CHILLED BEAMS

price | BEAMS

FROM CONSTRUCTION TO COMISSIONING

Proper construction methods of ductwork, selection, and balancing with chilled beams

INTRODUCTION TO CHILLED BEAM DUCTWORK AND DESIGN

Why is it important?

The goal of this document is to highlight best practices in design and construction of a chilled beam system. First, it is important to understand the pressures associated with the chilled beams and the system. With the system pressure, it is crucial in identifying areas in the duct work for potential leakage. Related to this, duct conditions at the air inlet should also be given consideration. Taking all of these factors into account will tie into beam and auxiliary product selections and finally balancing and commissioning.

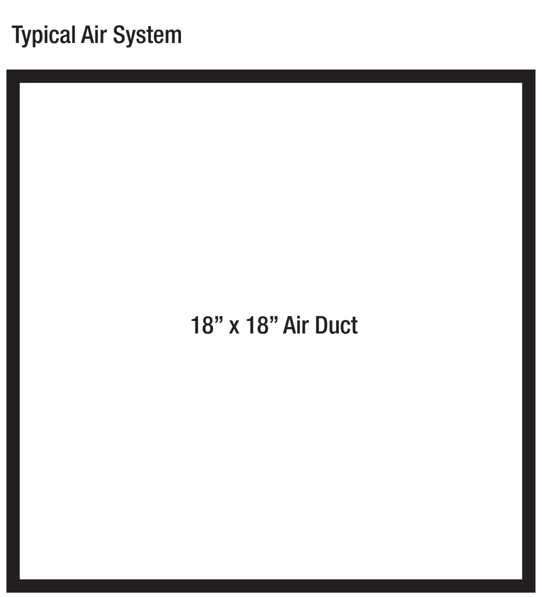
The goal of the chilled beams technology is to move the energy required to maintain a comfortable space condition from the air side (air handler) to the water side (chiller or boiler).

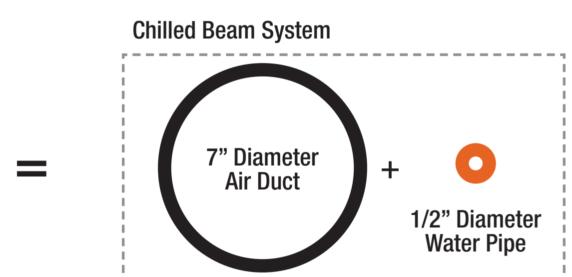
This means reducing the amount of primary air typically needed to meet space heating and cooling requirements by all air systems. Typical all air systems need about 1.0-1.5 CFM / sq. ft.

In contrast, with the chilled beam, the volume of air needed can be reduced to as low as 0.2 CFM/sq.ft as the water side handles a significant amount of the load.

Reduced primary air means reductions in air handler size, fan energy consumption, and ductwork size as shown in Figure 1 below. This leads to energy savings throughout the life cycle of the HVAC system.

HEAT TRANSFER: AIR VS. WATER





Comparison Highlights

- 1lb water at 6°F Δt transports **4x more sensible cooling than 1lb air at 20°F Δt**
- **Duct height reduced by 60%** (18" square duct compared to 7" round duct
- Cross-sectional **area reduced by 85%**
- **Material cost** per foot **reduced by 75%**

Figure 1

Figure 2

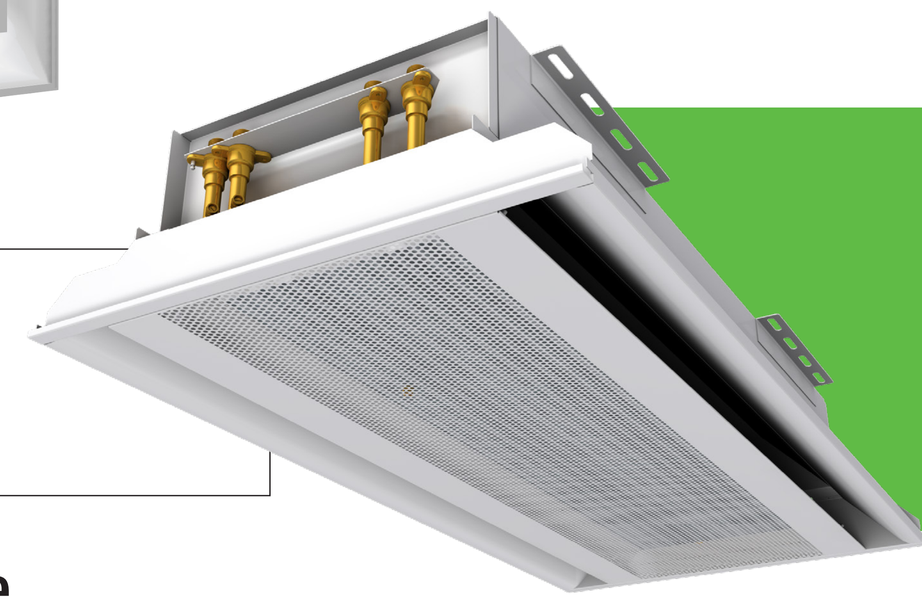
Example:

Consider a cooling load of approx. 8500 BTUH.

Example selections for the two products can be seen below.

SQUARE PLAQUE DIFFUSER

(24" x 24", 12" inlet)
Needs 0.029" in. wg. @ 400 CFM



LINEAR CHILLED BEAM

6ft Size 607 Nozzle
Needs 0.63" in wg@140 CFM

Figure 2

Impact on Air Leakage

Equation for leakage through orifice:

$$Q_L = K A_L \sqrt{p_{duct}}$$

$$\frac{\cancel{K A_L} \sqrt{p_{duct}}}{\cancel{K A_L} \sqrt{p_{duct}}} = \frac{\sqrt{0.63}}{\sqrt{0.029}} \approx \text{4x more leakage}$$

When taking a ratio of the two leakage rates comparing square roots of the pressures, as shown above, the chilled beam system may leak more than 4x the amount of the diffuser system in this scenario. So, if the ductwork leaks 10 CFM for the square plaque diffuser, this is only a 2.5% deficit, whereas the chilled beam may see 40 CFM leakage, which leads to a 21% deficit in airflow.

Air leakage can have a greater effect on the performance of a chilled beam then it would for a square plaque diffuser.

DUCTWORK CONSTRUCTION

Pressure and Leakage Classifications

PRESSURE

Beam Pressure:
This is the static pressure internal to a chilled beam's plenum, typically ranging between 0.2 to 0.8 in. wg.

Duct Pressure:
This is the pressure internal to the ductwork, upstream of the chilled beam or terminal unit. This pressure range can vary depending on the quantity of terminal devices that will be fed air along a branch of ductwork.

As shown in the Figure 2 example, the operating pressures for a chilled beam system ductwork are typically higher than conventional all air systems. These conventional air systems can be be considered low pressure pressure systems while chilled beam system ductwork pressures should be considered a hybrid between low and medium pressure systems.

With higher pressures generated at the beam and needed in the ductwork, the potential for leakage is higher.

LEAKAGE

ASHRAE and SMACNA standards classify duct sealing standards into three classes:

Class A - All transverse joints and longitudinal seams and duct wall penetrations shall be sealed. Pressure sensitive tape shall not be used as primary sealant. Max. 2 to 5 percent total system leakage.

Class B - All transverse joints and longitudinal seams shall be sealed. Pressure sensitive tape shall not be used as primary sealant. Max. 3 to 10 percent total system leakage.

Class C - All transverse joints shall be sealed. Max. 5 to 20 percent total system leakage.

Unsealed - 10 to 40 percent total system leakage.

