Model Numbers:

1. **ACB-1**: Aesthetic ceiling brace, 12 in. (300 mm).
2. **ACH-1**: Aesthetic ceiling hanger, 12 in. (300 mm).
3. **ACM-1:** Aesthetic ceiling main beam, 12 ft. (3.7 m) long.
4. **ACT-2B**: Aesthetic ceiling tee, 2 ft. (0.6 m) long, butt joint.
5. **ACT-2L**: Aesthetic ceiling tee, 2 ft. (0.6 m) long, lap joint.
6. **ACT-4B**: Aesthetic ceiling tee, 4 ft. (1.2 m) long, lap joint.
7. **ACT-4L**: Aesthetic ceiling tee, 4 ft. (1.2 m) long, lap joint.
8. **CWA-1**: Ceiling wall angle, 10 ft. (3 m) long.

B. Components: All main beams and cross tees shall be commercial quality hot-dipped galvanized steel as per ASTM A653. Main beams and cross tees are double-web steel construction with type exposed flange design. All exposed surfaces of main beams, tees, wall angles, moldings and other components shall be chemically cleaned, with pre-finished galvanized steel capped in baked polyester paint. Main beams and cross tees shall have rotary stitching.

1. Structural Classification: ASTM C635 Intermediate duty.
2. Color: White and match the actual color of the selected ceiling tile, unless noted otherwise.
3. Acceptable Product: Armstrong World Industries, Inc. Prelude XL 15/16" Exposed Tee.

C. High Humidity Finish: Comply with ASTM C635 requirements for Coating Classification for Severe Environment Performance where high humidity finishes are indicated.

1. SS Prelude Plus by Armstrong World Industries, Inc., 100% Type 304 stainless steel.
2. AL Prelude Plus by Armstrong World Industries, Inc., all aluminum.
3. Prelude Plus XL Fire Guard by Armstrong World Industries, Inc., G-60 hot-dipped galvanized with aluminum capping.
4. Structural Classification: ASTM C635 duty class.
5. Color: [Stainless for SS only][White aluminum] [Clear Anodized Aluminum].

D. Attachment Devices: Size for five times design load indicated in ASTM C635, Table 1, Direct Hung unless otherwise indicated.

E. Wire for Hangers and Ties: ASTM A641, Class 1 zinc coating, soft temper, pre-stretched, with a yield stress load of at least three times design load, but not less than 12 gauge.

F. Aesthetic Ceiling Hanger (ACH-1): A heavy-gauge, galvanized steel sheet metal hanger designed for use with Airway systems may be used in lieu of hanger wires. The aesthetic ceiling hanger shall be designed to securely attach to the median and aesthetic ceiling support systems and maintain a uniform 12-inch (300 mm) separation between the median ceiling and the aesthetic ceiling.

G. Aesthetic Ceiling Brace (ACB-1): A heavy-gauge, galvanized steel sheet metal brace designed for use with Airway systems to provide vertical support and lateral bracing of the aesthetic ceiling. The aesthetic ceiling brace shall be designed to securely attach to the median and aesthetic ceiling support systems and maintain a uniform 12-inch (300 mm) separation between the median ceiling and the aesthetic ceiling.

H. Wall Angles, Edge Moldings and Trim: Galvanized sheet metal or extruded aluminum of types and profiles indicated or, if not indicated, manufacturer's standard moldings for edges and penetrations, including light fixtures, that fit the type of edge detail and suspension system indicated. Provide wall angles and moldings with exposed flange of the same width as exposed main beams and tees.

I. Gasket: Factory-applied, closed-cell, self-adhesive, on the upper flange surface of all main beam flanges, cross tee flanges, wall angles and edge moldings to provide an airtight joint at the point the panels rest on the flange.

2.04 Ceiling Panels

A. Median Ceiling Panels:

1. Surface: Smooth or fine textured airtight vinyl facing.
2. Composition: Fiberglass backed, mineral fiberboard.
3. Size: [48 inches x 24 inches x 1 inch thick (1200 mm x 600 mm x 25 mm)], or [48 inches x 24 inches x 1.25 inches thick (1200 mm x 600 mm x 32 mm)].
4. Edge Profile: Square lay-in for interface with compatible grid.
5. Noise Reduction Coefficient (NRC): ASTM C423; Classified with UL label on product carton; NC 0.65 or greater.
6. Flame Spread: ASTM E1264; Class A (UL).
7. Thermal Performance: R3.85 (R5 with film coefficients).
8. Dimensional Stability: Temperatures up to 120°F (49°C) and high humidity excluding exterior use, use over standing water, and direct contact with moisture.

B. Aesthetic Ceiling Panels:

1. Aesthetic ceiling panels shall have airtight (non-porous) construction.
2. Surface Texture: [insert description].
3. Composition: [insert description].
4. Color: [insert description].
5. Size: [48 inches x 24 inches x 1 inch thick (1200 mm x 600 mm x 25 mm)], or [24 inches x 24 inches x 1 inch thick (600 mm x 600 mm x 25 mm)].
6. Edge Profile: Square lay-in for interface with compatible grid.
7. Noise Reduction Coefficient (NRC): ASTM C423; Classified with UL label on product carton; NC [___] or greater.
8. Ceiling Attenuation Class (CAC): ASTM E1414; [insert description].
9. Articulation Class (AC): ASTM E 1111; [insert description].
10. Flame Spread: ASTM E 1264; Class A (UL).
11. Light Reflectance (LR): ASTM E1477; white panel; [insert description].
12. Dimensional Stability: temperatures up to 120°F (49°F) and high humidity excluding exterior use, use over standing water, and direct contact with moisture.
13. Acceptable Product: [insert description].

PART 3 - EXECUTION

3.01 Examination

A. Do not proceed with installation until all wet work such as concrete, terrazzo, plastering and painting has been completed and thoroughly dried, unless expressly permitted by manufacturer's printed recommendations.

Guide Specifications *(continued)*

B. Coordinate with other trades to avoid any unnecessary ceiling penetrations, and field-cut penetrations not shown on the drawings.

3.02 Preparation

A. Measure each ceiling area and establish layout of ceiling units to balance border widths at opposite edges of each ceiling. Avoid use of less than half width units at borders, and comply with reflected ceiling plans. Coordinate panel layout with mechanical and electrical fixtures.

B. Coordination: Furnish layouts for preset inserts, clips, and other ceiling anchors whose installation is specified in other sections.

1. Furnish concrete inserts and similar devices to other trades for installation well in advance of time needed for coordination of other work.
2. Verify elevations and alignment of median and aesthetic ceiling position agrees with electrical and mechanical fixture positioning.

3.03 Median Ceiling Installation

A. Install median ceiling suspension system and panels in accordance with the manufacturer's instructions, in compliance with ASTM C636, and with the authority having jurisdiction.

B. Suspend structural cross from overhead construction with hanger wires spaced 4 feet (1.2 m) on center along the length of the structural cross. Install hanger wires plumb and straight.

C. Install median ceiling wall moldings at intersection of suspended ceiling and vertical surfaces. Miter corners where wall angles or moldings intersect or install corner caps.

D. Install median panels in coordination with suspended system, with edges resting on flanges of structural crosses and cross tees. Cut and fit panels neatly against abutting surfaces. Support edges by wall angles or moldings.

E. All panels with cut penetrations shall be caulked in place with the penetration edges and the void through the penetration sealed with caulk to assure airtight performance.

F. Install aesthetic ceiling suspension system and panels after median ceiling is complete in coordination with mechanical and electrical trades, following manufacturer's recommendations.

3.04 Aesthetic Ceiling Installation

A. Install main beams of aesthetic ceiling suspension system vertically aligned with the main structural crosses of the median ceiling. Overall installation of aesthetic ceiling suspension system and panels shall be in accordance with the manufacturer's instructions, and in compliance with ASTM C636 and with the authority having jurisdiction.

B. Suspend main beams from main structural crosses of the median ceiling with hanger wires spaced 4 feet (1.2 m) on center along the length of the beam. Install hanger wires plumb and straight.

C. Install aesthetic ceiling wall angles or moldings at intersection of suspended ceiling and vertical surfaces. Miter corners where wall moldings intersect or install corner caps.

