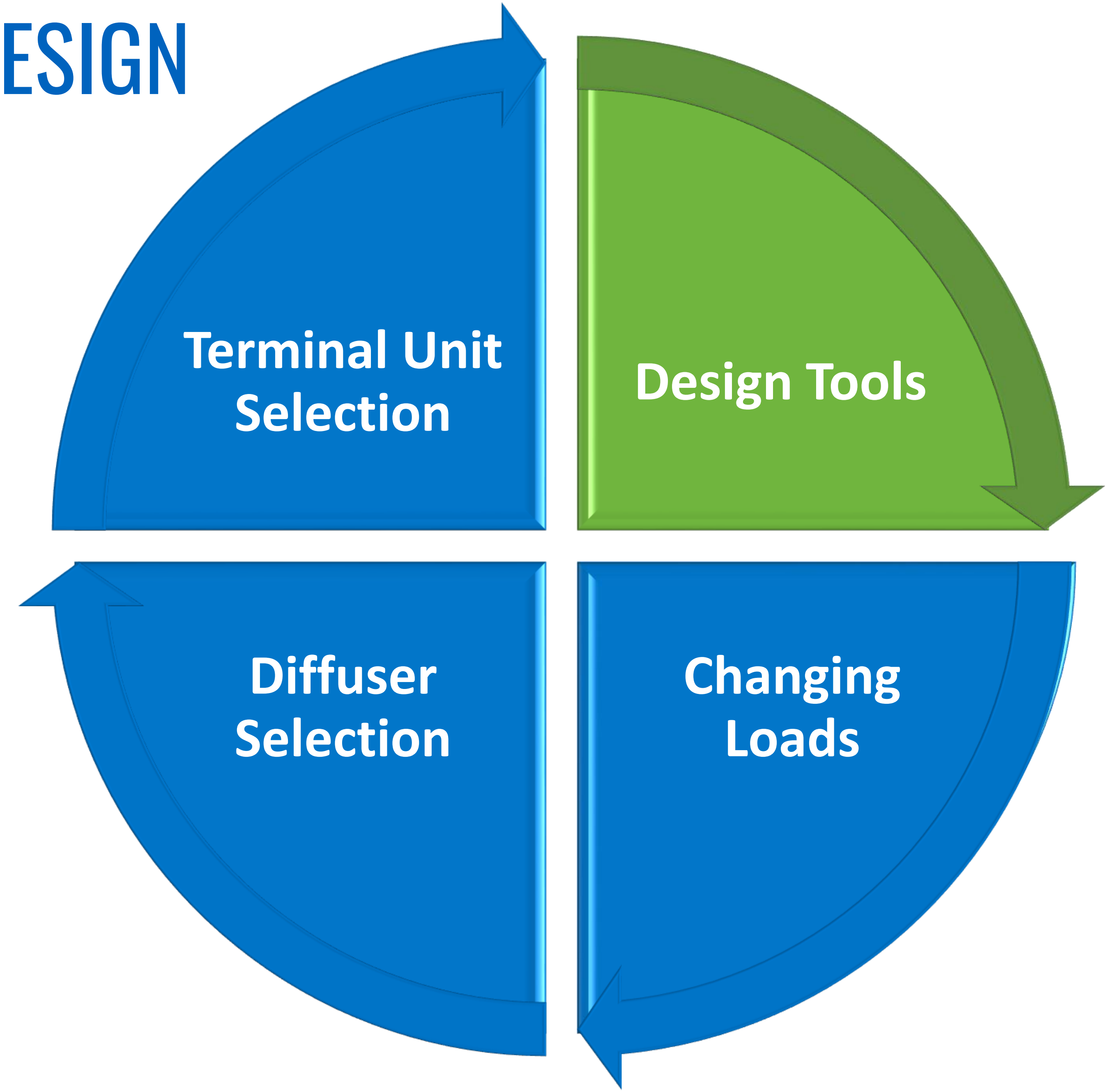
AIR DISTRIBUTION SYSTEM DESIGN

ABOUT ME

- Dan Int-Hout
- Chief Engineer
- 43 years of experience
- ASHRAE / Distinguished Lecturer
- Published over 50 articles / technical papers
- Manage presentation of product data
- Provide advanced application engineering


To create comfort!

SYSTEM DESIGN



ADPI FOR DIFFUSER SPACING

Optimal ADPI
representing “well mixed”

ADPI is based on the ratio of isothermal throw at 50 fpm (T_{50}) to the mid point between diffusers (L) (Note: an open office is assumed)

In simple terms, it helps you design for comfort, making sure that the space is well-mixed and that you avoid drafts and stratification

CALCULATING DIFFUSER SPACING (OPEN OFFICE)

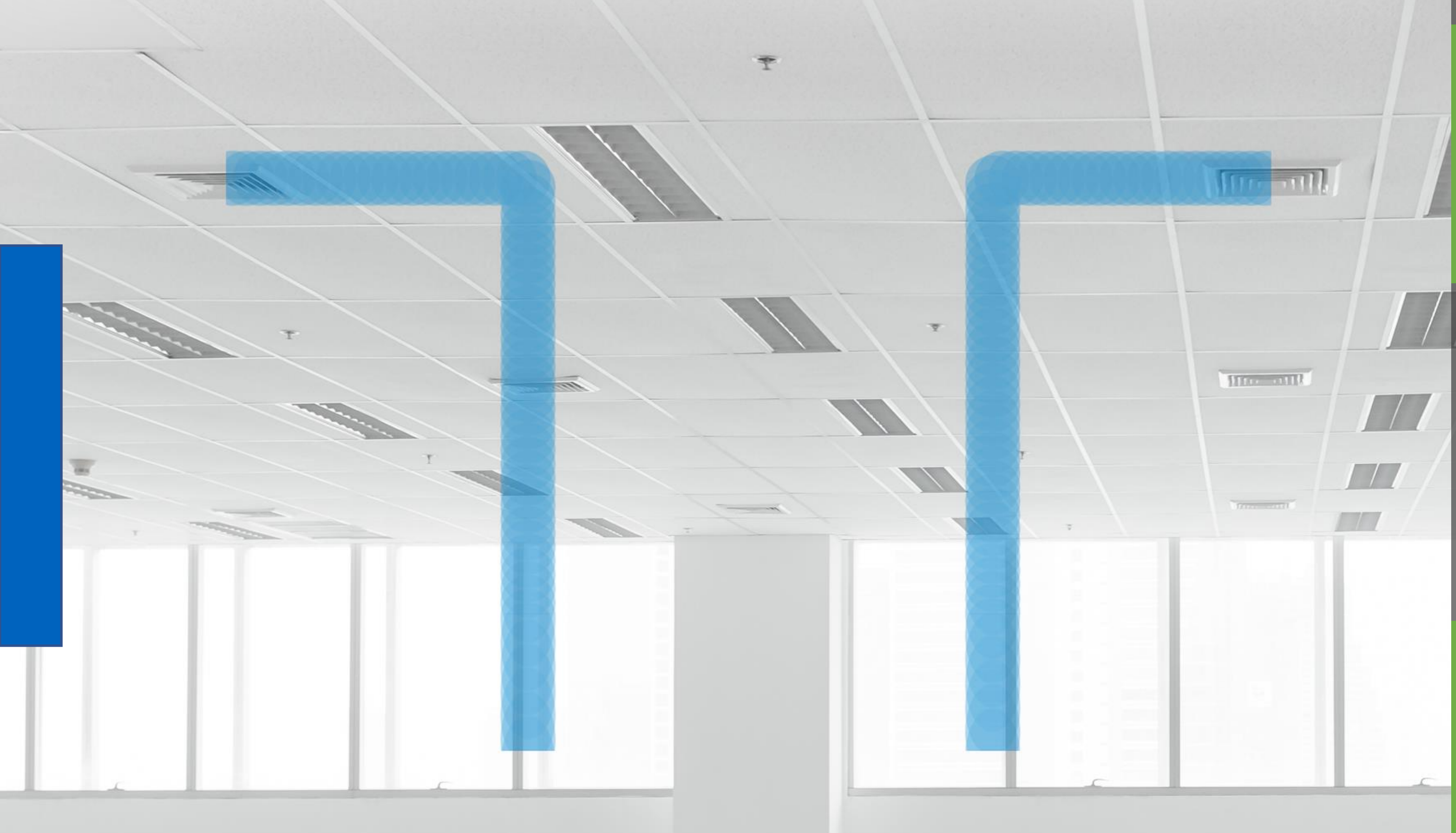
Calculate spacing for any <u>4-way air outlet</u> in an <u>open plan</u> office:

