
80-6-ISD A Better Solution for Proper Space Air Distribution

In designing an HVAC system, an engineer has the following goals:

1. True building load requirements
2. Load reduction possibilities
3. Economical equipment selection
4. Effective air distribution system

An effective room air distribution is probably the most important goal. For instance, excellent distribution of air within a room can compensate to a large extent for a minor deficiency in equipment capacity. But, no level of excellence in the refrigeration system can compensate for a poorly designed room air distribution. The object of air distribution is to create an acceptable combination of temperature, humidity, and air motion in the occupied zone of the conditioned room, usually considered to be from the floor to 6.5 feet above floor level. Discomfort may arise from excessive room air temperature variations, excessive air motion (drafts), failure to deliver adequate air to local cold or hot spots, or too rapid a fluctuation of room temperature or air motion (gusts).

Two good rules that will assure comfortable conditions in the occupied zone are:

1. Limit temperature variations in the occupied zone to a maximum of 3°F.
2. Maintain general air motion in the occupied zone between 15 and 50 fpm.

To achieve the established condition in the occupied zone, the engineer will select the supply air outlet. There are three different types of supply air outlets in common use:

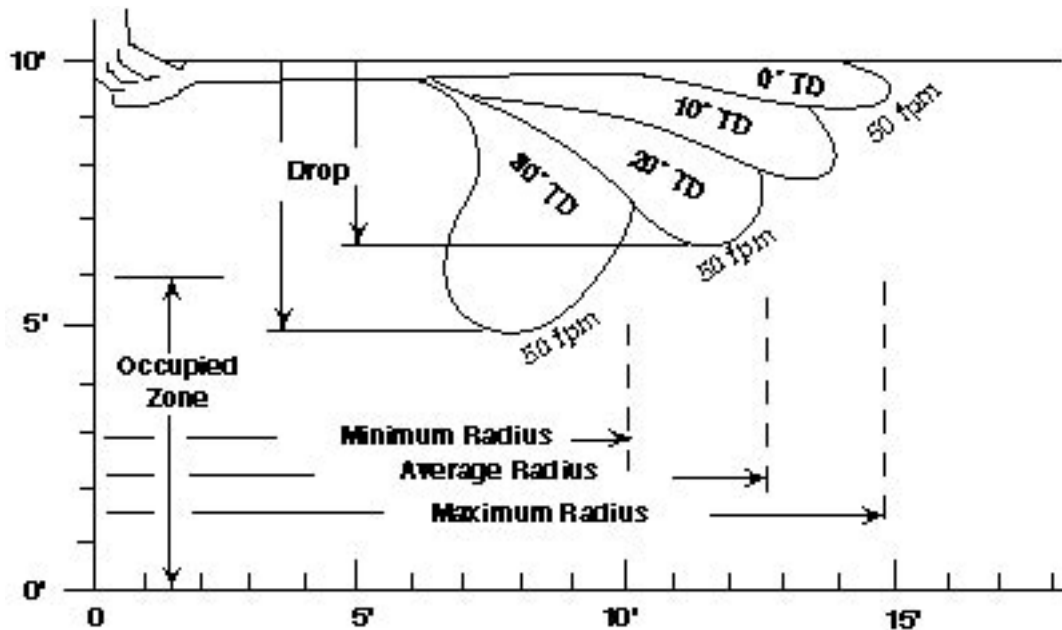
1. Grilles and registers
2. Slot diffusers
3. Ceiling diffusers

Each type of diffuser has characteristics which make it desirable for certain applications. Grilles and registers have the lowest induction rates, the longest throw and the lowest temperature diffusion. Ceiling diffusers have the highest induction rates, short throws and rapid temperature equalization. Slot diffusers fall between the two.