D. Install aesthetic ceiling panels in coordination with suspended system, with edges resting on the gasketed flanges of main beams and cross tees. Cut and fit panels neatly against abutting surfaces. Support edges by wall angles or moldings.

E. All panels with cut penetrations shall be caulked in place with the penetration edges and void through the penetration sealed with caulk, to assure airtight performance.

3.05 Adjusting and Cleaning

A. Replace damaged, broken and loose fitting panels.

B. Clean exposed surfaces of aesthetic ceilings, including trim, edge moldings, and suspension members. Comply with manufacturer's instructions for cleaning and touch up of minor finish damage. Remove and replace work that cannot be successfully cleaned and repaired to permanently eliminate evidence of damage.

C. Coordinate sealing and caulking of any openings, holes, cracks or other features that may cause excessive air leakage from the Dual Airway. Visually inspect quality of sealing and correct any deficiencies before final testing.

D. Verify by visual inspection that all panels are in place in the median and aesthetic ceilings.

E. Verify that all appurtenances are in place and all penetrations and openings are caulked and sealed.

CEILING-RELATED SPECIFICATIONS

To control ceiling leakage, several specification sections must include references to Airway space sealing:

03251 – Expansion and Contraction Joints: should emphasize the need to have sealed, airtight Airway joints.
07951 – Sealants and Caulking: should define caulking material for Airway ceiling system and partitions exposed to Airway spaces.
09260 – Gypsum Wallboard Systems: should include an installation reference to close the top of non-full-height partitions, caulk at openings and penetrations, and tape and seal wallboard joints exposed to the Airway spaces.
15092 – Wall Seal: should address sealing around pipes and ducts that penetrate Airway spaces.
16111 – Conduits: should be revised to include sealing requirements for conduits and penetrations in supply Airway spaces.

Section 03251 – Expansion and Contraction Joints

Experience has shown that even though NFPA requires no leakage of air between floors, expansion joints leak excessively. This appears to be the result of no practical testing methods in the field with conventional construction. However, the Airway pressure testing often reveals excessive leakage that requires correction. The following text should be added to the joint specification under Part 3 - Execution:

> Expansion and contraction joints in floor slabs forming a portion of an Airway space shall be sealed to an airtight state in accordance with NFPA requirements using approved methods and materials for fire-rated partitions. Any joints demonstrated to be leaking under the test pressure of 0.05 inches w.g. (12.4 Pa) shall be repaired or replaced as necessary at no additional cost to the Owner.

Section 09260 – Gypsum Wallboard Systems

The following text should be added to the material specifications in Part 2 - Products:

> Ceiling Trim Ring (CTR-1): Galvanized steel sheet metal or extruded aluminum assembly to support supply and return air terminals in Airway systems. Exposed surfaces shall be chemically cleaned and pre-finished with baked polyester paint. Color: white.

The following text should be added to the joint specification under Part 3 - Execution:

> The top of all steel stud walls terminating within a supply Airway space shall be sealed airtight using a metal track or similar closure that is free of holes, and is securely fastened to the wallboard at the partition top.
>
> All holes and penetrations in gypsum wallboard partitions shall be caulked and sealed airtight within supply Airway spaces.
>
> All seams in gypsum wallboard partitions within supply Airway spaces shall be finished. Pre-fill open joints with setting-type joint compound. Embed tape in joint compound and apply second coat of compound over tape.

DIVISION 15 - MECHANICAL SPECIFICATIONS

There are a number of Division 15 sections that should address requirements for a Single or Dual Airway air distribution system:

15020 – Work Included
15021 – Work Not Included
15042 – Tests
15043 – Balancing of Air Systems
15510 – Sprinkler Equipment
15740 – Access Floor Air Terminals
15763 – Air-handling Units
15770 – Packaged Heating and Cooling Units

Guide Specifications *(continued)*

15800 – Air Distribution
15872 – Airway Air Distribution System
15900 – Controls and Instrumentation
15907 – Inspections, Testing and Balancing
15931 – Thermostats
15950 – Sequence of Operation

Section 15020 – Work Included

This section should include reference to the testing of Single and Dual Airways. The Mechanical Contractor should be made aware of his responsibility to conduct Airway leakage testing. In addition, the Mechanical Contractor shall be responsible for sealing and repairing any holes, penetrations, or openings made in the Airway spaces for items installed by the Mechanical Contractor.

Section 15021 – Work Not Included

This section should clarify that the Single or Dual Airway ceiling system will be provided by others; however, the Mechanical Contractor is responsible for installing and testing specific equipment in the Airway system as described in other sections.

Section 15042 – Tests

Traditional testing, adjusting and balancing are neither required nor feasible. However, the following tests should be required and specified:

Occupied Space to Return Airway Differential Static Pressure Test

After supply Airway ceiling leakage is verified within acceptable limits, and with the system is operating in its normal configuration, the Mechanical Contractor shall measure the static air pressure drop between the occupied space and the return Airway space. The pressure difference shall not exceed 0.02 inches w.g. (5 Pa). If the return air pressure differential is greater than 0.02 inches w.g. (5 Pa), then additional return air terminals or larger return air terminals must be installed in the system.

Building Pressurization Test

The return Airway space pressure shall be verified as slightly positive relative to outside ambient in the range of 0.008 to 0.01 inches w.g. (2 to 2.5 Pa). This requires the system to be operating normally with the Airways complete and all fixtures in place. With variable-air-volume systems, the Mechanical Contractor shall demonstrate the pressure controller and associated controls are capable of maintaining a stable building pressure as the system supply volume modulates.

For constant-volume systems, the outside air damper and exhaust dampers shall modulate to maintain a stable building pressure during both unoccupied and occupied operating modes and throughout the modulating range of outside air damper if a demand control ventilation sequence (carbon dioxide measurement) is used.

Design Supply Airflow Rate Test

The Mechanical Contractor shall open a number of supply terminals equal to the supply volume specified for the peak load. While supplying the peak airflow rate, the supply air system shall maintain an operating static pressure of not less than 0.03 inches w.g. (7.5 Pa) in the supply Airway space. The actual design pressure should be 0.05 inches w.g. (12.4 Pa), and every effort should be made to ensure that the system reaches the design level. If this test fails, the fan system should be adjusted to maintain the peak load volume and Airway static pressure.

Section 15043 – Balancing Air Systems

Conventional air terminal balancing is not required with a Single or Dual Airway system. Hoods and similar devices used to measure continuous airflow are not capable of measuring the terminal airflow accurately and should not be used. System balancing should be limited to the described tests. No other system balancing is required. Testing requirements for other mechanical equipment such as rooftop units and air-handling units shall remain as is customary.

Section 15510 – Sprinkler Equipment

This section should reference the use of a Dual Airway ceiling and require the Contractor to provide a secure, airtight penetration of both the median and aesthetic ceilings (through the supply Airway space). Concealed sprinkler heads should be protected from the cool supply air by a return air passage or other means.

Section 15740 – Access Floor Air Terminals

Refer to YORK FlexSys™ Under Floor Air System Guide Specifications, Form 130.15-GS2 (101), for complete access floor air distribution component specifications.

Section 15763 – Air-Handling Units

Larger variable-air-volume systems should use variable-speed drives for airflow and pressure control. In addition, cooling coils should be specified with adequate dehumidification capacity. If the project uses a Single Airway system for supply air in humid climates, the air-handling unit should have a return air bypass specified to control the supply air relative humidity.

Section 15770 – Packaged Unitary Heating and Cooling Units (Rooftop Units)

Larger rooftop variable-air-volume systems should use variable speed drives for airflow and pressure control. Cooling coils should be specified with adequate dehumidification capacity. If the project uses a Single Airway system for supply air in humid climates, the rooftop unit should have a return air bypass specified to control the supply air relative humidity. Multiple refrigeration stages (i.e., three stages) are desirable with larger systems greater than 15 tons. Smaller systems should have one or two stages if multiple units can be sequenced to maintain humidity control.