- Diffuser quantity/location is based on the design airflow per unit area and the amount of air delivered per unit at a design sound level
- For a given NC at a given CFM, the spacing between two units is the square root of the quantity (CFM divided by the design CFM per sqft)

Example

- 1400 Diffuser, 8” neck
- NC = 30 @ 380 CFM
- Design load = 0.6 CFM/sqft
- **Spacing = $\sqrt{(380/0.6)}$ = 25**

ADPI FOR MINIMUM FLOWS



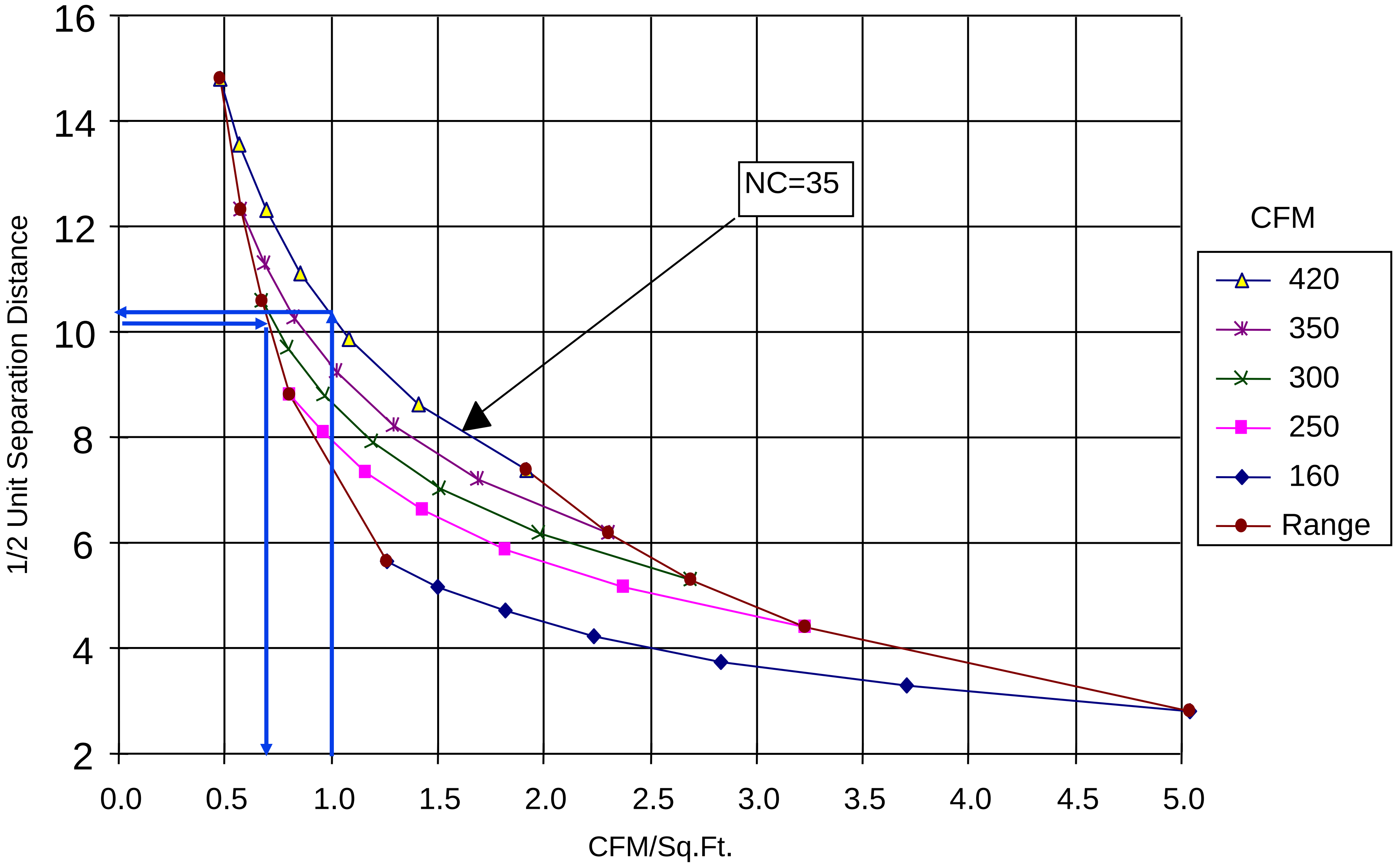
Poor ADPI
representing “dumping”

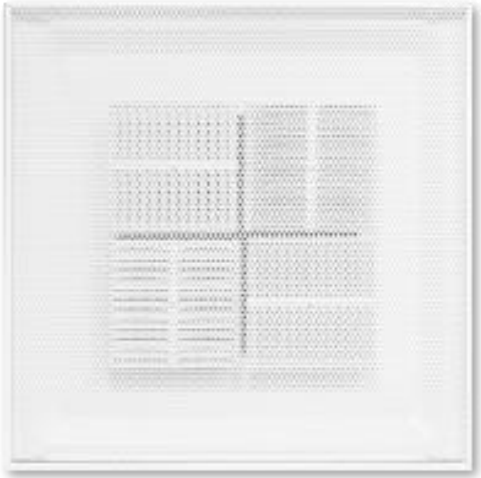
ADPI can help determine the lowest flow at a given separation distance

If an ADPI > 80% is achieved, it can be used to prove compliance to Standard 55’s Vertical Temperature Stratification limit of 5.4°F (3°C)