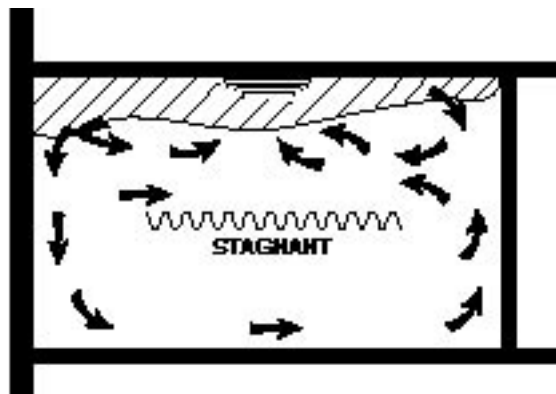
The following table gives some rough guidelines for selecting the type of diffusers.

Type Supply Outlet	cfm/ft ² Floor Area	Temperature Differential °F
Grilles	1 - 2	15 - 25
Slot Diffusers	1.5 - 2.5	20 - 25
Ceiling Diffusers	3 - 3.5	20 - 35

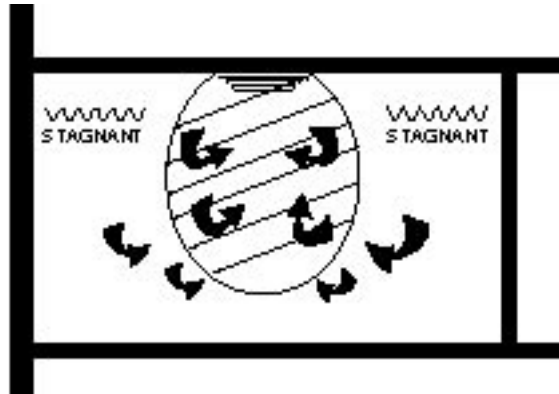
One of the parameters in selecting the proper supply outlet in the above table is temperature differential. For a conditioned room temperature of 70°F, the primary air temperature should be in a range of 50 to 55°F for slot diffusers. An even lower primary air temperature is needed in the case of ceiling diffusers. The need for a proper temperature differential can be seen in the graph below.



The above graph shows how the primary air motion of a ceiling diffuser is affected by the temperature differential. Changes in the drop and throw of the primary air due to variations in the temperature differential will result in a poor room air motion and large temperature variation within the occupied zone. Too small a temperature differential will cause a larger than desired ceiling effect. The result, as shown in the figure below, will be stagnant air in the occupied space.



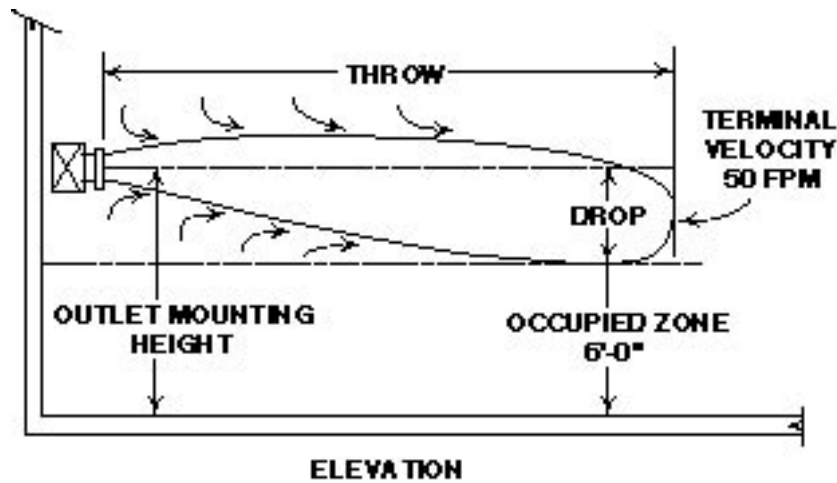
Too high a temperature differential will result in dumping of cool air as shown in the graph below.



Included in this bulletin is a copy of an article in *Air Conditioning, Heating and Refrigeration News* of July 28, 1980. The author, Harold Stroub, comments on a typical problem of VAV systems. Because of the reduced air flow of VAV systems, heat gain by the supply duct will raise the primary air temperature by as much as 15 to 20°F, too high to achieve a proper room air distribution. Similar temperature rises are often found in a constant volume system. This range in temperature rise would be typical of bare sheet metal ducts located in a return air plenum. By failing to achieve a proper air distribution, the objective of the HVAC system to provide comfort has not been achieved. A solution will be to reduce the heat gain by adding insulation to the duct.