Smaller systems should include modulating outside air and exhaust dampers that modulate to maintain building pressure and ventilation rate. If possible, the unit should have an economizer section. If not, the specification should include a description for manual adjustment of dampers for building pressure control and ventilation. The unit should close the outdoor air damper whenever de-energized.

Supply fan airflow rates may require adjustment because of the low external static pressure at which the system operates. In addition, the fan speed may need to be reduced to improve dehumidification (reduced cfm per ton).

Ideally, the rooftop unit or air-handling unit should be supplied as a package with the air distribution system to insure coordination, compatibility, and single source responsibility.

Section 15800 – Air Distribution

The Dual Airway and Single Airway systems should be described to the Mechanical Contractor even though much of the system is supplied by others. The following recommendations apply:

- In Dual Airway systems, coordination between with the ceiling installation contractor and the Mechanical Contractor is critical. The Mechanical Contractor shall be required to review the ceiling plans and drawings, and provide compatible devices. All tests shall be coordinated and supported by the both the ceiling installation contractor AND the Mechanical Contractor.
- All air distribution devices in the Airway distribution system shall be specified from a single source as a ***system***. This includes supply and return terminals, control cables, power supplies, controls, thermostatic devices and bypass fans.
- It should be clear that only suppliers having experience in manufacturing devices for Airway systems will be acceptable. Items substituted or converted for Airway system application shall not be acceptable. All air distribution system components used on the project shall be included in submittals for approval.
- Ducted air distribution systems should clearly be described as “not acceptable.” Use of non-modular cables should also be rejected as unacceptable.

Section 15872 – Airway Air Distribution System

PART 1 – GENERAL

1.01 Mechanical General Provisions

A. Provisions of Section 15010 - Mechanical General Provisions, shall be made an integral part of this Section.

Guide Specifications *(continued)*

1.02 Work Included

A. The Contractor shall furnish and install a complete Dual [Single] Airway air supply system as shown on the drawings. All wiring, controls and other accessories required for a complete system shall be furnished and installed. Mechanical Contractor shall provide submittals, samples, and operation and maintenance documentation. Specific equipment includes:

[*Edit the following list to include only those components required for the project.*]

BFP-1, bypass fan, 400 cfm (189 L/sec)
BFP-2, bypass fan, 800 cfm (378 L/sec), 120 vac
BFP-3, bypass fan, 800 cfm (378 L/sec), 240 or 277 vac
CRO-1, return air terminal, 680 cfm (321 L/sec)
CSO-1, supply terminal, 1-way throw, constant-volume, 150 cfm (71 L/sec)
CSO-2, supply terminal, 2-way throw, constant-volume, 300 cfm (142 L/sec)
CSO-3, supply terminal, 3-way throw, constant-volume, 300 cfm (142 L/sec)
CSO-4, supply terminal, 4-way throw, constant-volume, 300 cfm (142 L/sec)
CSR-1, combination supply and return terminal, 1-way throw, constant-volume, 150 cfm (71 L/sec) supply, 400 cfm (189 L/sec) return
CSR-2, combination supply and return terminal, 2-way throw, constant-volume, 300 cfm (142 L/sec) supply, 400 cfm (189 L/sec) return
EJB-1, electrical junction box, median ceiling-mounted
EPS-1, electrical power supply (control power)
FTE-1, fan terminal unit, direct connects to HCR-1 and HCR-2 terminals, electric heating, 150 cfm (71 L/sec)
HCD-1, combination heating and cooling supply, and return terminal, 1-way throw, variable-air-volume 150 cfm (71 L/sec) cooling, constant-volume 150 cfm (71 L/sec) heating with ducted connection, 400 cfm (189 L/sec) return
HCD-2, combination heating and cooling supply, and return terminal, 2-way throw, variable-air-volume 300 cfm (142 L/sec) cooling, constant-volume 150 cfm (71 L/sec) heating with ducted connection, 400 cfm (189 L/sec) return
HCR-1, combination heating and cooling supply, and return terminal, 1-way throw, variable-air-volume 150 cfm (71 L/sec) cooling, constant-volume 150 cfm (71 L/sec) heating, 400 cfm (189 L/sec) return
HCR-2, combination heating and cooling supply and return terminal, 2-way throw, variable-air-volume 300 cfm (142 L/sec) cooling, constant-volume 150 cfm (71 L/sec) heating, 400 cfm (189 L/sec) return
HCS-1, heating and cooling switch
HSD-1V, heating supply terminal, ducted supply connection, vertical-down throw, 150 cfm (71 L/sec)
IBX-1, **-2**, **-3** and **-4**, supply Airway pressure controllers and communication interface
MFT-B, fan-powered, electric/hydronic heating unit, 300 cfm (142 L/sec)
MFT-C, fan-powered, electric/hydronic heating unit, 600 cfm (284 L/sec)
PAP-1, **-2**, **-3**, **-5, -6** and **-7**, modular control wiring
RAP-1, return air passage
SAB-1 and **SAB-2**, supply Airway barrier
TCD-1, space thermostat for pulse-modulation control with communications and temperature display
TCD-2, space thermostat for pulse-modulation control
TCD-3, space thermostat for cooler-warmer control, cooling only
TCD-4, space thermostat for cooler-warmer control, cooling and heating
VSO-1, supply terminal, 1-way throw, variable-air-volume, 150 cfm (71 L/sec)
VSO-2, supply terminal, 2-way throw, variable-air-volume, 300 cfm (142 L/sec)
VSO-3, supply terminal, 3-way throw, variable-air-volume, 300 cfm (142 L/sec)
VSO-4, supply terminal, 4-way throw, variable-air-volume, 300 cfm (142 L/sec)
VSR-1, combination supply and return terminal, 1-way throw, variable-air-volume, 150 cfm (71 L/sec) supply, 400 cfm (189 L/sec) return
VSR-2, combination supply and return terminals, 2-way throw, variable-air-volume, 300 cfm (142 L/sec) supply, 400 cfm (189 L/sec) return

1.03 Related Work Not Included

A. The Dual [Single] Airway ceilings required for installation of air terminals shall be coordinated with the ceiling installation contractor. All ceiling supports, ceiling panels and related accessories will be furnished and installed by the ceiling installation contractor [General Contractor] as shown on the reflected ceiling plan drawings. Required Airway barriers, Airway sealing, structural grid supports and any other ceiling related appurtenances will be furnished and installed by the ceiling installation contractor [General Contractor] as shown on the drawings.

B. All electrical power necessary for terminal operation shall be coordinated with the electrical contractor. All electrical power wiring and components shall be furnished and installed by the Electrical Contractor as shown on the drawings.

C. Control interfaces and integration to the Building Management System or other control system shall be furnished and installed by the Controls Contractor.

1.04 References

A. Applicable Standards:

1. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE):
   a. ANSI/ASHRAE 70 – Method of Testing for Rating the Performance of Outlets and Inlets.
2. American Society for Testing Materials (ASTM):
   a. B117 – Standard Practice for Operating Salt Spray (Fog) Apparatus.
   b. C177 – Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus.
   c. C518 – Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus.
   d. D870 – Standard Practice for Testing Water Resistance of Coatings Using Water Immersion.
   e. D1622 – Standard Test Method for Apparent Density of Rigid Cellular Plastics.
   f. D2794 – Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact).
   g. E84 – Standard Test Method for Surface Burning Characteristics of Building Materials.
   h. E96 – Standard Test Method for Water Vapor Transmission of Materials.
3. National Fire Protection Association (NFPA):
   a. 90A – Installation of Air Conditioning and Ventilation Systems.
4. Underwriter's Laboratories (UL):
   a. 94 – Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.

1.05 Quality Assurance

A. All equipment and components shall be suitable for use in an Airway distribution system.

B. All components within the air stream including ceiling terminals shall conform to the NFPA 90A Standard with flame/smoke/fire contribution of 25/50/0.

C. All units shall be the product of a manufacturer regularly engaged in the production of Dual [Single] Airway ceiling-mounted air terminals and all supplied units shall be from the same manufacturer.

D. Units shall be specifically designed for a Dual [Single] Airway installation and complete with all necessary controls and wiring as required to provide operation according to manufacturer's recommendations.