It is recommended that chilled beams and their respective ductwork are sealed to Class A and aiming for as low as 2 percent total system leakage, especially when knowing the impact of leakage can be higher with chilled beams.

Refer to figure 3 for examples of the various different ductwork surfaces.

Performance Impact of Leakage

As previously stated, chilled beam ductwork need to be adequately sealed for all leakage points, covered by Class A.

To help understand the impacts of each leakage class, this example shows the performance a chilled beam with the allowable leakage in each class compared to a baseline of no leakage. The zone parameters are shown on the right hand side. Water flow rates were kept constant.

Building Conditions							
Room Conditions Cooling		Primary Air Conditions Cooling		Entering Water Cooling			
Dry Bulb °F	**75.0 °F**	Dry Bulb °F	**55.0 °F**	Temperature °F		**57.0 °F**	
Relative Humidity %RH	**50%**	Wet Bulb °F	**51.6%**	Fluid Type	**Water**	Percent	**N/A**
Room Conditions Heating		Primary Air Conditions Heating		Entering Water Heating			
Dry Bulb °F	**72.0 °F**	Dry Bulb °F	**55.0 °F**	Temperature °F		**130.0 °F**	
Relative Humidity %RH	**50%**	Wet Bulb °F	**51.6%**	Fluid Type	**Water**	Percent	**N/A**

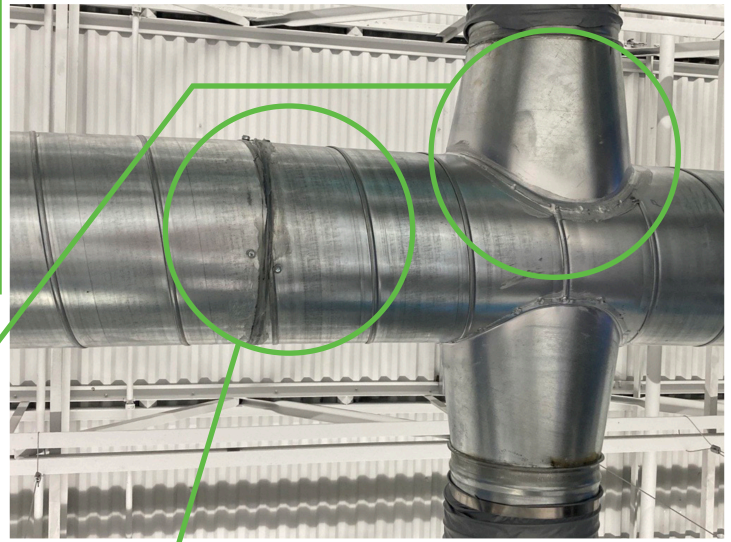
Room or Zone Number / Name	Model	Coil Type	Primary Air Flow	Primary Air Pressure	Nozzle Code	Sound Level	Cooling: Chilled Water	Cooling: Cooling Water Pressure	Cooling: Total Sensible	Heating: Hot Water	Heating: Heating Water Pressure	Heating: Total Sensible
			CFM	in WG		NC	GPM	ft W.G.	BTUH	GPM	ft W.G.	BTUH
ACBL - No Leakage	ACBL_24_2W	2P1C	100	0.52	506	22	1	3.5	6056	0.5	1	7958
ACBL - Class A - 5% Leakage	ACBL_24_2W	2P1C	95	0.47	506	21	1	3.5	5836	0.5	1	7810
ACBL - Class B - 10% Leakage	ACBL_24_2W	2P1C	90	0.43	506	19	1	3.5	5614	0.5	1	7650
ACBL - Class C - 20% Leakage	ACBL_24_2W	2P1C	80	0.34	506	16	1	3.5	5156	0.5	1	7301
ACBL - Unsealed - 40% Leakage	ACBL_24_2W	2P1C	60	0.20	506	<15	1	3.5	4185	0.5	1	6440

Figure 4

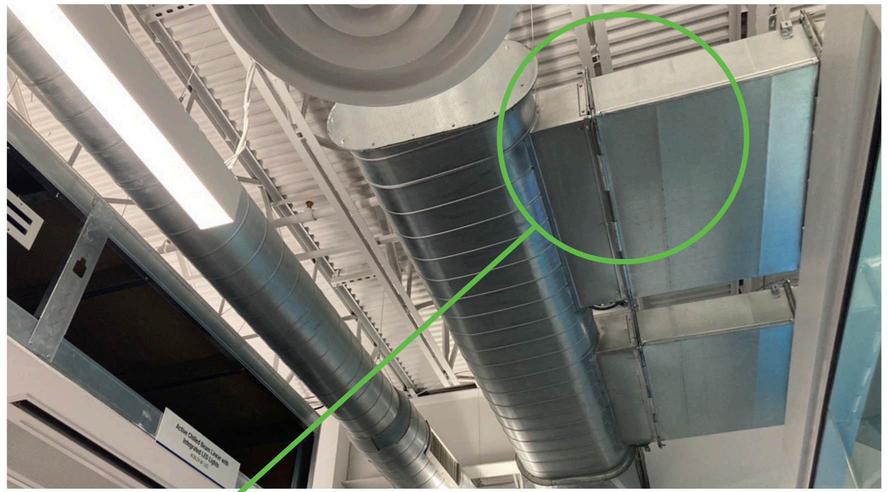
As shown above, leakage in the ductwork air CFM can affect the affect the performance on a chilled beam. Even a 5% loss in airflow can have a 10% impact on static pressure. In the worst case scenario of 40% leakage, there is a 62% drop in static pressure and 31% drop in sensible cooling capacity (reference highlights above in Figure 4). This swing in performance can affect setpoint and comfort in the space.