An even better solution, one that will reduce heat gain, noise level and leakage, is to use micro-air fiber glass duct systems (rigid round or board) to solve the engineering problem.

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Manager,
Engineering & Technical Services



Definitions (See above figure)

Primary Air: Air delivered through the outlet by the supply duct.

Secondary Air: Air entrained into the air stream after it has been discharged from the outlet.

Total Air: Mixture of primary and secondary air.

Induction Ratio: The total air divided by the primary air.

Outlet Velocity: Average velocity of air emerging from the outlet, measured in feet per minute.

Temperature Differential: Temperature difference between primary air and room air.

Throw: The horizontal or vertical axial distance an air stream travels after leaving an air outlet before the maximum stream velocity is reduced to a specified terminal level such as 150, 100, or 50 fpm.

Drop: The vertical distance that the lower edge of a horizontally projected air stream rises between the outlet and the end of its throw.

Rise: The vertical distance that the upper edge of a horizontally projected air stream rises between the outlet and the end of its throw.

Ceiling Effect: When an air stream is injected into a space near a ceiling or wall and parallel to that surface, it exhibits a phenomenon known as the "ceiling effect". The stream tends to maintain contact with the surface, even if other forces are tending to separate the two, over far longer distances than might be expected.

Occupied Zone: That portion of a room volume between the floor and 6 to 6½ feet above floor level.

A Consultant Looks at... Problems with VAV systems

BY JOSEPH B. OLIVIERI

DALLAS, Texas — Talking to Harold Straub, manager of technical development and services for the Titus Products Division of Koppers Environmental Elements Corp. here, about complaints with variable air volume (VAV) systems, he reflected that these problems are more numerous in the south than in the north.

In the milder climates, both heating and cooling are done from overhead systems. How quickly we forget.

He reminded me of the work done by Stan Gilman at the University of Illinois back in the late 1940's. This work is discussed in the "ASHRAE Handbook"; in the text, "Air Diffusion Dynamics," by Ralph Nevins; and in my own book, "How to Design Heating-Cooling Comfort Systems."

The research showed that, in a cooling mode, the most comfort is created if the supply of air is introduced at the ceiling. For heating, the air must be introduced from the floor.

When one attempts to heat from the ceiling, stratification occurs and locating return air grilles at floor level does nothing to change this. The stratification gets worse at higher supply temperatures and at lower air volumes.

Low air volumes occur in a VAV system when a system switches to heating. At high air volumes one gets maximum induction, which reduces the amount of stratification.

We next discussed the complaint that under EBTR (Emergency Building Temperature Restrictions), floor temperatures sometimes reach 56°F. Straub said that's probably true.

In fact, Straub added that, when he lived in Iowa, he was comfortable indoors when ambients were 20° and 30° below zero. The floor to ceiling temperatures varied by only 3°F.

But since moving to Texas, he has found out what discomfort is. He and his wife watch television with their feet on the coffee table. Again the villain is an overhead heating supply.

In northern climates air is introduced at the floor in residential buildings, or the residence is heated with baseboard hot water. This prevents stratification.

But, now that we have ASHRAE Standard 90-75, "Energy Conservation in New Building Design", there will be a temptation to use overhead air supplies. Straub agreed that this is probably what will happen. He went on to say that, just as with southern systems, the problem will occur during mild weather, when some heating is required. At low outdoor temperatures, the systems should be reasonably comfortable.

Straub brought out an interesting point. I questioned him about the advisability of controlling large zones from one VAV box. My fear is that the system will experience poor air distribution at reduced air flows. According to Straub, the air supply should be reduced equally in each outlet as the box throttles.

The problem that occurs is not unequal air distribution, but unequal duct temperatures.

In his laboratory, Straub showed me a 100-ft-long duct. The air is introduced through a continuous strip diffuser mounted in the bottom of the duct. At full flows, the heat transfer through the duct from the hot ceiling results in a rise of only one or two degrees.