E. Air terminal operation shall be coordinated with air-handling system and control system to assure complete compatibility.

F. Equipment shall be listed under and conform to appropriate sections of UL, CSA, ETL and other testing laboratory requirements.

1.06 Submittals

A. Submit dimensioned drawings, performance and product data for approval. Include listing of discharge and radiated sound power level for each of the second through sixth octaves for fan-power terminal units. Include a list of radiated NC level for all supply air terminals.

Guide Specifications *(continued)*

1.07 Operation and Maintenance Data

A. Quantity: [6].

B. Format: Minimum 8-1/2-inch by 11-inch loose leaf binder.

C. Content:

1. Maintenance and Service Contracts: Provide a list, with each product, name, address and telephone number of:
    a. Subcontractor or installer.
    b. Maintenance contractor, as appropriate.
    c. Identify area of responsibility of each.
    d. Local source of supply for parts and replacement.
2. Table of Contents: List all products in the order in which they appear in the specifications and label accordingly.
3. Sections: All sections shall be separated with an appropriate tabbed section divider with the appropriate specification section number. Provide the manufacturer's written installation and maintenance instructions for all items required.
4. Routine Maintenance: Provide a list indicating all routine maintenance procedures based on recommended intervals.
5. Contents: Include copies of approved submittal data, installation instructions, operation and maintenance instructions and parts lists.

1.08 Warranty

A. The air terminal materials and workmanship shall be guaranteed to be free from manufacturer's defects for a period of 18 months from the date of shipment.

PART 2 PRODUCTS

2.01 General Description

The Contractor shall furnish a Dual [Single] Airway air terminal system that includes all necessary components from a single manufacturer. All components including controls and wiring shall be furnished as a modular, plug-and-play system with interchangeable components that are factory-engineered to operate as a complete system.

2.02 Fabrication

A. General Requirements:

1. Panel Finish: The panel finish shall be white, anodic acrylic paint, baked at 315°F (157°C) for 30 minutes to an HB to H hardness. The paint must pass ASTM B117 Corrosive Environments Salt Spray Test without creepage, blistering or film deterioration; ASTM D870 Water Immersion Test; and ASTM D2794 Reverse Impact Cracking Test.
2. Air Terminal Finish: The face finish shall be white, anodic acrylic paint, baked at 315°F (157°C) for 30 minutes to an HB to H hardness. The paint must pass ASTM B117 Corrosive Environments Salt Spray Test without creepage, blistering or film deterioration; ASTM D870 Water Immersion Test; and ASTM D2794 Reverse Impact Cracking Test.
3. Materials of Construction: Terminal materials must meet NFPA 90A requirements for flame spread and smoke developed.
4. Panel Size: Unless noted otherwise, the nominal dimensions of all ceiling-mounted Airway system components shall be suitable for installation in a standard 24-inch by 24-inch (600-mm by 600-mm) ceiling suspension grid.
5. Airflow Performance: The manufacturer shall provide published airflow data for the all supply and return terminals in accordance with ANSI/ASHRAE Standard 70-1991.
6. Variable-Air-Volume Controls: Terminals specified for variable-air-volume service shall incorporate the following requirements:
    a. Terminal construction shall include an integral pulse-modulation damper and motor (air valve) that is specifically designed for low static pressure air distribution. The damper motor shall be a 90-degree stepper type motor having no stops, springs, gears, belts or linkages. The motor shall directly drive the damper blade. Modulation shall involve the timed duty cycle of fully open and closed periods to produce an average

open time corresponding to the average terminal air volume required.

b. Terminal shall include a microprocessor control that controls the damper movement in response to a remote open/close signal. The open/close signals and power shall be delivered to the device through a 4-conductor, plenum-rated modular cable. A “daisy-chain” output port shall be furnished that repeats the open/close signals with a nominal 6 second delay, and provides parallel connection of the 24 volts ac control power supply to other connected terminals. The modular cable input and output ports shall be interchangeable with no difference in operation occurring regardless of which port is used for input or output in a chain.

c. The damper and motor shall be designed for continuous use with a nominal design life of a 10,000,000 cycles or ten years. The installed damper and motor operation shall be silent and inaudible with a background sound level of 30 dbA. The unit shall feature all solid-state electronics, self-contained within the housing using printed circuit board mounted components with no relays, mechanical switches, or other mechanical devices required for operation of the device.

d. The terminal shall not require periodic lubrication or other maintenance. The device shall be delivered to the job site fully assembled and operational, needing no programming, setup or adjustment.

[*Edit the following equipment and material specifications to include only those items required for the specific project*]

B. **BFP-1** and **BFP-2**, Bypass Fan Panel
[*The Bypass Fan Panels provide relative humidity control in the Supply Airway and should be specified in all humid climates.*]

1. Bypass Fan Panels shall be factory-assembled units mounted on a one piece, die-stamped, 24 gauge, galvanized steel panel. Steel panel shall be designed for lay-in installation in the median ceiling and shall include independent mounting points for support from structure.
2. Fans shall be axial (propeller-type) fans, 10-inch (254 mm) diameter, with a die-cast aluminum housing, and ball bearings.
3. BFP-1: one fan, 400 cfm at 0.05 inches w.g. (189 L/sec at 12.4 Pa) total capacity.
4. BFP-2: two fans, 800 cfm at 0.05 inches w.g. (378 L/sec at 12.4 Pa) total capacity.
5. BFP-3: two fans, 800 cfm at 0.05 inches w.g. (378 L/sec at 12.4 Pa) total capacity.
6. BFP-1 fan motor: 1,650 RPM, 120 volts ac, single-phase, 60 hertz, with internal thermal protection.
7. BFP-2 fan motor: 1,650 RPM, 120 volts ac, single-phase, 60 hertz, with internal thermal protection.
8. BFP-3 fan motor: 1,650 RPM, [240 or 277] volts ac, single-phase, 60 hertz, with internal thermal protection.
9. Sound level: 52 PSIL or less.
10. Assembly shall include two standard double gang junction box for easy connection to building wiring system.
11. Each bypass fan assembly shall have a factory-wired control power supply installed in one of the junction boxes.
12. Control transformer: plenum rated, 90 volt-ampere capacity, input [120, 240, 277] volts ac, 3-wire, with ground, output 24 volts ac. Control transformer shall have the same input voltage as the bypass fan motor.
13. Transformer output connections: plug and play connector compatible with modular cable system.
14. Bypass fan panel assemblies shall be factory-wired so that field wiring connects to a single point serving both the fan motor and the control transformer.

C. **CRO-1**, Return Air Terminal

1. Unit shall be a single return terminal with a fixed grille and a sheet metal core.
2. Return Rating: 680 cfm at 0.02 inches w.g. negative (321 L/sec at 5 Pa negative).

Guide Specifications *(continued)*

3. Terminal face shall be constructed of extruded aluminum with a white finish on the exposed surfaces. The overall terminal height must be no greater than 14 inches (356 mm) and the return core must be easily detachable from the terminal face for installation. Each terminal shall include four ¼-inch (6 mm) holes for the installation of support wires if required by local code for independent support from the ceiling grid.

4. The unit return opening shall be fitted with a [perforated steel return air grille] or [metal egg grate grille with nominal ½-inch (13 mm) spacing] as indicated on the schedule. Grille material must meet NFPA 90A requirements for flame spread and smoke developed.

5. Return Air Core:

   a. Galvanized steel sheet metal, 20 gauge (minimum), lined.

   b. Liner: ¾ inch (19 mm) thickness, fiberglass, 6-pound density, with surface treatment to prevent release of fibers to the air stream. Liner surface shall be treated to inhibit microbial growth.

6. The return core shall include a mounting angle on all four sides to support and seal the median ceiling panels forming the return Airway space. When properly installed in accordance with the manufacturer's instructions, the terminals shall demonstrate a supply air to return air leakage rate no greater than 20 cfm at 0.05 inches w.g. (9.4 L/sec at 12.4 Pa) differential.

D. **CSO-1** and **CSO-2,** Supply Air Terminals, Constant-Volume

1. Unit shall be a supply air terminal designed for constant-volume air delivery. The unit shall have linear slot diffuser(s) for air supply.