An ADPI < 80% is likely to result in occupant discomfort and complaints

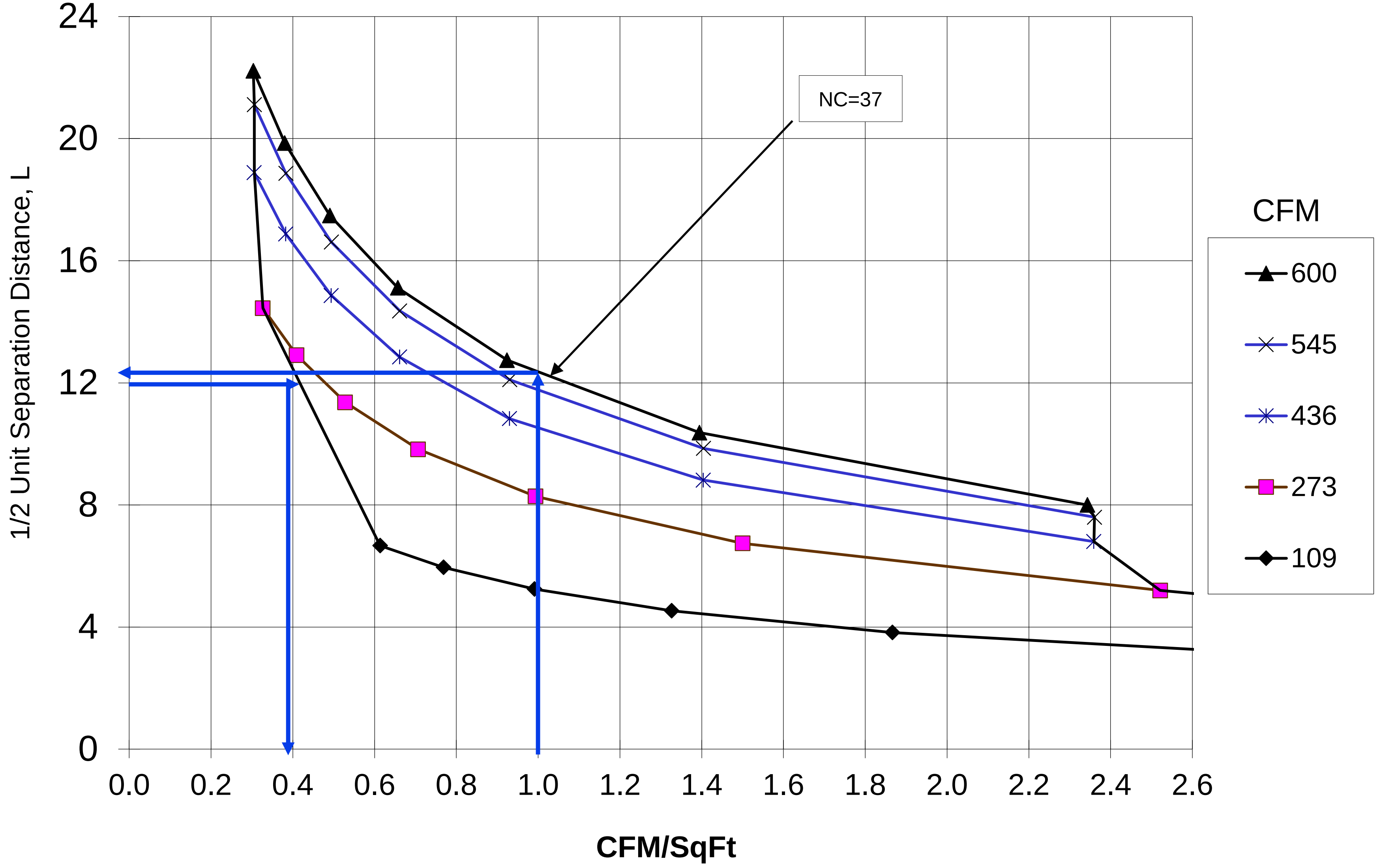
Perforated 24"x24", 10" inlet, 4 way, 20° ΔT
Spacing for 80% ADPI

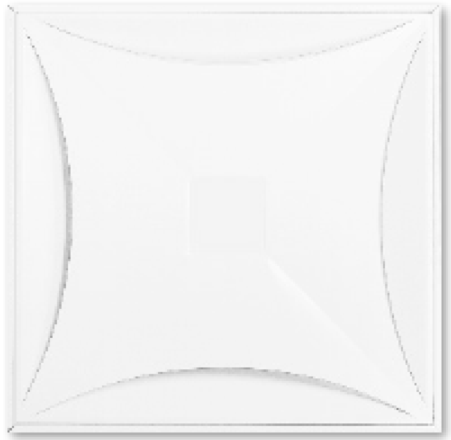




Operation below 0.5 CFM/sqft is probably not a good idea, but it can handle very high loads if required

4 way, 24"x24", 10" inlet, 20°ΔT
Spacing for 80% ADPI





80% ADPI is still achieved when turndown is to 0.4 CFM/sqft

By reducing the flow, you can reduce energy consumption!

QUICK REFERENCE PRODUCT CATALOG TABLES

SIZE		PERFORMANCE - HORIZONTAL THROW				DESIGN			DIMENSIONS
PANEL	NOMINAL INLET	NC (< 25)		NC (25 - 40)		CFM @ NC=30	SPACING @ 0.6 CFM/sf (ft)	MINIMUM CFM/sf	C
		CFM	THROW (ft)	CFM	THROW (ft)				
12"x12"	6"	39 - 177	3 - 12	196 - 300	13 - 17	215	19	0.18	1 1/8" (29)
	7"	53 - 241	3 - 14	267 - 400	15 - 19	285	22	0.19	1 1/8" (29)
	8"	70 - 314	3 - 16	349 - 520	17 - 22	375	25	0.20	1 1/4" (32)
24"x24"	6"	39 - 210	1 - 9	225 - 320	10 - 12	250	20	0.22	1 1/8" (29)
	8"	70 - 340	3 - 13	360 - 515	13 - 16	395	26	0.25	1 1/4" (32)
	10"	109 - 491	4 - 15	510 - 735	16 - 19	570	31	0.26	1 3/8" (35)
	12"	157 - 628	5 - 17	655 - 950	18 - 21	740	35	0.27	1 3/8" (35)
	14"	214 - 840	7 - 20	880 - 1270	20 - 25	980	40	0.28	1 3/8" (35)
	15"	245 - 925	7 - 21	982 - 1400	22 - 26	1100	43	0.29	1 3/8" (35)

Example: square plaque diffuser

UNACCEPTABLE OR NO TURNDOWN

Not all diffusers work at all flows.