DUCTWORK CONSTRUCTION

Duct Classifications

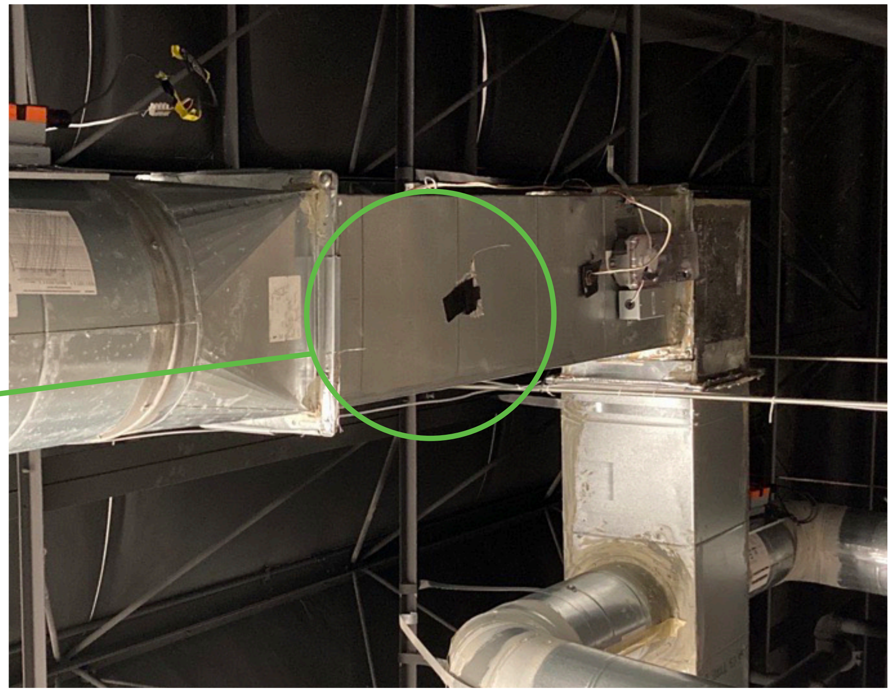


TRANSVERSE CONNECTION



LONGITUDINAL SEAM

DUCT WALL PENETRATIONS



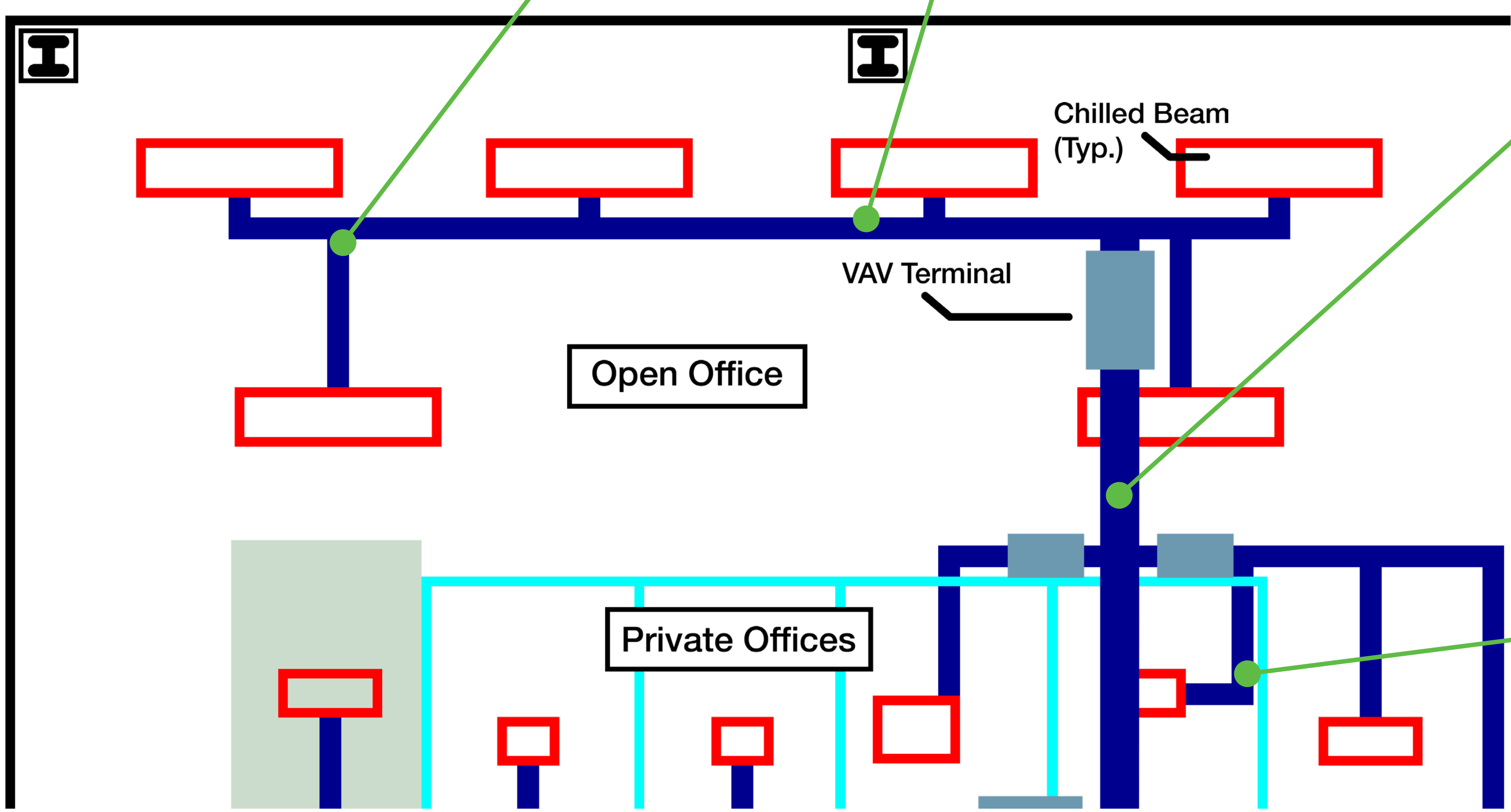


Figure 3

DUCTWORK CONSTRUCTION

Inlet Conditions

There are essentially two different types of duct shown below in Figure 5. Each of these duct types have respective properties that can affect the outcome of a chilled beam systems designs. Flex duct is known to have a wide range of pressure drop due to its ability to compress.

It is recommended for both hard and flex duct to be given adequate, straight runs into the inlet of a chilled beam, typically 3-5 duct diameters. Once the flex duct is fully extended, the impact of pressure drop in the system can be minimized. As shown on the right, the inlet conditions of the duct can affect the outcome of pressure and airflow in the system.

When the ductwork is kept straight with at least 3 duct diameters (3D) for both flex duct and hard duct, the pressure drop between the ductwork and the chilled beam is kept minimal. When the duct is curved or kinked as in figure C, the pressure drop increases dramatically between the ductwork and the beam.

Figure 5

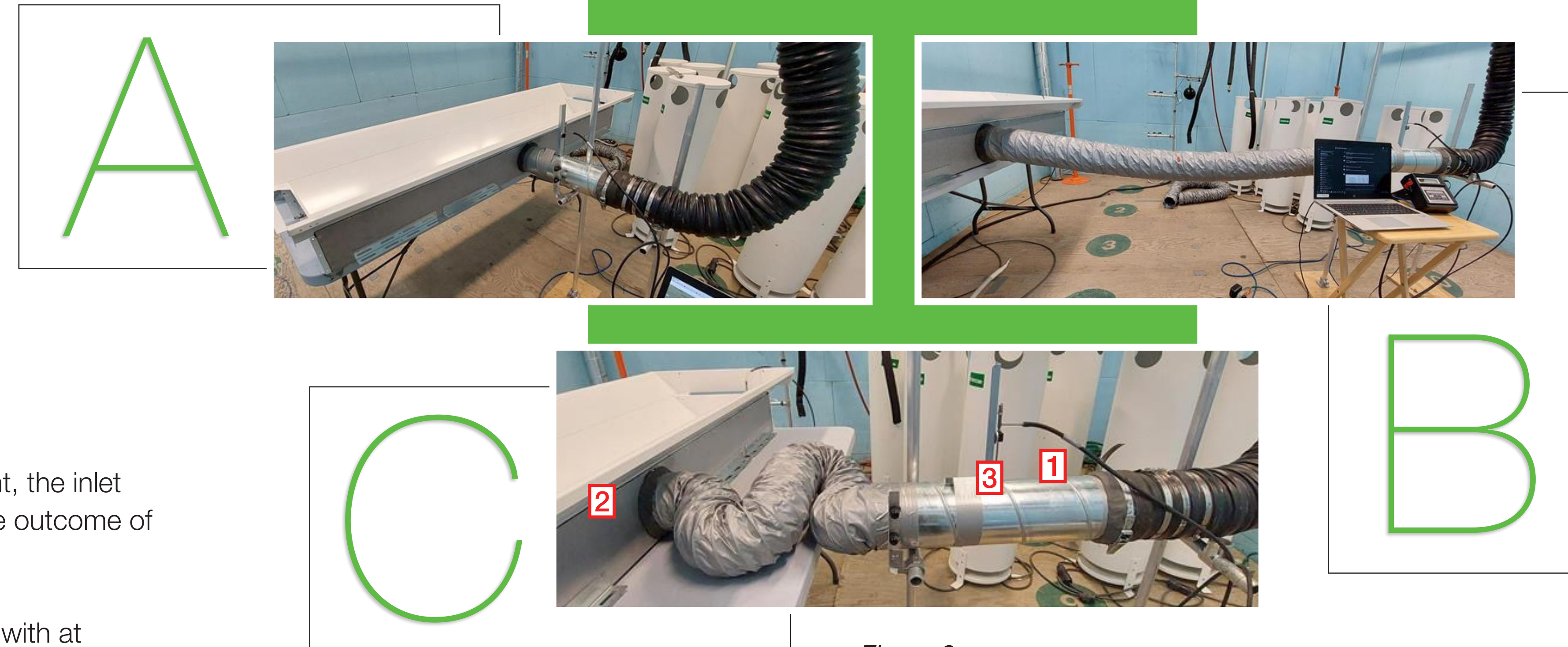


Figure 6

6ft Beam Maintaining Constant Duct Pressure				
Inlet Condition	Airflow SCFM	System Static Pressure in. wg. 1	Beam Static Pressure in. wg. 2	Duct Pressure Change in. wg. 3
A. Straight Hard Duct 3D	106.0	0.53	0.51	0.02
B. 6ft Straight Flex Duct	103.9	0.53	0.48	0.05
C. 6ft 'S' Curve Flex Duct	65.5	0.53	0.20	0.33