2. CSO-1 Supply Rating: one-way throw, 150 cfm (maximum) at 0.05 inches w.g. (71 L/sec at 12.4 Pa). Sound Rating: below NC27.

3. CSO-2 Supply Rating: two-way throw, 300 cfm (maximum) at 0.05 inches w.g. (142 L/sec at 12.4 Pa). Sound Rating: below NC27.

4. Terminal face shall be constructed of extruded aluminum with a white finish on the exposed surfaces.

5. Terminal design shall provide a high induction, well-mixed, air pattern. Unit shall have provisions for adjusting the terminal flow in 50-cfm (24 L/sec) fixed increments using an optional damper. Airflow from terminal shall minimize soiling of ceiling surface from entrained room air. Conventional slot terminals shall not be acceptable.

6. When so designated, CSO supply terminals shall be furnished with a vertical-down supply throw pattern (CSO-1V and CSO-2V).

E. **CSO-3** and **CSO-4**, Supply Air Terminals, Constant-Volume

1. Unit shall be a supply air terminal designed for constant-volume air delivery and shall have a symmetrical diffuser.

2. CSO-3:

   a. Supply Rating: three-way throw, 300 cfm (maximum) at 0.05 inches w.g. (142 L/sec at 12.4 Pa).

   b. Unit shall be equipped with an internal baffle that converts the throw pattern to three-way or two-way.

3. CSO-4:

   a. Supply Rating: four-way throw, 300 cfm (maximum) at 0.05 inches w.g. (142 L/sec at 12.4 Pa).

4. Sound Rating: below NC27.

5. Terminal face panel and back pan shall be constructed of 22-gauge steel with a white painted finish. The back pan shall have rolled edges at the perimeter to provide an aerodynamically smooth surface to induce horizontal air movement. The face panel shall be flush within ¼ inch (6 mm) of the ceiling plane and shall be removable. The exposed surface of the face panel shall be free of visible fasteners.

6. Terminal design shall provide a high induction, well-mixed, air pattern. Airflow from terminal shall minimize soiling of ceiling surface from entrained room air.

7. Unit shall have provisions for adjusting the terminal flow in 50-cfm (24 L/sec) fixed increments using an optional damper.

F. **CSR-1** and **CSR-2**, Combination Supply and Return Terminals, Constant-Volume

1. Unit shall be a combination supply and return terminal designed for constant-volume air delivery. The unit shall have linear slot diffuser(s) for air supply and a fixed grille with a sheet metal core for air return.
2. CSR-1:
   a. Supply Rating: one-way throw, 150 cfm (maximum) at 0.05 inches w.g. (71 L/sec at 12.4 Pa)
   b. Return Rating: 400 cfm at 0.02 inches w.g. negative (189 L/sec at 5 Pa negative)
   c. Sound Rating: below NC27.
3. CSR-2:
   a. Supply Rating: two-way throw, 300 cfm (maximum) at 0.05 inches w.g. (142 L/sec at 12.4 Pa)
   b. Return Rating: 400 cfm at 0.02 inches w.g. negative (189 L/sec at 5 Pa negative)
   c. Sound Rating: below NC27.
4. Terminal face shall be constructed of extruded aluminum with a white finish on the exposed surfaces. The overall terminal height must be no greater than 14 inches (356 mm) and the return core must be easily detachable from the terminal face for installation. Each terminal shall include four ¼-inch (6-mm) holes for the installation of support wires if required by local code for independent support from the ceiling grid.
5. Terminal design shall provide a high induction, well-mixed, air pattern. Unit shall have provisions for adjusting the terminal flow in 50-cfm (24 L/sec) fixed increments using an optional damper. Airflow from supply terminals shall minimize soiling of ceiling surface from entrained room air. Conventional slot terminals shall not be acceptable.
6. The unit return opening shall be fitted with a [perforated steel return air grille] or [metal egg grate grille with nominal ½-inch (13-mm) spacing] as indicated on the schedule. Grille material must meet NFPA 90A requirements for flame spread and smoke developed.
7. Return Air Core:
   a. Galvanized steel sheet metal, 20 gauge (minimum), lined.
   b. Liner: ¾ inch thickness (19 mm), fiberglass, 6-pound density, with surface treatment to prevent release of fibers to the air stream. Liner surface shall be treated to inhibit microbial growth.
8. The return core shall include a mounting angle on all four sides to support and seal the median ceiling panels forming the return Airway space. When properly installed in accordance with the manufacturer’s instructions, the terminals shall demonstrate a supply air to return air leakage rate no greater than 20 cfm at 0.05 inches w.g. (9.4 L/sec at 12.4 Pa) differential.
9. When so designated, CSR supply terminals shall be furnished with a vertical-down supply throw pattern (CSR-1V and CSR-2V).

G. **EJB-1**, Electrical Junction Box Panel [*Required for electrical penetrations through the median ceiling*]

1. Electrical junction box panels (for penetrations through the median ceiling) shall be factory-assembled units consisting of a one piece, die-stamped, 24 gauge, steel panel with two, standard 4-inch by 4-inch (100-mm x 100-mm) electrical junction boxes.
2. Junction boxes shall be equipped with knockouts for conduit installation.
3. Assembly shall be designed for lay-in installation in the median ceiling and shall include independent mounting points for support from the building structure.

H. **EPS-1**, Electrical Power Supply [*Required with VAV terminal units, serves up to 14 terminals*]

1. Unit shall be a one piece, die-stamped, 24 gauge, galvanized steel panel designed for lay-in installation in the median ceiling and shall include independent mounting points for support from structure.
2. Control Transformer: plenum rated, 90 volt-ampere capacity, input [120, 240, 277] volts ac, 3-wire, with ground, output 24 volts ac.

Guide Specifications *(continued)*

3. Output connections: plug and play connector compatible with modular cable system.

I. **FTE-1**, Fan Terminal with Electric Heating Coil

1. Casing: Heavy-gauge galvanized steel sheet metal, insulated with mastic-faced rigid fiberglass.
2. Fan: Centrifugal, SWSI with narrow profile, galvanized steel fan wheel with forward curved blades, painted steel housing.
3. Fan Motor: single speed, direct connected, open drip-proof construction.
4. Power Supply: [120, 240, 277] volts, single-phase, 60 Hertz.
5. Control Power Transformer: 90 volt-ampere capacity, input [120, 240, 277] volts ac, 3-wire, with ground, output 24 volts ac, integral circuit breaker and thermal overload.
6. Fuses: mounted for external access and replacement.
7. Wiring: manufactured wiring system with armored cable, modular connector for positive disconnect, and the system voltage permanently marked on the connector.
8. Electrical Heating Element: two 0.75 kW, stainless steel sheathed elements (1.5 kW total), designed for three stages of heating (fan only, 0.75 kW and 1.5 kW).

J. **HCD-1** and **HCD-2**, Combination Heating (Ducted) and Cooling Supply and Return Terminal

1. Unit shall be a combination supply and return terminal designed for variable-air-volume delivery of cooling air and constant-volume delivery of heating air. Heating supply connection shall be ducted. The unit shall have linear slot diffuser(s) for air supply and a fixed grille with a sheet metal core for air return.
2. HCD-1 Cooling Supply Rating: one-way throw, 150 cfm (maximum) at 0.05 inches w.g. (71 L/sec at 12.4 Pa).
3. HCD-2 Cooling Supply Rating: two-way throw, 300 cfm (maximum) at 0.05 inches w.g. (142 L/sec at 12.4 Pa).
4. Return Rating: 400 cfm at 0.02 inches w.g. negative (189 L/sec at 5 Pa negative)
5. Heating Supply Rating: vertical-down throw, 150 cfm (71 L/sec) maximum, 75 cfm (35 L/sec) minimum.
6. Heating Supply Duct Connection: 5-inch (125 mm) round.
7. Terminal face shall be constructed of extruded aluminum with a white finish on the exposed surfaces. The overall terminal height must be no greater than 14 inches (356 mm) and the return core must be easily detachable from the terminal face for installation. Each terminal shall include four ¼-inch (6-mm) holes for the installation of support wires if required by local code for independent support from the ceiling grid.
8. Supply terminal design shall provide a high induction, well-mixed air pattern. Airflow from terminal shall minimize soiling of ceiling surface from entrained room air. Conventional slot terminals shall not be acceptable.
9. The unit return opening shall be fitted with a [perforated steel return air grille] or [metal egg grate grille with nominal ½-inch (13-mm) spacing] as indicated on the schedule. Grille material must meet NFPA 90A requirements for flame spread and smoke developed.
10. Return Air Core:
    a. Galvanized steel sheet metal, 20 gauge (minimum), lined.
    b. Liner: ¾ inch thickness (19 mm), fiberglass, 6-pound density, with surface treatment to prevent release of fibers to the air stream. Liner surface shall be treated to inhibit microbial growth.
11. The return core shall include a mounting angle on all four sides to support and seal the median ceiling panels forming the return Airway space. When properly installed in accordance with the manufacturer’s instructions, the terminals shall demonstrate a supply air to return air leakage rate no greater than 20 cfm at 0.05 inches w.g. (9.4 L/sec at 12.4 Pa) differential.