SIZE		PERFORMANCE - HORIZONTAL THROW				DESIGN		
PANEL	NOMINAL INLET	NC (< 25)		NC (25 - 40)		CFM @ NC=30	SPACING @ 0.6 CFM/sf (ft)	MINIMUM CFM/sf
		CFM	THROW (ft)	CFM	THROW (ft)			
24"x24"	6"	59 - 216	1 - 7	230 - 375	7 - 11	275	21	N/A
	8"	105 - 314	1 - 7	349 - 550	7 - 13	380	25	N/A
	10"	164 - 420	2 - 8	436 - 730	8 - 13	500	29	N/A
	12"	235 - 515	2 - 8	549 - 863	9 - 13	675	34	N/A
	14"	320 - 641	3 - 10	675 - 1068	11 - 16	800	37	N/A
	16"	419 - 770	4 - 10	837 - 1256	11 - 17	900	39	N/A

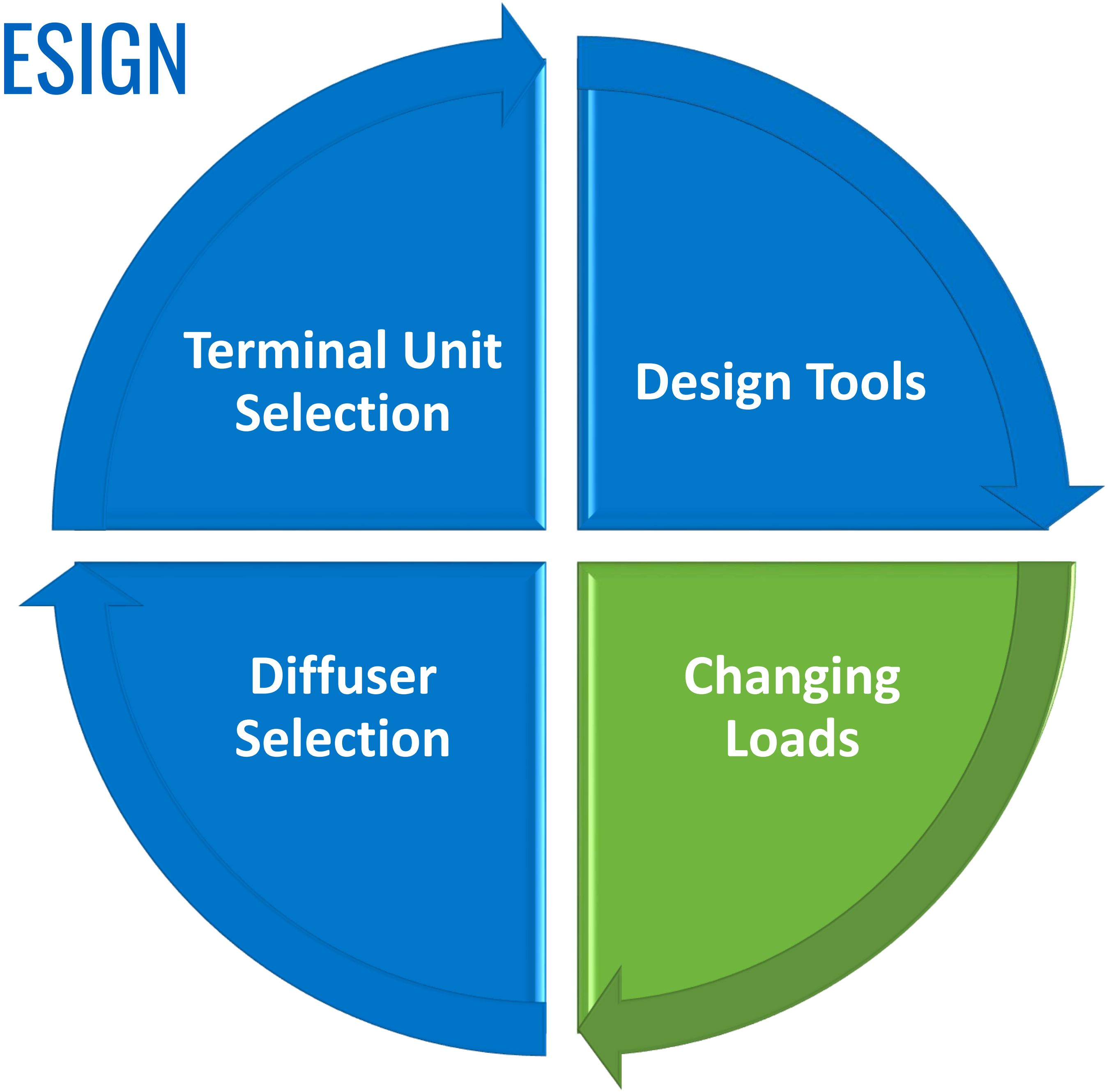
Example: molded fiberglass backpan

- In the quick select catalog, the 6300 has no turndown
- ADPI is actually < 80% at 0.6 CFM/sqft

MEETING STANDARDS

- ASHRAE Standards 62.1 and 90.1 are referenced directly in many (most) codes; Standard 55 (Comfort) is usually referenced but not specified
- **ASHRAE Standards 62.1 and 90.1 are LEED Prerequisites and must be met to be a LEED project; compliance with ASHRAE Standard 55 is worth up to 3 points**
- The ASHRAE Handbook suggests that if discharge temperatures are high, excessive room stratification will be likely
- ASHRAE Standard 90.1 limits the quantity of air that may be reheated; in northern climates, it will be difficult to maintain comfort with single duct reheat systems