At low flows, the same amount of heat enters the duct but now there can be 15° to 20° difference between the beginning and end of the duct.

Straub feels research is needed in the area of diffusers and VAV

system application if heating is to be supplied successfully from overhead. We found out, as we talked, that we had at one time proposed similar solutions to this problem.

Straub stated that, with a dual duct VAV, one usually would like half the airflow on heating. This means that the diffuser is in the heating mode, twice as large as required.

Straub's device closes off half the diffuser during the heating season. He also described another system in which a mechanical device, he called it a pill, moves the diffuser rings from a horizontal pattern to a projected flow when it senses heat.

I asked Straub about the use of VAV with direct expansion (DX) coils. He doesn't think too much of the VAV bypass box because it doesn't reduce fan usage. He recommends that, for rooftop units of less than 25 tons, a bypass system is needed.

The bypass is at the fan — not the room.

On units larger than 25 tons, the units have sufficient capacity control so that there will not be any problems with the refrigerant circuit.

Straub is disappointed because many manufacturers are not using ADPI (Air Diffusion Performance Index).

Using ADPI, his research has shown that the most comfortable selection with sidewall grilles occurs, not when the throw is three-quarters of the room dimension, but when it is one to two times the room dimension.

ADPI is a must when designing VAV systems, according to Straub. ADPI has shown that sidewall grilles are not as comfortable as other outlets.

Another good reason for ADPI is that, once an installation has been completed, the ADPI can be checked to see if it meets the specification. Straub also pointed out an ASHRAE study that attempts to create comfort curves similar to the NC curve for

Problems with VAV systems--

noise.

"What do you think of the inverter drive that York introduced at the last industry exposition in Los Angeles?" I asked Straub. Straub showed me his company's device which is a mechanical device designed to produce the same result.

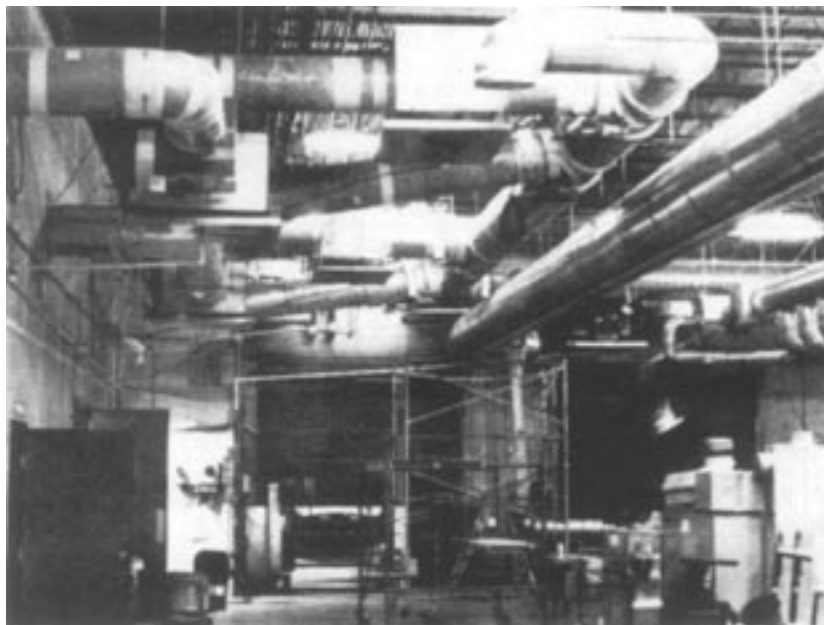
He is in favor of any device that will give maximum energy savings but, to reach the maximum potential, you have to match the speed vs hp fan law. Both of these devices come close to this.

My visit ended with a tour of the laboratory. Straub has one area that is used to make up customers' requirements. They have the ability to create a cold wall to simulate heating seasons. His laboratory also contains a large sound room for reverberant testing.

While touring the lab I saw a system that Straub feels will see increased use. It combines a primary air duct with a fan box.

The primary air carries cold air only. Air quantities are controlled by a VAV valve. When a minimum setting is reached, the fan turns on. The fan draws warm air from above the suspended ceiling through filters and mixes it with primary air. If more heat is required, then electric or hydronic heating elements are utilized.