12. When so designated, HCD supply terminals shall be furnished with a vertical-down supply throw pattern (HCD-1EV, HCD-1PV, HCD-2EV and HCD-2PV).

K. **HCR-1** and **HCR-2**, Combination Heating and Cooling Supply and Return Terminal

1. Unit shall be a combination supply and return terminal designed for variable-air-volume delivery of cooling air and constant-volume delivery of heating air. The unit shall have linear slot diffuser(s) for air supply and a fixed grille with a sheet metal core for air return.
2. HCR-1 Cooling Supply Rating: one-way throw, 150 cfm (maximum) at 0.05 inches w.g. (71 L/sec at 12.4 Pa).
3. HCR-2 Cooling Supply Rating: two-way throw, 300 cfm (maximum) at 0.05 inches w.g. (142 L/sec at 12.4 Pa).
4. Return Rating: 400 cfm at 0.02 inches w.g. negative (189 L/sec at 5 Pa negative)
5. Heating Supply Rating: vertical-down throw, 150 cfm (71 L/sec) maximum, 75 cfm (35 L/sec) minimum.
6. Terminal face shall be constructed of extruded aluminum with a white finish on the exposed surfaces. The overall terminal height must be no greater than 14 inches (356 mm) and the return core must be easily detachable from the terminal face for installation. Each terminal shall include four ¼-inch (6-mm) holes for the installation of support wires if required by local code for independent support from the ceiling grid.
7. Supply terminal design shall provide a high induction, well-mixed air pattern. Airflow from terminal shall minimize soiling of ceiling surface from entrained room air. Conventional slot terminals shall not be acceptable.
8. The unit return opening shall be fitted with a [perforated steel return air grille] or [metal egg grate grille with nominal ½-inch (13-mm) spacing] as indicated on the schedule. Grille material must meet NFPA 90A requirements for flame spread and smoke developed.
9. Return Air Core:
   a. Galvanized steel sheet metal, 20 gauge (minimum), lined.
   b. Liner: ¾ inch thickness (19 mm), fiberglass, 6-pound density, with surface treatment to prevent release of fibers to the air stream. Liner surface shall be treated to inhibit microbial growth.
10. The return core shall include a mounting angle on all four sides to support and seal the median ceiling panels forming the return Airway space. When properly installed in accordance with the manufacturer's instructions, the terminals shall demonstrate a supply air to return air leakage rate no greater than 20 cfm at 0.05 inches w.g. (9.4 L/sec at 12.4 Pa) differential.
11. When so designated, HCR supply terminals shall be furnished with a vertical-down supply throw pattern (HCR-1EV, HCR-1PV, HCR-2EV and HCR-2PV).

L. **HCS-1**, Heating and Cooling Switch

1. Heating and cooling switch shall monitor the supply Airway temperature and provide automatic reversal of the control response in variable-air-volume supply air terminals.
2. Operating temperature range: 45°F to 120°F (7.2°C to 48.9°C).
3. Electric power supply: 24 volts ac, single-phase, 60 hertz.
4. Electrical connections: modular.

M. **HSD-1V,** Supply Air Terminals, Heating Only, Ducted, Constant-Volume

1. Unit shall be a heating-only supply air terminal designed for constant-volume air delivery. The heating supply connection shall be ducted. The unit shall have a linear slot diffuser designed for vertical-down throw.
2. Heating Supply Rating: one-way, vertical-down throw, 150 cfm at 0.05 inches w.g. (71 L/sec at 12.4 Pa) maximum, 75 cfm at 0.05 inches w.g. (35 L/sec at 12.4 Pa) minimum.
3. Sound Rating: below NC27.

Guide Specifications *(continued)*

4. Heating Supply Duct Connection: 5-inch (125 mm) round.
5. Terminal face shall be constructed of extruded aluminum with a white finish on the exposed surfaces.

N. **IBX-1**, Pressure Controller

1. IBX-1 shall be a single-function static pressure controller for the supply Airway space. The unit shall be packaged in a return air terminal.
   a. Set point: factory calibrated and set for 0.05 inches w.g. (12.4 Pa) operating pressure.
   b. External communications: none.
   c. Output signal: 0-10 volts dc. Also equipped with staging relays for up to 6 incremental control steps to maintain set point pressure.
   d. Remote alarm contacts: for remote indication of: 1) pressure below set point, 2) pressure at set point, or 3) pressure above set point.
   e. Local Indicator: for pressure and pressure set point indication, 7-segment LCD display, indicates pressure in hundredths of an inch (0.00 to 0.09 inches).
   f. Input power supply: 24 volts ac, single-phase, 60 hertz.
   g. Accessories: none.
2. Unit shall be a single return terminal with a fixed grille and a sheet metal core.
3. Return Rating: 400 cfm at 0.02 inches w.g. negative (189 L/sec at 5 Pa negative)
4. Terminal face shall be constructed of extruded aluminum with a white finish on the exposed surfaces. The overall terminal height must be no greater than 14 inches (356 mm) and the return core must be easily detachable from the terminal face for installation. Each terminal shall include four ¼-inch (6-mm) holes for the installation of support wires if required by local code for independent support from the ceiling grid.
5. The unit return opening shall be fitted with a [perforated steel return air grille] or [metal egg grate grille with nominal ½-inch (13-mm) spacing] as indicated on the schedule. Grille material must meet NFPA 90A requirements for flame spread and smoke developed.
6. Return Air Core:
   a. Galvanized steel sheet metal, 20 gauge (minimum), lined.
   b. Liner: ¾ inch (19 mm) thickness, fiberglass, 6-pound density, with surface treatment to prevent release of fibers to the air stream. Liner surface shall be treated to inhibit microbial growth.
7. The return core shall include a mounting angle on all four sides to support and seal the median ceiling panels forming the return Airway space. When properly installed in accordance with the manufacturer's instructions, the terminals shall demonstrate a supply air to return air leakage rate no greater than 20 cfm at 0.05 inches w.g. (9.4 L/sec at 12.4 Pa) differential.

O. **IBX-2,** Communications Interface

1. IBX-2 shall be a communications interface between the building automation system and the systems AirSwitches.
   a. Set point: none.
   b. External communications: Modbus RTU communications. Unit shall also be designed for network communication with up to 63 TCD-1 AirSwitches.
   c. Output signal: none.
   d. Monitoring points: none.
   e. Input power supply: 24 volts ac, single-phase, 60 hertz.

P. **IBX-3**, Communications Interface

1. IBX-3 shall be a communications interface (only) between the building automation system and the system's AirSwitches.
   a. Set point: none.
   b. External communications: BACNET communications. Unit shall also be designed for network communication with up to 63 TCD-1 AirSwitches.
   c. Output signal: none.
   d. Monitoring points: none.

e. Input power supply: 24 volts ac, single-phase, 60 hertz.

Q. **IBX-4**, Communications Interface

1. IBX-4 shall be a communications interface (only) between the building automation system and the system's AirSwitches.

a. Set point: none.

b. External communications: Serial ASCII communications. Unit shall also be designed for network communication with up to 63 TCD-1 AirSwitches.

c. Output signal: none.

d. Monitoring points: none.

e. Control power supply: 24 volts ac, single-phase, 60 hertz.