SYSTEM DESIGN



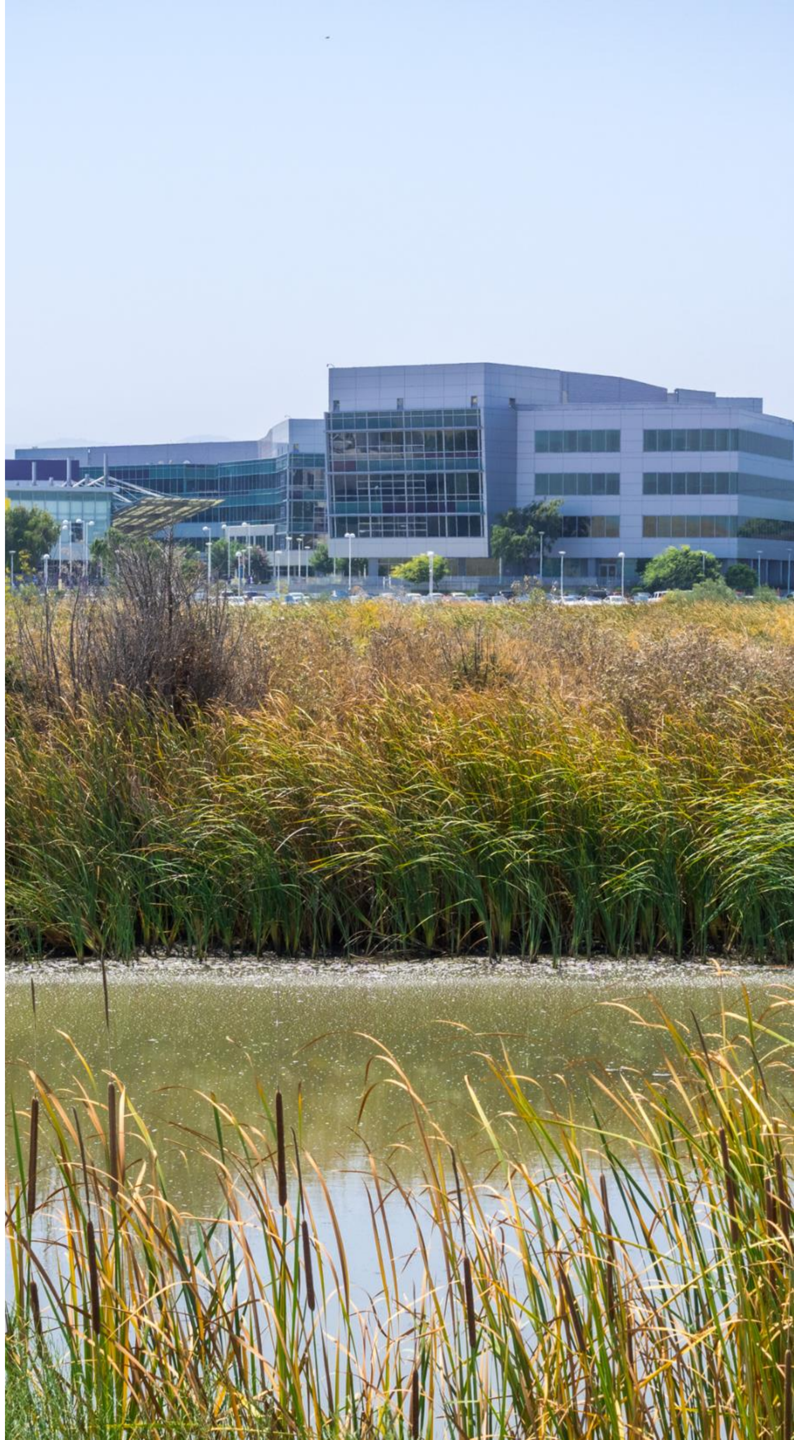
Current **vs** **Future**

CHANGE IS CONSTANT

- Changes in occupancy (conference rooms, auditoriums)
- Changes in seasons (heating vs cooling)
- Actual building loads are significantly lower than the traditional 1 CFM/sqft
- Minimum ventilation rates may now exceed 0.2 CFM/sqft
- The “rule of thumb” that VAV boxes should be set at 30% of maximum is likely driving many spaces below setpoint every afternoon in many offices

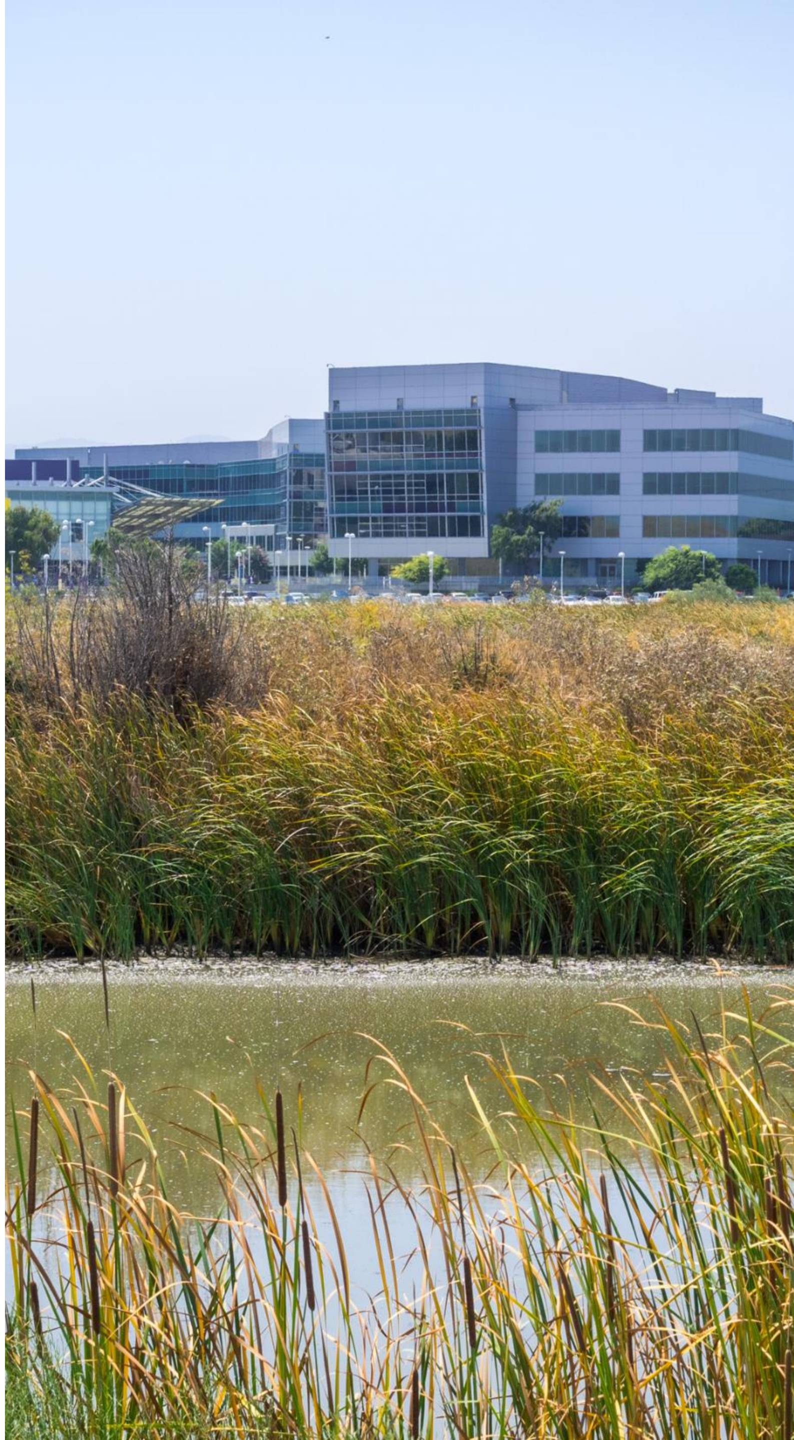
ASHRAE RESEARCH PROJECT 1515

- ASHRAE sponsored a research project in California a couple years ago
- Subject was the Yahoo campus (1M sqft) and a couple other buildings
- They measured occupant satisfaction, equipment operation, environmental variables and energy use
- Yahoo system was DDC single duct VAV reheat
- Interior airflow was set 1 CFM/sqft, 30% turn down
- Diffusers were plaque type