Table 1A

6ft Beam Maintaining Constant Airflow				
Inlet Condition	Airflow SCFM	System Static Pressure in. wg. 1	Beam Static Pressure in. wg. 2	Duct Pressure Change in. wg. 3
A. Straight Hard Duct 3D	106.0	0.53	0.51	0.02
B. 6ft Straight Flex Duct	106.0	0.55	0.50	0.05
C. 6ft 'S' Curve Flex Duct	106.0	1.32	0.49	0.83

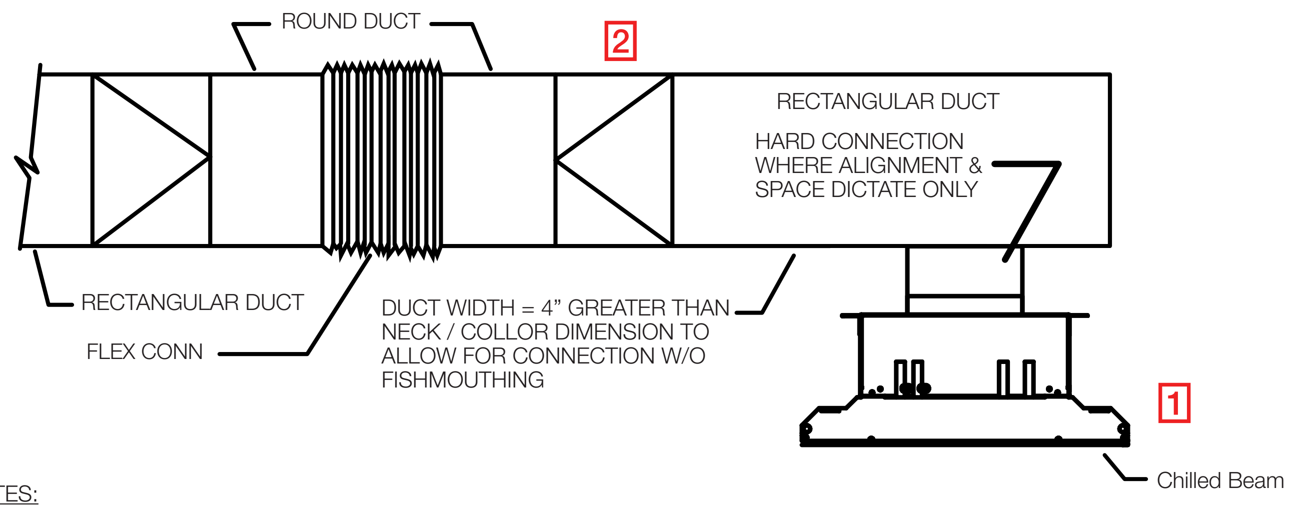
Table 1B

In both scenarios above, it should be noted that when using straight hard duct or straight flex duct, the impact on Beam static pressure is negligible or minimal. It should also be noted that for Inlet Condition C, that the airflow at the chilled beam is maintained at 106 CFM even with the flex duct.

For isolated beams where the duct pressure may increase, the beams themselves still maintain airflow and performance. This means, however, that the system must have the necessary static pressure available for the chilled beams to operate as designed.