Straub's final words to me were: "Remember, comfort is what the game is all about."



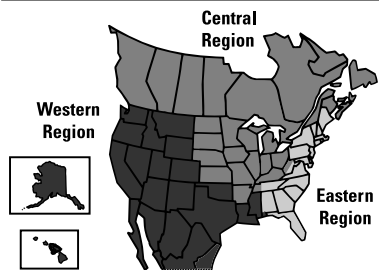
WALL OUTLET RATINGS, FOR COOLING ONLY
For Flat Ceilings

OUTLET VELOCITY		250 FPM				375 FPM				500 FPM				750 FPM										
STATIC PRESSURE		Str B = .01, 22 1/2° = .01 45° = .01				Str B = .013, 22 1/2° = .015 45° = .019				Str B = .024, 22 1/2° = .028 45° = .035				Str B = .051, 22 1/2° = .061 45° = .08										
STANDARD OUTLET																								
STATIC PRESSURE WITH METERING PLATE		Str B = .01, 22 1/2° = .015 45° = .028				Str B = .024, 22 1/2° = .043 45° = .065				Str B = .061, 22 1/2° = .082 45° = .118				Str B = .175, 22 1/2° = .19 45° = .27										
Nom. Size of Outlet (and Free Area)	Vane Setting	Air Quantity (cfm)	Blow (ft)	Temp Diff (F)			Air Quantity (cfm)	Blow (ft)	Temp Diff (F)			Air Quantity (cfm)	Blow (ft)	Temp Diff (F)			Air Quantity (cfm)	Blow (ft)	Temp Diff (F)					
				15 Min	20 Clg	25 Ht			15 Min	20 Clg	25 Ht			15 Min	20 Clg	25 Ht			15 Min	20 Clg	25 Ht			
8 x 4 (16.9)	Straight 22 1/2° 45°	30	3.5 2.5 1.8	6.5	7.0	7.0	44	7.0 5.1 3.5	7.5	7.5	8.0	59	10.0 7.5 5.0	7.5	8.0	8.5	89	17.0 13.0 9.0	8.5	9.0	9.0			
				6.5	6.5	6.5			6.5	7.0	7.0			6.5	7.5	7.5			6.5	7.5	8.0	7.5	8.0	8.5
				6.0	6.0	6.5			6.5	6.5	7.0			6.5	6.5	7.0			6.5	6.5	7.0	6.5	7.0	7.0
10 x 4 (21.7)	Straight 22 1/2° 45°	37	3.5 2.5 1.8	6.5	7.0	7.5	57	7.4 5.5 3.7	7.5	7.5	8.0	75	10.5 8.0 5.4	7.5	8.0	8.5	112	18.0 13.0 9.0	8.5	9.0	9.0			
				6.5	6.5	7.0			6.5	7.0	7.0			6.5	7.5	7.5			6.5	7.5	8.0	7.5	8.0	8.5
				6.0	6.0	6.5			6.5	6.5	7.0			6.5	6.5	7.0			6.5	6.5	7.0	6.5	7.0	7.0
12 x 4 (24.6)	Straight 22 1/2° 45°	44	3.5 2.5 1.8	6.5	7.0	7.5	68	7.5 5.5 3.9	7.5	7.5	8.0	91	11.0 8.1 5.5	8.0	8.0	8.5	136	18.0 13.0 9.0	8.5	9.0	9.5			
				6.5	6.5	7.0			6.5	7.0	7.5			6.5	7.0	7.5			6.5	7.5	7.5	6.5	7.5	8.0
				6.0	6.0	6.5			6.5	6.5	7.0			6.5	6.5	7.0			6.5	6.5	7.0	6.5	7.0	7.0
16 x 4 (35.9)	Straight 22 1/2° 45°	61	3.7 2.7 2.0	7.0	7.0	7.5	92	7.9 6.0 4.0	7.5	7.5	8.0	122	11.0 8.1 5.5	8.0	8.0	8.5	183	19.0 14.0 10.0	8.5	9.0	9.5			