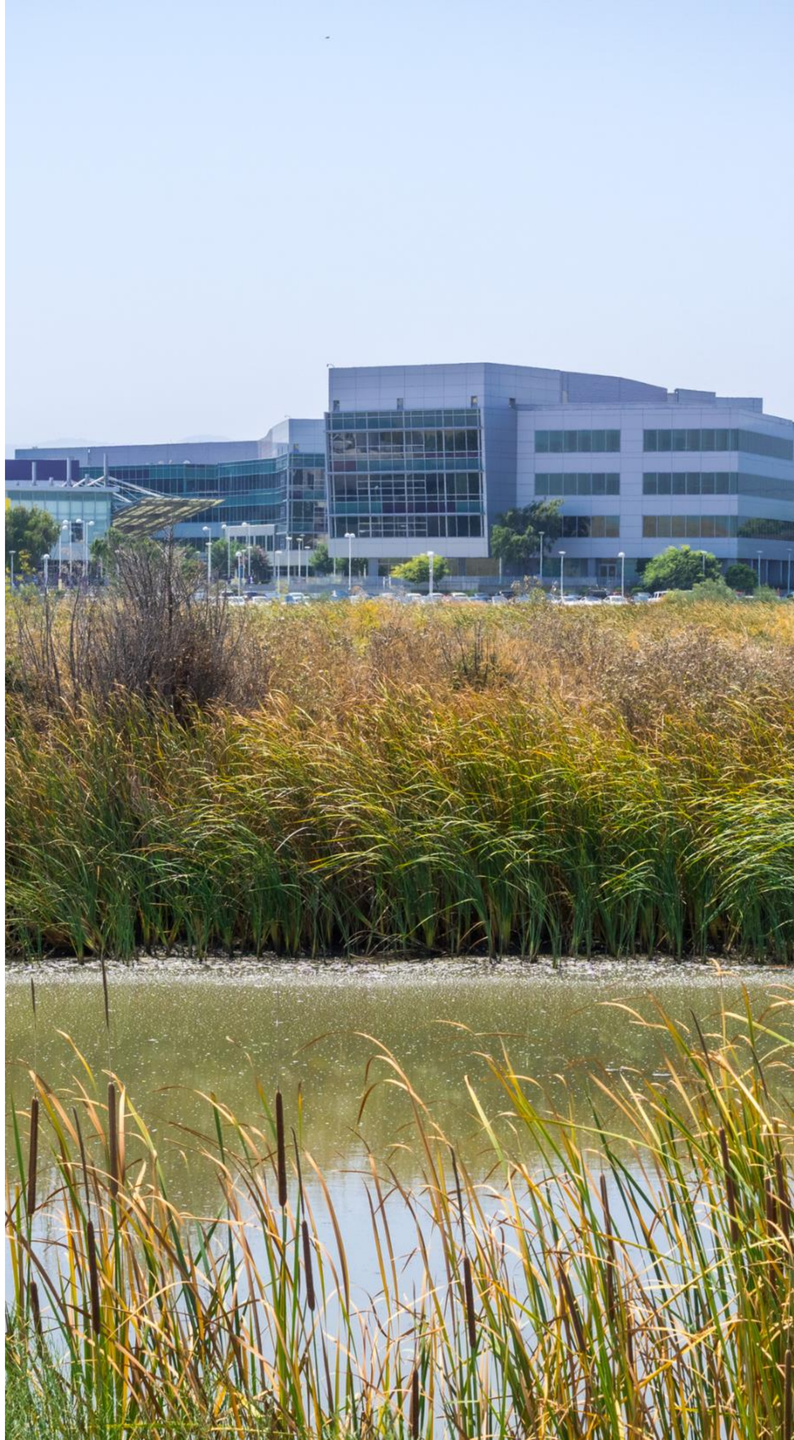
ASHRAE RP 1515: DIAGNOSTICS

- At 30% of max interior airflow, space was getting cold
- When space hit 68°F, VAV boxes went into heating mode, with 68°F setpoint (per California code)
- Space was maintained at 68°F until the end of the day
- VAV boxes were reset to 10% (0.1 CFM/sqft)
- System settled at 0.22 CFM/sqft (= minimum ventilation rate per Title 24)
- Occupant satisfaction soared as space was maintained 73°F
- Boilers shut down

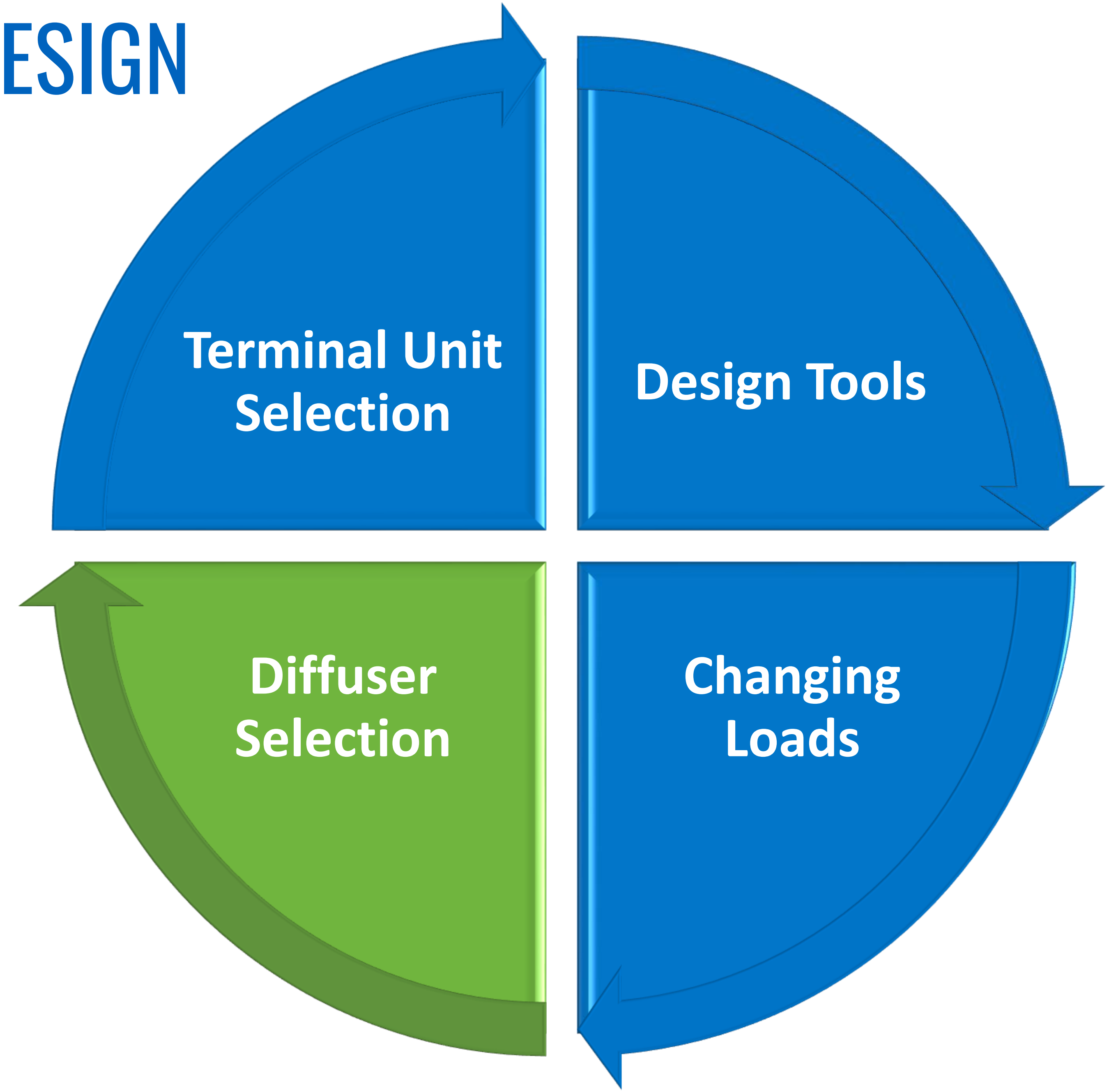


ASHRAE RP 1515: CONCLUSIONS

- Interior loads are far less than 1 CFM/sqft (the national average)
- Occupant satisfaction above 80% can be achieved at 0.22 CFM/sqft (with good diffusers)
- Interior loads are close to 100% outside air, meaning 100% of interior loads are discharged, not returned to air handler
- The load in the building is controlled where outside air is introduced into the building, not by equipment in the zone
- PS: This is Huge!