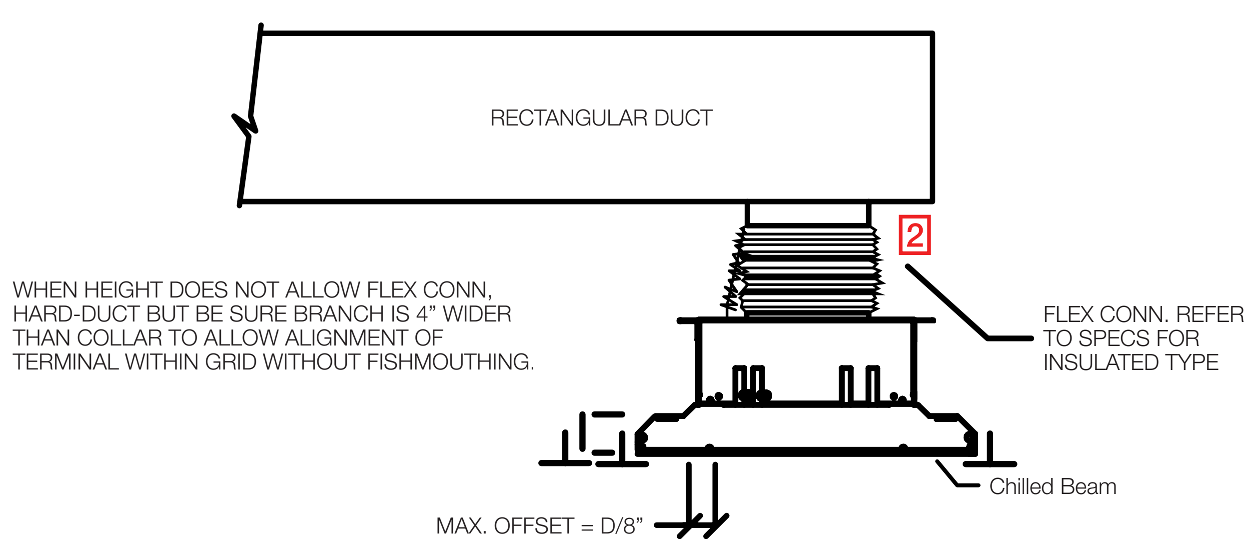
COMMON DUCTWORK PRACTICES

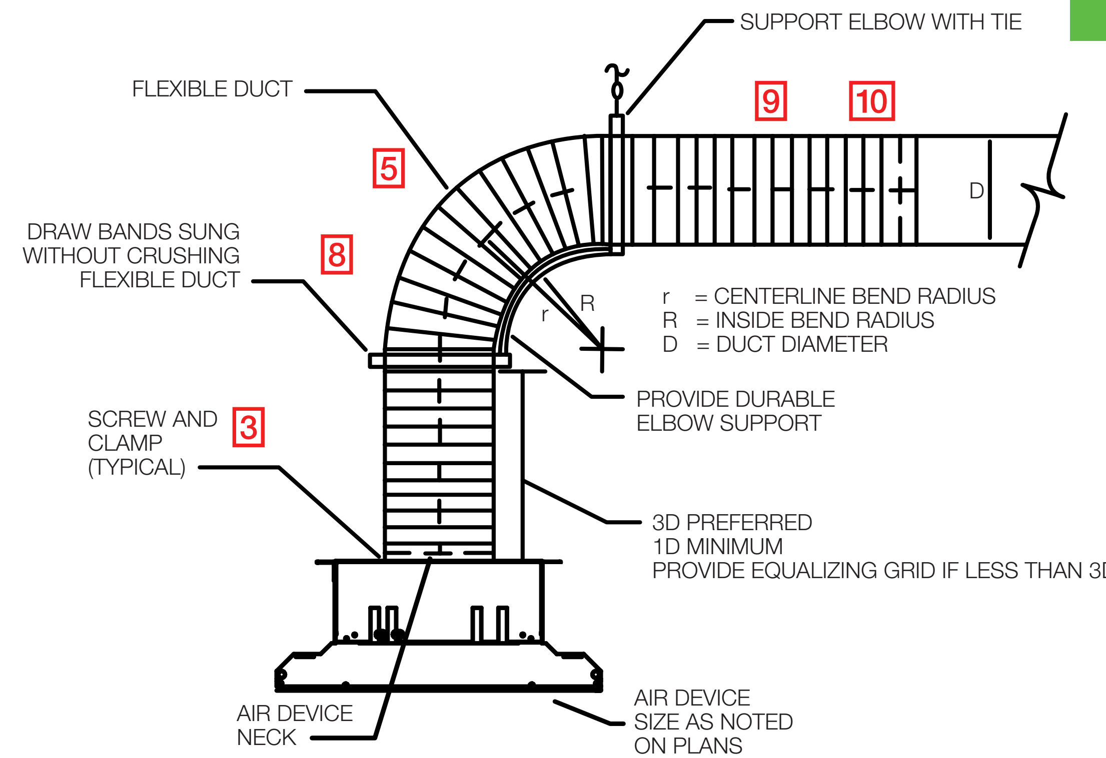
The following provides general guidelines for best practices in ductwork installation and connections.



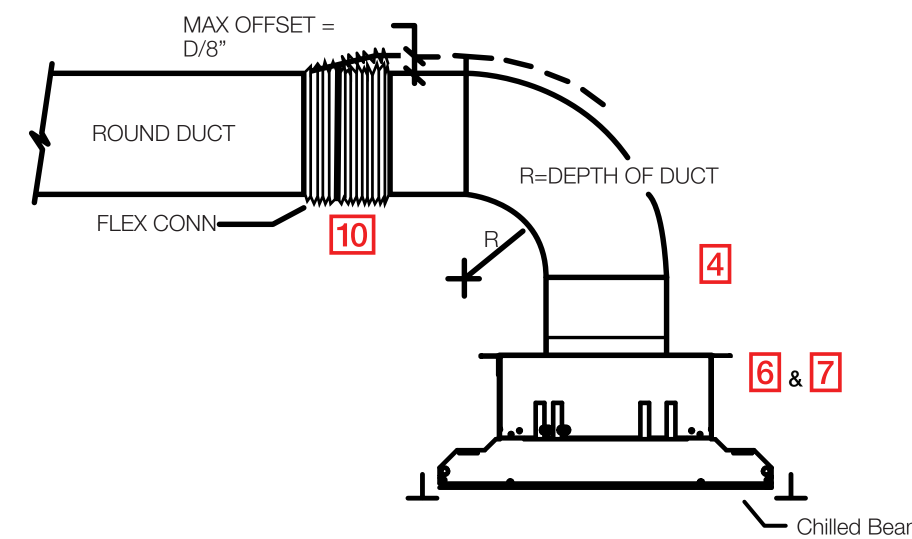
NOTES:

1. DETAIL ALLOWS DUCTWORK TO BE INSTALLED BEFORE CEILING GRID THEN ALLOWS DIFFUSERS AND REGISTERS TO BE POSITIONED INTO GRID.
2. PROVIDE INSULATED TRANSITION ROUND TO SQUARE INLET DIFFUSERS.
3. SECURE FLEXIBLE DUCT TO METAL DUCT WITH (2) STAINLESS STEEL CLAMPS OR NYLON TY-WRAPS TO INDIVIDUALLY SECURE FLEXIBLE DUCT INNER SLEEVE AND OUTER SLEEVE. WHEN INSTALLED ON INSULATED SYSTEM SEAL INSULATION JOINT WITH VAPOR BARRIER MASTIC. PROVIDE NYLON TY-WRAP TOOL OR REUSABLE SS DRAW BANDS.
4. PROVIDE DUCT MOUNTED VOLUME DAMPER. AVOID NECK DAMPERS.
5. FLEXIBLE DUCTS SHALL BEND IN ONE DIRECTION ONLY WITH A MAXIMUM CHANGE IN DIFFERENCE OF 90 DEGREES.





6. UNLESS SHOWN OTHERWISE FLEXIBLE DUCT SIZE AND COLLAR OF TAP OFF SHALL BE SAME SIZE AS DIFFUSER NECK.
7. IF RUN-OUT LENGTH REQUIRES SEGMENT OF HARD DUCT, SIZE SHALL BE SAME AS DIFFUSER NECK. RUN-OUT TO DIFFUSER SHALL BE AS STRAIGHT AS POSSIBLE.
8. INSTALL BENDS IN FLEXIBLE DUCTS WITH A MINIMUM CENTERLING RADIUS EQUAL TO 1.5 DUCT DIAMETERS (r >= 1.5 x D).
9. DO NOT EXCEED 6'-0" MAXIMUM LENGTH OF FLEX DUCT RECOMMENDED IN THE 2017 ASHRAE FUNDAMENTALS HANDBOOK. INSTALL FLEX DUCT WITH NO MORE THAN 1/2" SAG PER FOOT.
10. MAXIMUM SUPPORT SPACING SHALL BE 3 FT. FLEX DUCT SHALL NOT BE COMPRESSED PER SMACNA DUCT CONSTRUCTION MANUAL.



PRODUCT SELECTION

Chilled Beam Design Parameters

When designing a chilled beam system, there are multiple parameters to consider, such as chilled beam model, length, discharge pattern, inlet size & location, as well as nozzle.

For example, beam model selection can affect where the units will be installed. For instance, if a floor mounted cabinet unit is selected instead of overhead, ductwork length and geometry may change to accommodate ceiling to ground connection.

Figure 7

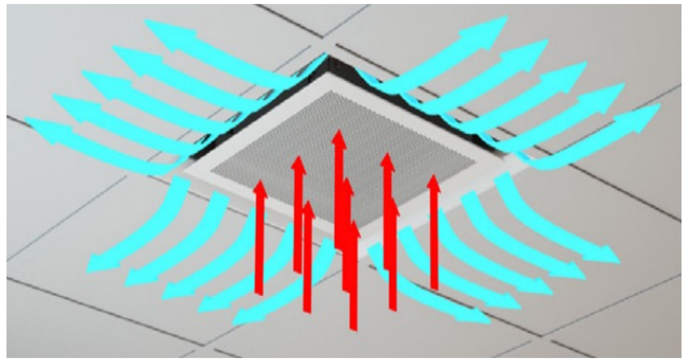


Figure 8

Along with model selection, a beam's length, discharge pattern, and inlet size can affect the volume of airflow and pressure.

The size of a beam's primary air inlet should also be given consideration. The inlet size may also determine if transition collars or reducers are needed, such as 6" to 5" reducer or an oval to round connection, which have their own effects on the system. If the inlet is not properly connected, pressure loss and leakage can be an outcome.

A chilled beam's nozzle selection can also affect many of the parameters listed previously. Generally, nozzles constructed of sheet metal can work with a range of airflow. If the air volume in the field changes, the pressure at the beam and ductwork can drastically change. There are adjustable nozzle options available in the market as well, but are not commonly used.

AUXILIARY COMPONENTS

Other Products and their Effects

Just as the chilled beam's parameters can affect airflow and pressure in the system, auxiliary components that work hand in hand with the beams can affect the system in similar ways. Trimming dampers, whether they are operated manually, actuated, or flow regulators (Figure 9), all have their own respective effects on pressure in the system.