R. **MFT-B**, fan-powered, electric/hydronic heating unit, 300 cfm (142 L/sec)
[*See York Guide Specification Form 130.15-GS2 (101), Flexsys Underfloor Air System*]

S. **MFT-C**, fan-powered, electric/hydronic heating unit, 600 cfm (284 L/sec)
[*See York Guide Specification Form 130.15-GS2 (101), Flexsys Underfloor Air System*]

T. Modular Control System Cables: [*These items may be included in Division 16, but will require coordination between the Mechanical Contractor and the Electrical Contractor.*] All modular control cables shall be rated for plenum service and shall be equipped (unless indicated otherwise) with modular plug-and-play electrical connectors. All cables shall be factory-tested for continuity, shorts, opens and proper impedance.

1. **PAP-1**, General purpose cable: 4-conductor, 18-gauge, 25 feet (7.6 m) long, with receptacles at both ends. Identification color: blue.

2. **PAP-2**, External device (whip) cable: 4 conductor, 18 gauge, 50 feet (15.2 m.) long, with modular receptacle on one end and pig tail on the other. Identification color: yellow.

3. **PAP-3**, Extension cable: 4-conductor, 18-gauge, 25 feet (7.6 m) long, with modular receptacle on one end and plug on the other end. Identification color: blue.

4. **PAP-5**, Power only cable: 2-conductor, 18-gauge, 25 feet (7.6 m.) long, with receptacles at both ends. One end shall have an additional short extension with a plug to permit daisy-chaining one power distribution cable to another. For 24 volts ac, single-phase, 60 hertz power only. Identification color: green.

5. **PAP-6**, Jumper cable: 4 conductor, 18-gauge, 2 feet (0.6 m.) long, with modular receptacles at both ends. One end shall have an additional short extension with a plug. Identification color: black.

6. **PAP-7**, Heating and cooling cable: 3 twisted pairs, 22-gauge shielded, 30 feet (9.1 m.) long, with modular receptacle on one end, and a single receptacle and two plugs on the other end. Identification color: white.

U. **RAP-1**, Return Air Passage

1. Return Air Passages shall be designed for sprinkler pipes, conduits and other small penetrations of the supply Airway space. Passages shall be of the types shown on the plans and/or device schedule. Passages must provide an airtight, easily sealed opening from the return Airway space through the supply Airway space to the aesthetic ceiling plane in a single factory-assembled unit.

2. When properly installed in accordance with the manufacturer's instructions, the terminals shall demonstrate a supply air to return air leakage rate no greater than 1.5 cfm at 0.05 inches w.g. (0.7 L/sec at 12.4 Pa) differential.

3. Main body of passage shall have a nominal 4-inch (100-mm) diameter and shall be formed from 26 gauge galvanized steel.

4. The passage exterior shall be insulated with closed cell, plenum rated insulation. Insulation shall meet NFPA 90A requirements of 25/50 for flame spread and smoke developed per ASTM E84.

a. Insulation thickness: ¾ inches (19 mm)

b. Thermal conductivity: 0.25 Btu-in/hr-ft^2-°F (0.036 watts/m-°K) at 75°F (24°C) as tested by ASTM C177 or C518.

Guide Specifications *(continued)*

c. Water vapor transmission: not more than 0.02 perm in ($2.9x10^{-14}$ kg/sec-m-Pa) as tested under ASTM E96.

d. Insulation density: 2 lbs/ft^3 (32 kg/m^3) per ASTM D1622.

e. Temperature limits: 32°F to 200°F (0°C to 93°C).

V. **SAB-1** and **SAB-2**, Supply Airway Barrier

1. Designed for installation in the supply Airway space, attaching to the median ceiling and aesthetic ceiling support grids.
2. Nominal dimensions: 12 inches by 48 inches (300 mm by 1200 mm).
3. Panel: heavy-gauge, galvanized steel sheet metal.
4. Insulation (model SAB-2 only): ¾ inch (19 mm) thickness, fiberglass, 6-pound density, with surface treatment to prevent release of fibers to the air stream.

W. **TCD-1**, AirSwitch™, Heating and Cooling Space Thermostat for Pulse-Modulation Control
[*Required when using pulse-modulation controlled terminals and network communications. Provides local control and display, and remote set point adjustment and monitoring.*]

1. TCD-1 AirSwitch shall be a wall-mounted heating and cooling thermostat device.
2. Enclosure: plastic, in accordance with UL 94. Enclosure shall be suitable for mounting on a single gang electrical box in either the horizontal or vertical orientation.
3. Wiring connections: modular.
4. Adjustment: push button (higher and lower)
5. Display: LCD display of set point and space temperature.
6. Set point range: 55°F to 90°F (12.8°C to 32.2°C).
7. Device shall provide 64 network addresses using an integral DIP switch, and use an RS-485 network to provide remote connection to an area controller or communications device. Network protocol and voltages shall be compatible with plug-and-play modular wiring and shall be resistant to tampering by others. Unit shall operate as a stand-alone unit or as part of a proprietary area network compatible with the IBX-2, IBX-3 and IBX-4 units.
8. Device shall provide proportional and pulse modulation control to enable control of fan terminal units and supply terminals.
9. Device shall have self-test capability.
10. Device shall comply with FCC Part 15, NEC Class 2, and be listed by UL.
11. Color: white.

W. **TCD-2**, AirSwitch™, Cooling Only Space Thermostat for Pulse-Modulation Control
[*Required when using pulse-modulation controlled terminals and network communications. Provides local control and display.*]

1. TCD-2 AirSwitch shall be a wall-mounted cooling only thermostat device.
2. Enclosure: plastic, in accordance with UL 94. Enclosure shall be suitable for mounting on a single gang electrical box in either the horizontal or vertical orientation.
3. Wiring connections: modular.
4. Adjustment: push button (higher and lower)
5. Display: LCD display of set point and space temperature.
6. Set point range: 55°F to 90°F (12.8°C to 32.2°C).
7. The operating voltages shall be compatible with plug-and-play modular wiring and shall be resistant to tampering by others. Unit shall operate as a stand-alone unit.
8. Device shall have self-test capability.
9. Unit shall comply with FCC Part 15, NEC Class 2, and be listed by UL.
10. Color: white.

X. **TCD-3**, ComfortSwitch™, Space Thermostat, Cooling Only
[*Provides local only set point adjustment, no temperature or set point display and no remote monitoring.*]

1. Enclosure: none. Unit shall be suitable for mounting on a single gang electrical box in either the horizontal or vertical orientation. Front thermostat cover shall be a standard electrical light switch cover.
2. Device shall use an NTC thermistor with low drift and have compatible output/input with modular control wiring terminals. Unit shall provide cooler-warmer control of pulse-modulation air terminals.
3. Unit shall comply with FCC Part 15, NEC Class 2, and be listed by UL.
4. Wiring connections: modular.
5. Adjustment: rotary knob.
6. Device shall have self-test capability.

Y. **TCD-4**, ComfortSwitch™, Space Thermostat, Cooling and Heating
[*Provides local only set point adjustment, no temperature or set point display and no remote monitoring.*]

1. Enclosure: none. Unit shall be suitable for mounting on a single gang electrical box in either the horizontal or vertical orientation. Front thermostat cover shall be a standard electrical light switch cover.
2. Device shall use an NTC thermistor with low drift and have compatible output/input with modular control wiring terminals. Unit shall provide cooler-warmer control of pulse-modulation air terminals.
3. Unit shall comply with FCC Part 15, NEC Class 2, and be listed by UL.
4. Wiring connections: modular.
5. Adjustment: rotary knob.
6. Device shall have self-test capability.
7. Device shall be furnished with an Airway space temperature sensing cable for operation with a switchover system.