SYSTEM DESIGN



WHERE DO I PLACE MY OUTLETS?

IT DEPENDS!

Aesthetics

Performance

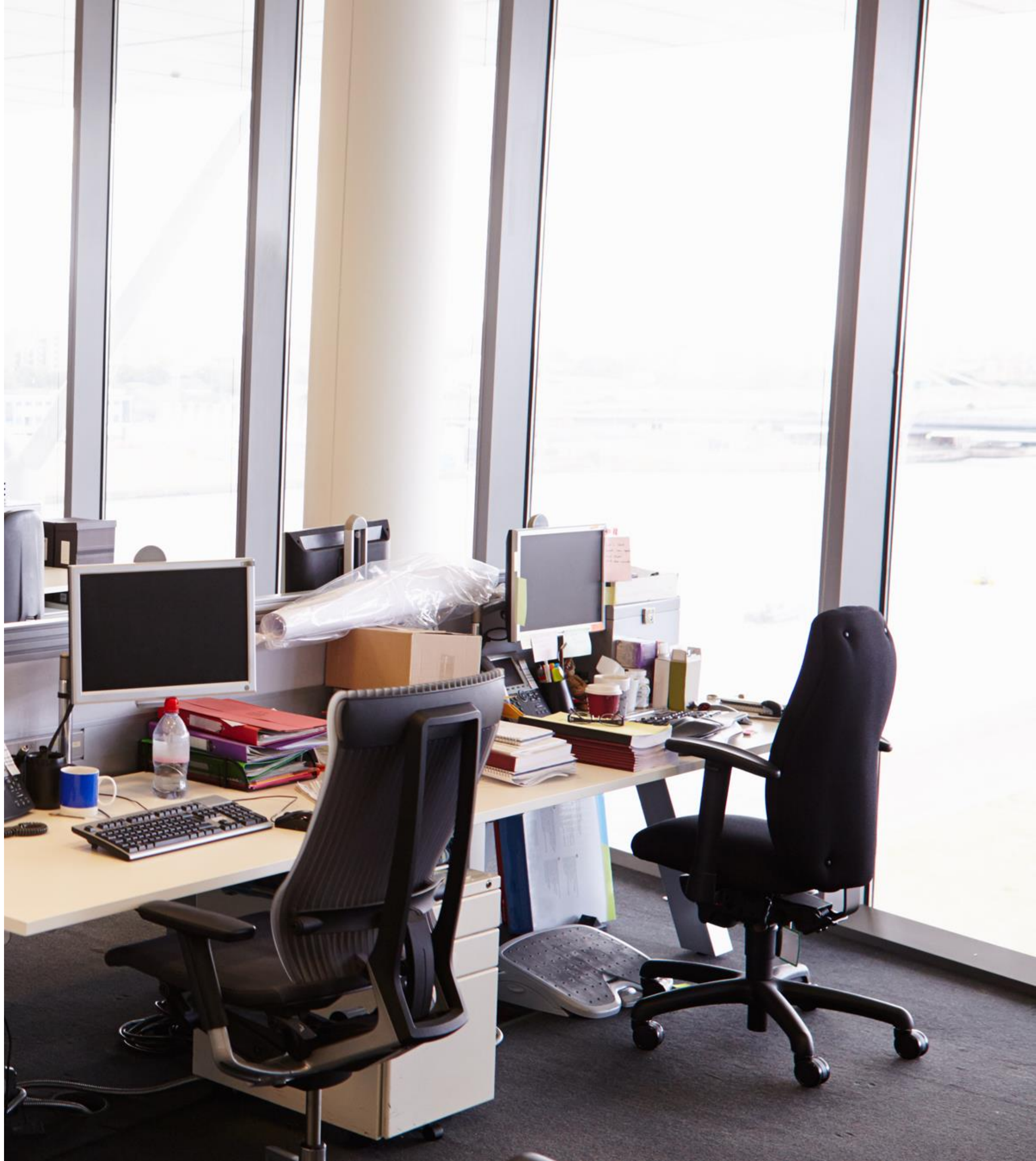
Cost

KRUEGER

Perimeter vs Interior

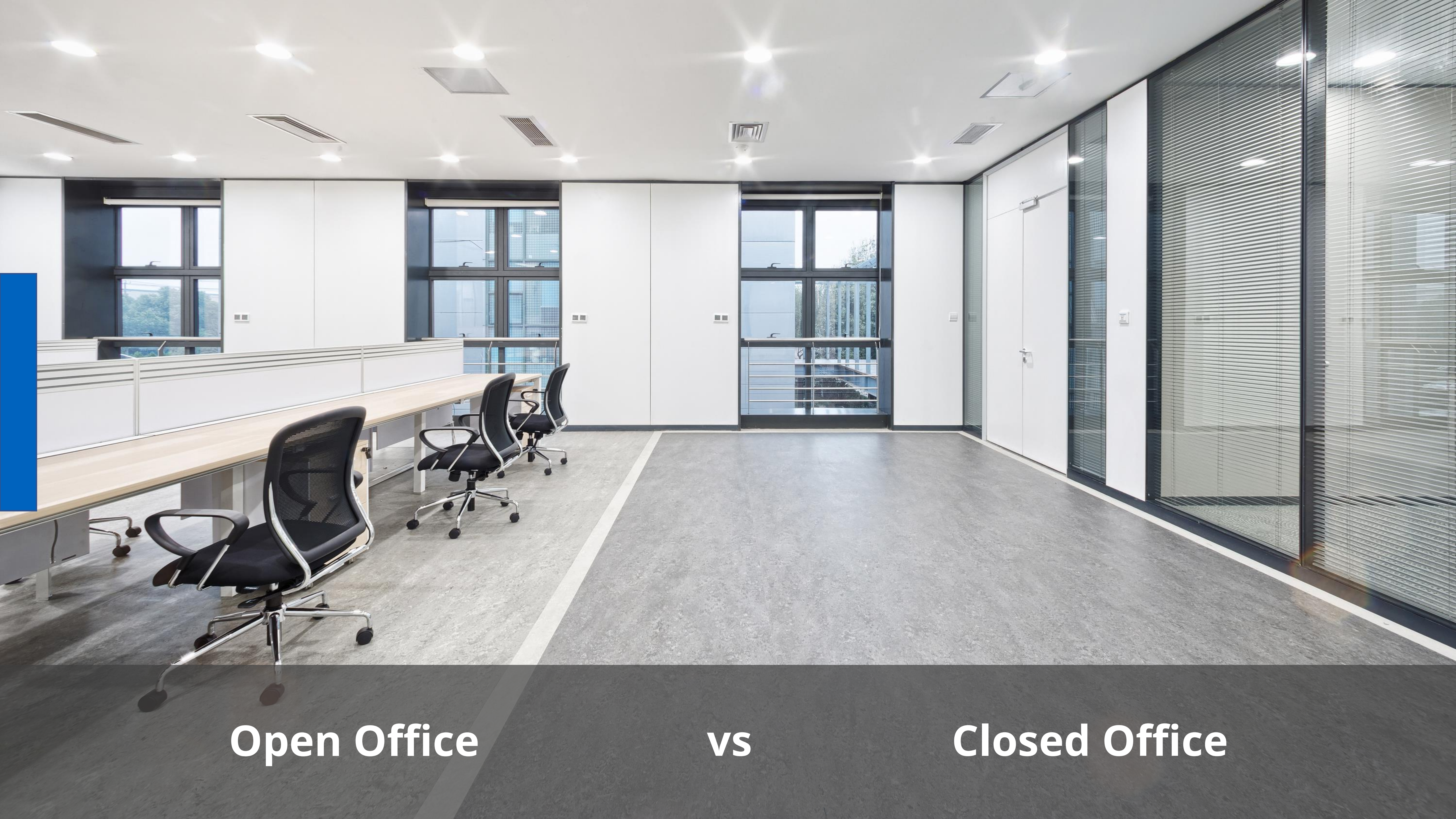
PERIMETER ZONES

- Cold window surfaces generate a downward convective flow
- Effective overhead heating requires that room discharge delta-t never exceed 15°F to avoid stratification
- ASHRAE Standard 62.1: If the delta-t exceeds 15°F, or if the 150 fpm throw doesn't make it down to within 4.5 ft of the floor, ventilation air will short circuit out ceiling returns, requiring additional ventilation



INTERIOR ZONES

- Interior = 15 ft from a perimeter surface
- Independent of outside temperatures and humidity
- Code mandated minimum ventilation rates is supplied with cold air, which may exceed space loads
- Additional recirculated warm plenum air can mitigate the sub cooling with mixing devices


Open Office
vs
Closed Office

OPEN OFFICE

- Many office spaces today are open plan offices

- Partitions divide the workplace and provide some acoustical privacy

- Multiple diffusers are usually required; jet patterns and potential collisions of airstreams need to be evaluated

- With a suspended ceiling around 9ft high, ADPI can be used

CLOSED OFFICE

- A closed office usually needs only a single air supply outlet