Figure 9

These dampers should be selected accordingly with ductwork size, airflow, and given proper straight runs (3 – 5 duct diameters) before and after them.

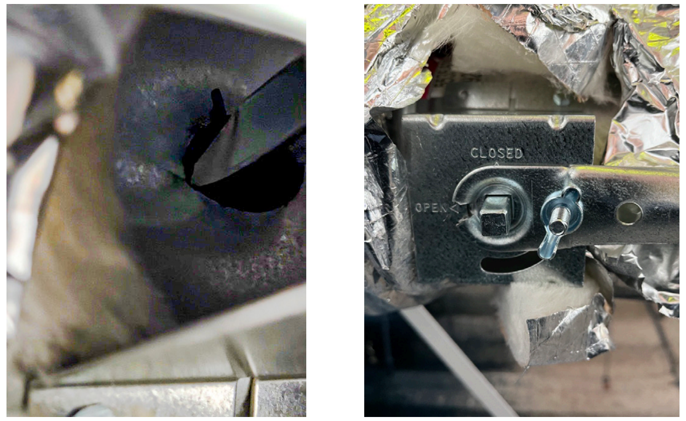


Figure 10
Example installation of inadequate sealing.

Duct accessories should be installed in such a manner as to keep connections tight, with no leakage (Figure 10).

Terminal Units (Figure 11), such as fan powered and single duct boxes are typically applied to low pressure duct systems. When applied to the elevated pressures of a chilled beam system, terminals and their downstream ductwork can be an unintended source of pressure drop and leakage if not selected correctly. SMACNA indicates that low pressure ductwork should be seal class C and leakage class 24 for rectangular duct systems which is often insufficient (refer to Page 2 on chilled beam leakage class recommendations).

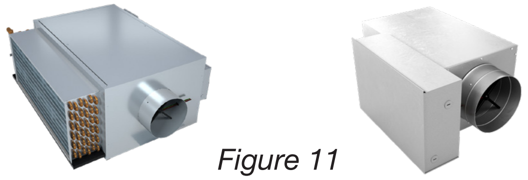


Figure 11

If the chilled beam does not have enough pressure, leakage and pressure drop of terminal units and ductwork should be reviewed. Terminal units should be specified to the correct leakage requirements in accordance with ASHRAE Standard 130, and duct-work should be specified with the appropriate leakage and seal class per SMACNA. It is also important to consider that various terminal components such as coils, access doors, and slip and drive connections can be sources of leakage after installation if not specified and sealed correctly.

Consideration should also be given downstream of any flow sensors, as these leaks may not be accounted for during balancing.

COMMISSIONING

Balancing Procedures

During the commissioning stage of a project, the chilled beams require balancing to ensure proper flow and function of the chilled beam. Balancing procedures typically require the following considerations:

- Setting the airflow set point upstream of the unit at the VAV box, trimming airflow damper, and/or fan.
- Ensure an air tight connection between the supply duct and the active beam. Duct connections are recommended to meet SMACNA Class A standard up to 2 in.w.g
- Any air connections at joints, inlets, or transition points should ideally have straight connections before and after (3 – 5 duct diameters). Straight duct connections at the inlet provide the most reliable pressure port measurements.
- A static pressure measurement should be taken at the Active Beam's pressure port using a pressure measuring device. This pressure will correspond to an airflow calibration chart and/or airflow schedule. The pressure measurement is noted in ASHRAE 200 as the method to obtain the primary air flow at the beam. Chilled Beam manufacturers should have validated performance to ASHRAE 200 and provide calibrated air flow charts for the balancing procedure.

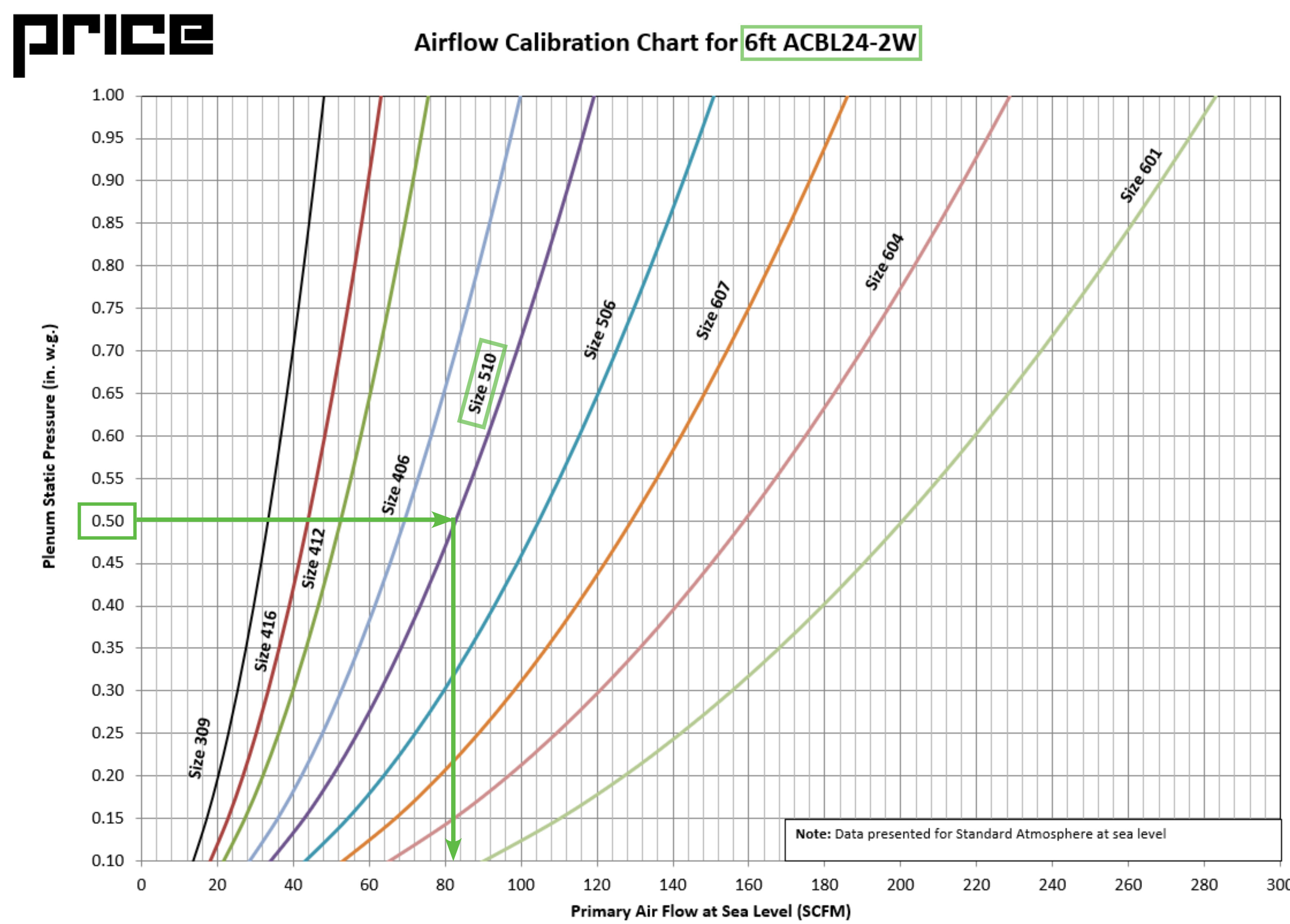


Figure 12

Note: Data from testing done at PRCN in accordance with ASHRAE 200 at an ISO 17025 Certified facility

COMMON BALANCING ERRORS

- Flow hoods are NOT recommended. A chilled beam's induction process will prevent accurate readings at the hood.
- Traversing the ductwork for airflow can help as a reference for airflow, but the pressure reading is the most accurate way to balance a chilled beam.
- Improper duct connections can lead to leakage, so make sure to check these connections at each beam.