				6.5	6.5	7.0			6.5	7.0	7.5			6.5	7.0	7.5			6.5	7.5	7.5	6.5	7.5	8.0
				6.0	6.0	6.5			6.5	6.5	7.0			6.5	6.5	7.0			6.5	6.5	7.0	6.5	7.0	7.0
20 x 4 (45.5)	Straight 22 1/2° 45°	77	4.0 3.0 2.0	7.0	7.0	7.5	115	8.0 6.0 4.0	7.5	8.0	8.0	154	11.5 8.5 6.0	8.0	8.0	8.5	231	20.0 15.0 10.0	8.5	9.0	9.5			
				6.5	6.5	7.0			6.5	7.0	7.5			6.5	7.0	7.5			6.5	7.5	8.0	6.5	7.5	8.0
				6.0	6.0	6.5			6.5	6.5	7.0			6.5	6.5	7.0			6.5	6.5	7.0	6.5	7.0	7.0
24 x 4 (55.0)	Straight 22 1/2° 45°	93	4.1 3.1 2.0	7.0	7.0	7.5	139	8.0 6.0 4.0	7.5	8.0	8.0	185	11.5 8.5 6.0	8.0	8.0	8.5	278	20.0 15.0 10.6	8.5	9.0	10.0			
				6.5	6.5	7.0			6.5	7.0	7.5			6.5	7.0	7.5			6.5	7.5	8.0	6.5	7.5	8.0
				6.0	6.0	6.5			6.5	6.5	7.0			6.5	6.5	7.0			6.5	6.5	7.0	6.5	7.0	7.0
30 x 4 (68.3)	Straight 22 1/2° 45°	116	4.2 3.1 2.1	7.0	7.0	7.5	175	8.0 6.0 4.0	7.5	8.0	8.0	233	12.0 9.0 6.0	8.0	8.0	8.5	349	21.0 16.0 11.0	8.5	9.5	10.0			
				6.5	6.5	7.0			6.5	7.0	7.5			6.5	7.0	7.5			6.5	7.5	8.0	6.5	7.5	8.5
				6.0	6.0	6.5			6.5	6.5	7.0			6.5	6.5	7.0			6.5	6.5	7.0	6.5	7.0	7.0
36 x 4 (83.5)	Straight 22 1/2° 45°	140	4.4 3.3 2.2	7.0	7.5	7.5	210	8.0 6.0 4.0	7.5	8.0	8.0	279	12.0 9.0 6.0	8.0	8.5	9.0	420	21.0 16.0 11.0	9.0	9.5	10.0			
				7.5	7.0	7.0			7.5	7.5	7.5			7.5	7.5	8.0			7.5	7.5	8.0	7.5	8.5	8.5
				6.5	6.5	6.5			6.5	6.5	7.0			6.5	6.5	7.0			6.5	6.5	7.0	6.5	7.0	7.0
8 x 6 (26.5)	Straight 22 1/2° 45°	52	5.0 3.8 2.5	7.5	7.5	8.0	77	9.5 7.0 4.8	8.0	8.0	8.5	103	13.0 10.0 6.0	8.5	9.0	9.0	155	24.0 18.0 12.0	8.5	10.0	10.5			
				7.0	7.0	7.5			7.5	8.0	8.0			7.5	8.0	8.5			7.5	8.0	8.5	7.5	8.5	9.5
				6.0	6.0	6.5			6.5	6.5	7.0			6.5	6.5	7.0			6.5	6.5	7.0	6.5	7.0	7.5
10 x 6 (34.0)	Straight 22 1/2° 45°	66	5.5 4.1 2.8	7.5	8.0	8.0	98	10.0 7.5 5.0	8.0	8.5	9.0	131	15.0 11.0 7.0	9.0	9.5	10.0	196	27.0 20.0 14.0	10.0	10.5	11.5			
				7.5	7.5	7.5			7.5	8.0	8.5			7.5	8.0	8.5			7.5	8.0	9.0	7.5	8.5	10.0
				7.0	7.0	7.0			7.0	7.0	7.5			7.0	7.0	7.5			7.0	7.0	7.5	7.0	7.5	8.0