Z. **VSO-1** and **VSO-2**, Supply Air Terminals, Variable-Air-Volume

1. Unit shall be a supply terminal with linear slot diffuser(s) designed for variable-air-volume delivery.
2. VSO-1 Supply Rating: one-way throw, 150 cfm (maximum) at 0.05 inches w.g. (71 L/sec at 12.4 Pa). Sound Rating: below NC27.
3. VSO-2 Supply Rating: two-way throw, 300 cfm (maximum) at 0.05 inches w.g. (142 L/sec at 12.4 Pa). Sound Rating: below NC27.
4. Terminal face shall be constructed of extruded aluminum with a white finish on the exposed surfaces.
5. Terminal design shall provide a high induction, well-mixed, air pattern. Airflow from terminal shall minimize soiling of ceiling surface from entrained room air. Conventional slot terminals shall not be acceptable.
6. When so designated, VSO supply terminals shall be furnished with a vertical-down supply throw pattern (VSO-1V and VSO-2V).

AA. **VSO-3** and **VSO-4**, Supply Air Terminals, Variable-Air-Volume

1. Unit shall be a supply air terminal designed for variable-air-volume air delivery and shall have a symmetrical diffuser.
2. VSO-3:
   a. Supply Rating: three-way throw, 300 cfm (maximum) at 0.05 inches w.g. (142 L/sec at 12.4 Pa).
   b. Unit shall be equipped with an internal baffle that converts the throw pattern to three-way or two-way.
3. VSO-4:
   a. Supply Rating: four-way throw, 300 cfm (maximum) at 0.05 inches w.g. (142 L/sec at 12.4 Pa).
4. Sound Rating: below NC27.
5. Terminal face panel and back pan shall be constructed of 22-gauge steel with a white painted finish. The back pan shall have rolled edges at the perimeter to provide an aerodynamically smooth surface to induce horizontal air movement. The face panel shall be flush within ¼ inch (6 mm) of the ceiling plane and shall be removable. The exposed surface of the face panel shall be free of visible fasteners.

Guide Specifications *(continued)*

6. Terminal design shall provide a high induction, well-mixed, air pattern. Airflow from terminal shall minimize soiling of ceiling surface from entrained room air.

AB. **VSR-1** and **VSR-2**, Combination Supply and Return Terminals, Variable-Air-Volume

1. Unit shall be a combination supply and return terminal designed for variable-air-volume delivery. The unit shall have linear slot diffuser(s) for air supply and a fixed grille with a sheet metal core for air return.
2. VSR-1:
   a. Supply Rating: one-way throw, 150 cfm (maximum) at 0.05 inches w.g. (71 L/sec at 12.4 Pa)
   b. Return Rating: 400 cfm at 0.02 inches w.g. negative (189 L/sec at 5 Pa negative)
   c. Sound Rating: below NC27.
3. VSR-2:
   a. Supply Rating: two-way throw, 300 cfm (maximum) at 0.05 inches w.g. (142 L/sec at 12.4 Pa)
   b. Return Rating: 400 cfm at 0.02 inches w.g. negative (189 L/sec at 5 Pa negative)
   c. Sound Rating: below NC27.
4. Terminal face shall be constructed of extruded aluminum with a white finish on the exposed surfaces. The overall terminal height must be no greater than 14 inches (356 mm) and the return core must be easily detachable from the terminal face for installation. Each terminal shall include four ¼-inch (6-mm) holes for the installation of support wires if required by local code for independent support from the ceiling grid.
5. Terminal design shall provide a high induction, well-mixed, air pattern. Airflow from terminal shall minimize soiling of ceiling surface from entrained room air. Conventional slot terminals shall not be acceptable.
6. The unit return opening shall be fitted with a [perforated steel return air grille] or [metal egg grate grille with nominal ½-inch (13-mm) spacing] as indicated on the schedule. Grille material must meet NFPA 90A requirements for flame spread and smoke developed.
7. Return Air Core:
   a. Galvanized steel sheet metal, 20 gauge (minimum), lined.
   b. Liner: ¾ inch thickness (19 mm), fiberglass, 6-pound density, with surface treatment to prevent release of fibers to the air stream. Liner surface shall be treated to inhibit microbial growth.
8. The return core shall include a mounting angle on all four sides to support and seal the median ceiling panels forming the return Airway space. When properly installed in accordance with the manufacturer's instructions, the terminals shall demonstrate a supply air to return air leakage rate no greater than 20 cfm at 0.05 inches w.g. (9.4 L/sec at 12.4 Pa) differential.
9. When so designated, VSR supply terminals shall be furnished with a vertical-down supply throw pattern (VSR-1V and VSR-2V).

Section 15900 - Controls and Instrumentation

Dual Airway and Single Airway system controls should be specified as integral with the system. Only controls furnished by the manufacturer should be accepted for this portion of the system.

Specific items should be specified and scheduled on the drawings:

- **TCD-1** and **TCD-2** AirSwitches (Digital thermostats that communicate and display the temperature/set point)
- **TCD-3** and **TCD-4** ComfortSwitches (thermostat that has a set point knob – warmer/cooler only and provides cooler-warmer control of PM air terminals)
- **PAP-1** through **PAP-7** modular control cabling
- **EPS-1** Power supply
- **HCS-1** Heating and cooling switch
- **IBX-1** Pressure controller
- **IBX-2** BAS interface

- **IBX-3** BAS interface
- **IBX-4** BAS Interface

DIVISION 16 – ELECTRICAL SPECIFICATIONS

There are a number of sections within Division 16 that should address the use of a Dual or Single Airway System and associated pulse-modulated air distribution controls:

16020 – Work Included
16021 - Work Not Included
16111 – Conduits
16120 – Wires and Cables
16130 – Outlet Boxes
16510 – Interior Lighting Fixtures

Section 16020 – Work Included

This section should include reference to the pressure and leakage testing of Dual or Single Airway spaces and the Electrical Contractor's responsibility to support the testing. The Electrical Contractor should be responsible for sealing and or repairing any holes or openings made in the Airway spaces for items installed by the Electrical Contractor.

It is important that ceiling-mounted lighting fixtures be furnished and installed that do not leak excessively. Providing appropriate fixtures must be the responsibility of the Electrical Contractor.

The Electrical Contractor must be responsible to route and install conduits and raceways to minimize penetrations to the Airway spaces if no details or information is included on the drawings.

Section 16021 – Work Not Included

This section should clarify that the median and aesthetic ceilings are furnished and installed by others; however, the Electrical Contractor is responsible for installing and testing specific equipment in the Airway system as described in other sections.

Section 16111 – Conduits

The Electrical Contractor should be advised in this section to avoid any unnecessary penetrations of the Airway spaces. In addition, all open conduits stubbed into the supply Airway space conduit shall have the open ends sealed. All conduit penetrations to the median and aesthetic ceilings shall be caulked and sealed. Damages to the median ceiling, aesthetic ceiling or to walls during installation of conduit shall be repaired at the Electrical Contractor's expense.

Section 16120 – Wires and Cables

The Electrical Contractor should be cautioned to use only plenum rated cables supplied by the Airway components manufacturer. This section should reference the modular cables furnished under Section 15872 - Airway Air Distribution System.

Section 16130 – Outlet Boxes

Specifications for electrical junction box panel EJB-1 provided under Section 15872 - Airway Air Distribution System should be referenced in this section, and described as an acceptable means of penetrating the median ceiling with circuits to light fixtures and other electric devices.

Section 16510 – Interior Lighting Fixtures

All specifications for ceiling-mounted light fixtures installed in the aesthetic ceiling shall include instructions that the lighting fixtures shall be sealed similar to "Chicago Plenum Construction" to limit airflow through the fixture to a maximum rate. For 24-inch by 24-inch (600-mm x 600-mm) fixtures, the maximum leakage rate should be 5 cfm (2.4 L/sec). For 24-inch by 48-inch (600-mm x 1200-mm) fixtures the maximum leakage rate should be 10 cfm (4.7 L/sec). Each fixture should have a rating for leakage, or be tested by the Electrical Contractor or by AirFixture LLC, and then have a leakage rate from the test submitted in writing. Recessed can fixtures should leak not more than 5 cfm (2.4 L/sec) each. Fixtures that do not meet air leakage rates should be rejected, repaired or replaced.

Form 130.30-EG1 (704)
Supercedes: Nothing