Figure 13

Figure 14

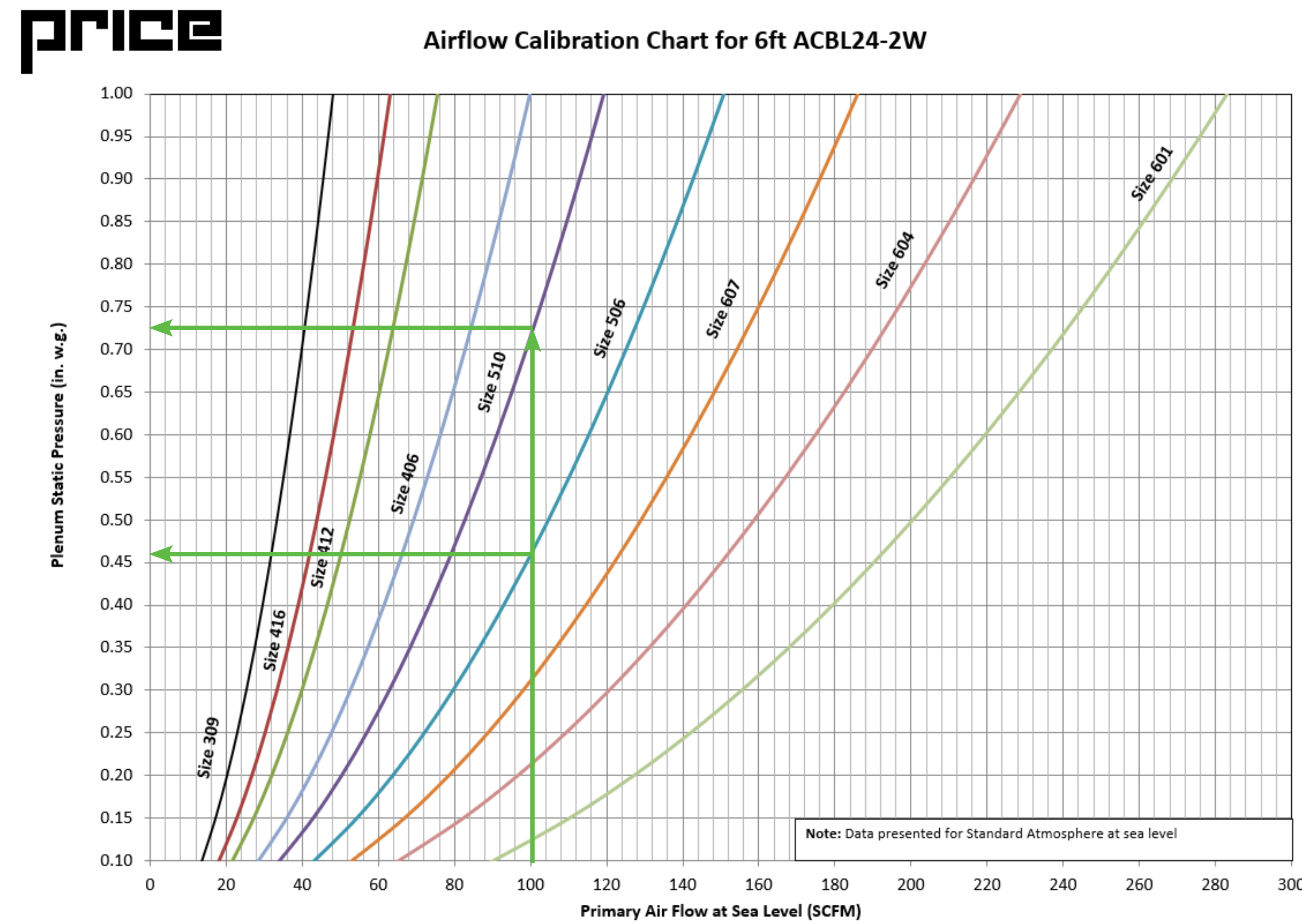


Figure 15

Identical looking beams may not have identical performance, so it is essential to have the correct nozzle chilled beam installed in its designated zone. As shown on the figure above, the incorrect nozzle can lead to drastically different static pressure measurements.

CONSTRUCTION INTEGRITY VALIDATION

Commissioning Mock Up

Consider setting a standard for the job site by doing a construction integrity validation. This can involve the following:

- Identify floorplate that is representative of the building and considers the layout and function of multiple chilled beams, any VAV boxes, and
- Isolating building space and conducting a design and install mock-up of that space with running air and water (procure sample units). Reference Figure 15 on the right for example of space to review such as the green highlighted conference room.
- Observing best practices in design and construction of the ductwork system
- Conducting leakage tests and balancing one or multiple products in accordance with their IOMs