12 x 6 (41.6)	Straight 22 1/2° 45°	80	6.0 4.5 3.0	7.5	8.0	8.5	119	11.0 8.1 5.5	8.0	9.0	9.5	159	15.0 11.0 7.0	9.0	9.5	10.0	238	28.0 21.0 14.0	10.0	11.0	11.5			
				7.5	7.5	7.5			7.5	8.0	8.5			7.5	8.0	8.5			7.5	8.0	9.0	7.5	8.5	10.0
				7.0	7.0	7.0			7.0	7.0	7.5			7.0	7.0	7.5			7.0	7.0	7.5	7.0	7.5	8.0
16 x 6 (56.6)	Straight 22 1/2° 45°	107	6.2 4.7 3.2	8.0	8.0	8.5	161	12.0 9.0 6.0	8.5	9.0	9.5	214	16.0 12.0 8.0	9.0	10.0	10.5	321	30.0 22.0 15.0	11.0	11.5	12.5			
				8.0	7.5	7.5			8.0	8.0	8.5			8.0	8.0	8.5			8.0	8.5	9.5	8.0	9.5	10.5
				7.0	7.0	7.0			7.0	7.0	7.5			7.0	7.0	7.5			7.0	7.0	7.5	7.0	7.5	8.0
20 x 6 (71.5)	Straight 22 1/2° 45°	135	6.6 5.0 3.2	8.0	8.5	9.0	202	12.0 9.0 6.6	9.0	9.5	10.0	269	17.0 13.0 9.0	9.5	10.0	11.0	403	32.0 24.0 16.0	11.5	12.0	13.0			
				8.5	7.5	8.0			8.5	8.5	9.0			8.5	8.5	9.0			8.5	9.0	9.5	8.5	9.5	11.0
				7.0	7.0	7.0			7.0	7.0	7.5			7.0	7.0	7.5			7.0	7.0	7.5	7.0	7.5	8.0
24 x 6 (86.5)	Straight 22 1/2° 45°	162	7.0 5.1 3.5	8.0	8.5	9.0	243	13.0 10.0 6.5	9.0	9.5	10.0	324	18.0 13.0 9.0	10.0	10.5	11.0	486	33.0 25.0 17.0	12.0	12.5	13.0			
				8.5	7.5	8.0			8.5	8.5	9.0			8.5	8.5	9.0			8.5	9.0	10.0	8.5	10.0	11.0
				7.0	7.0	7.0			7.0	7.0	7.5			7.0	7.0	7.5			7.0	7.0	7.5	7.0	7.5	8.0
30 X 6 (109.0)	Straight 22 1/2° 45°	203	7.0 5.4 3.5	8.5	8.5	9.5	304	13.0 10.0 6.5	9.0	10.0	10.5	406	19.0 14.0 10.0	10.0	11.0	11.5	609	34.0 25.0 17.0	12.0	12.5	13.5			
				8.5	7.5	8.0			8.5	8.5	9.0			8.5	8.5	9.0			8.5	9.0	10.0	8.5	10.0	11.5
				7.0	7.0	7.0			7.0	7.0	7.5			7.0	7.0	7.5			7.0	7.0	7.5	7.0	7.5	8.0
36 x 6 (131.3)	Straight 22 1/2° 45°	245	7.1 5.5 3.5	8.5	9.0	9.5	368	13.0 10.0 6.5	9.5	10.0	10.5	490	19.0 14.0 10.0	10.0	11.0	12.0	735	35.0 26.0 8.0	12.0	13.0	14.0			
				8.5	7.5	8.0			8.5	8.5	9.5			8.5	8.5	9.5			8.5	9.0	10.0	8.5	10.0	11.5
				7.0	7.0	7.0			7.0	7.0	7.5			7.0	7.0	7.5			7.0	7.0	7.5	7.0	7.5	8.0

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Max Cfm/Sq Ft Outlet Wall Area	29.0	19.0	14.0	9.6
Min Cfm/Sq Ft Outlet Wall Area	8.7	5.7	4.2	2.9

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