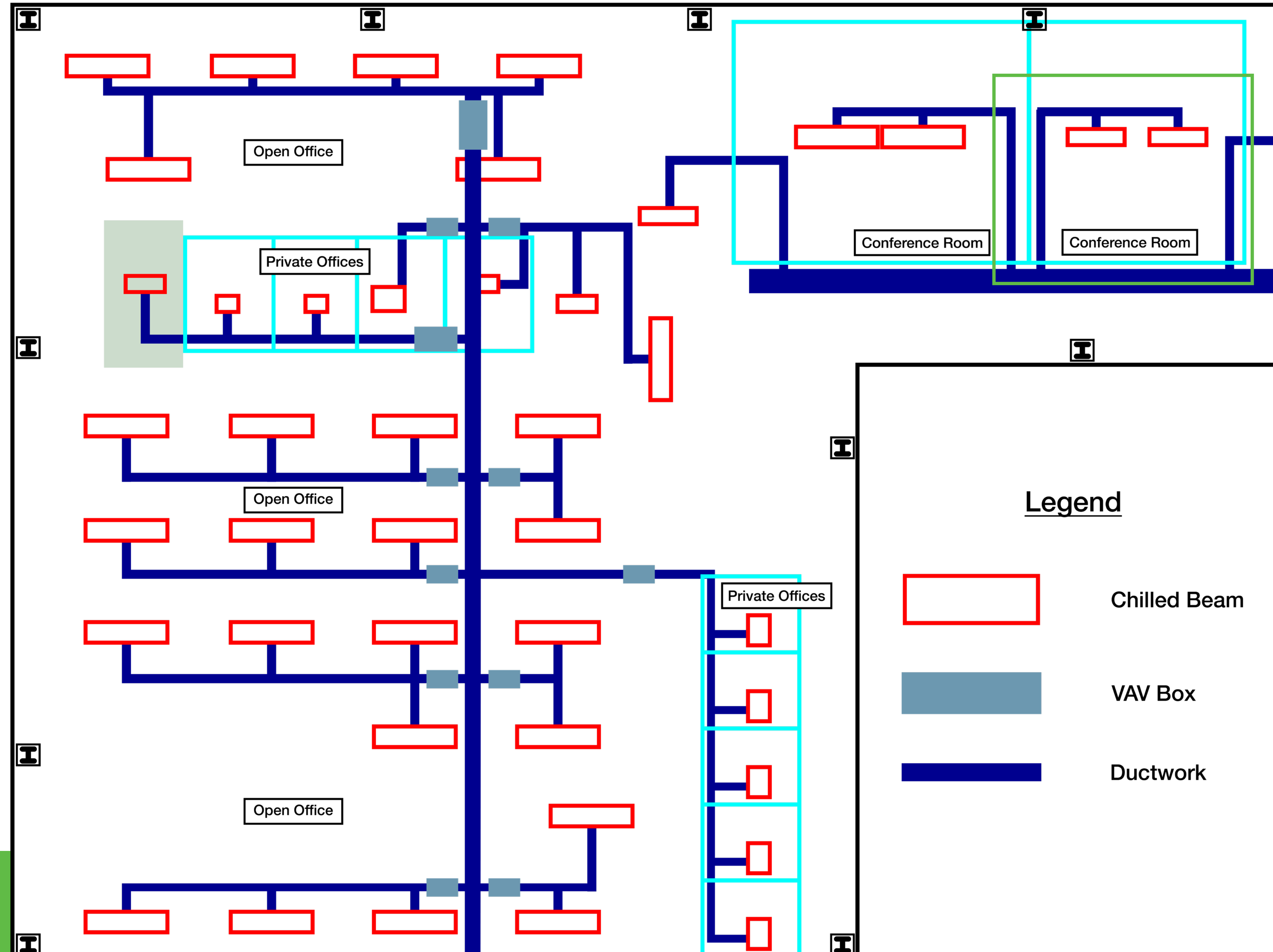


Figure 17

SUMMARY

CHILLED BEAMS FROM CONSTRUCTION TO COMMISSIONING

WHY IS IT IMPORTANT

- Achieve system performance as designed
- Optimizing Space Comfort
- Smoother balancing process

DUCTWORK DESIGN

- Seal ducts to SMACNA Class A
- Be able to identify leakage points
- Inlet conditions matter

PRODUCT SELECTION

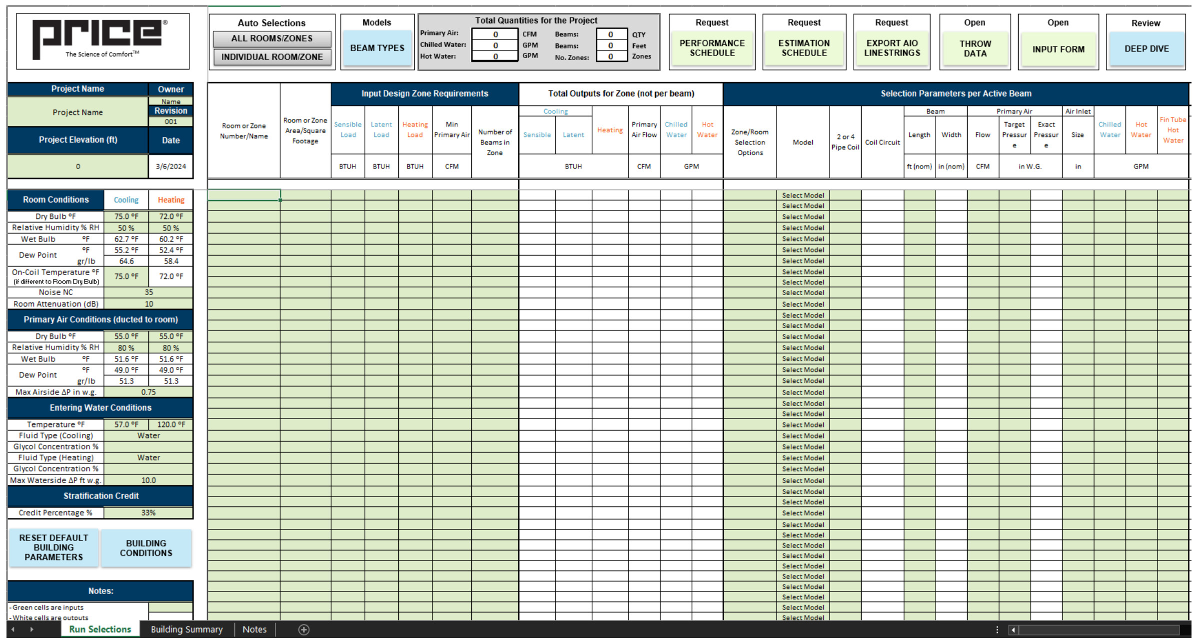
- Consider all beam parameters such as model, size, airflow, etc.
- Select appropriate terminal units and duct accessories

BALANCING

- Beam pressure measurement is key
- Understand balancing procedure

REFERENCES

- ASHRAE 200 Method of Testing Chilled Beams
- Price Engineer's HVAC Handbook 2nd Ed
- https://www.smacna.org/



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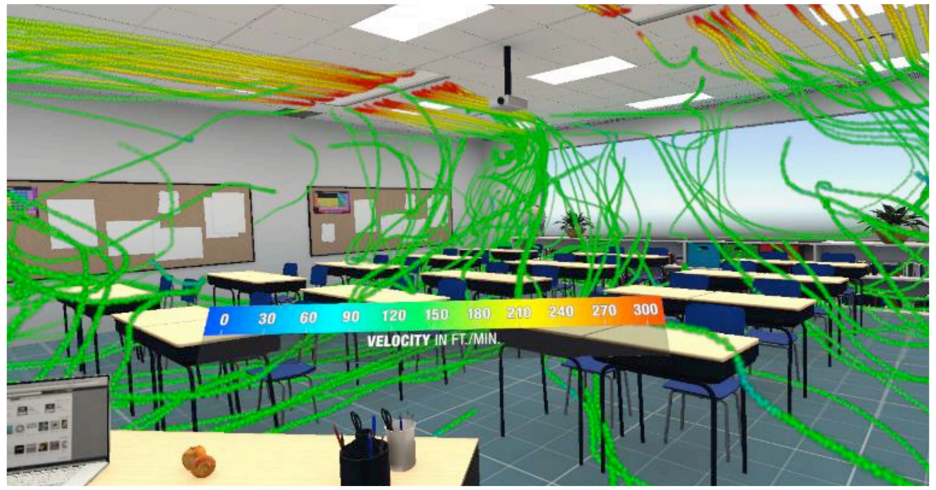
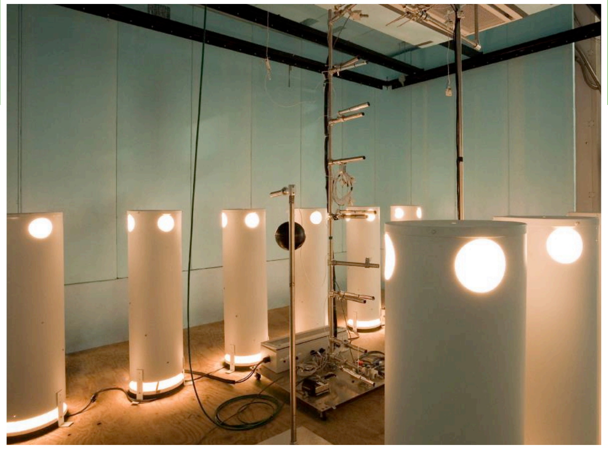


Price is a service oriented company and has a dedicated Chilled Beam applications team devoted to answering your questions quickly, completely, and correctly. We are here to help — our applications team regularly provides support on:

- Model Selection
- Layout Assistance
- Calculation Assistance
- On-site Training
- On-site Performance Validation
- Variety of testing capabilities at PRCN in accordance with EN 14037, 14240, 14518, and 15116, ASHRAE 70, 55, 129, 200, 138, and SPC 200, and ISO IEC 17025



Price Commissioning Service

Price offers an industry-leading commissioning service, through which our trained Applications team will travel to the installation site and perform some or all the following valuable services:

- Pre-construction meetings
- Construction site walk-throughs
- Installation examples
- On-site product review and troubleshooting
- Training and education for owner, occupants, and maintenance personnel.