- ADPI is not a meaningful tool in closed offices when the outlet airstreams wash down walls
- Turn down on a diffuser, however, is an important concern, as the outlet is almost always located over the office occupant

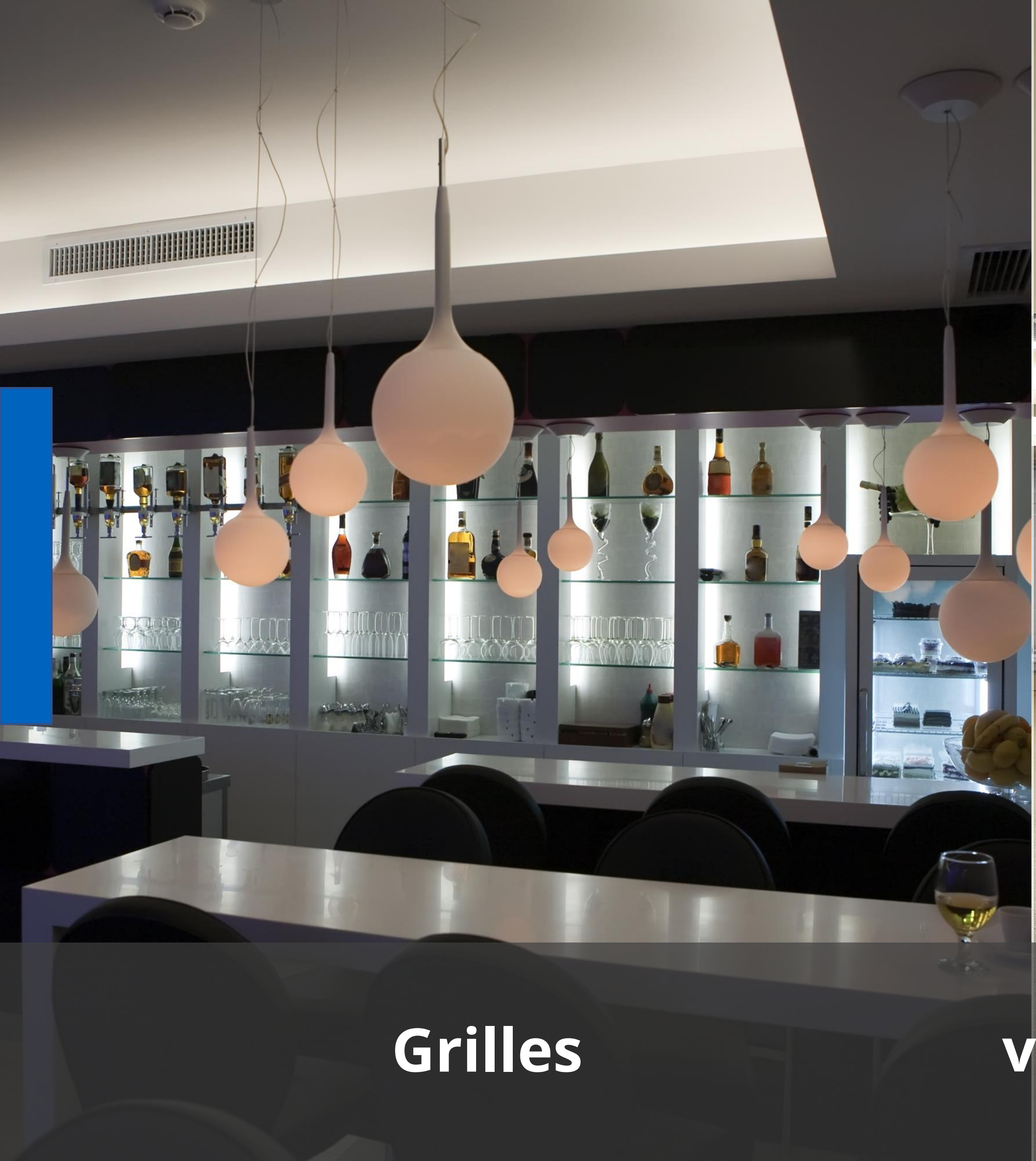

Open Ceiling
vs
Closed Ceiling

OPEN CEILING

- Most catalog throw data is along a surface; if there is no ceiling, throw is shortened by about 30%
- The larger the diameter of the supply duct, the more uniform the discharge is from a short drop
- Round diffusers on spiral drops is the optimal solution
- Most round diffusers have a slightly upward discharge pattern when there is no ceiling

CLOSED CEILING

- With the air outlet located in the ceiling, the air jets flow along a surface, keeping cold supply air from falling into the space
- ADPI calculations assume flow along a surface and a ceiling to floor distance of about 9 ft
- If ceilings heights are greater than 10 feet, jet collision mapping should be performed



Grilles vs **Diffusers**

GRILLES

- Seldom used in open plan offices
- Spacing between outlets is used to determine the area served at a given design flow rate
- Grille throws may be shortened by increasing the spread; excessive drop can be controlled by horizontal blades being adjusted
- Throws to 100 fpm from opposing grilles should never meet to avoid drafts

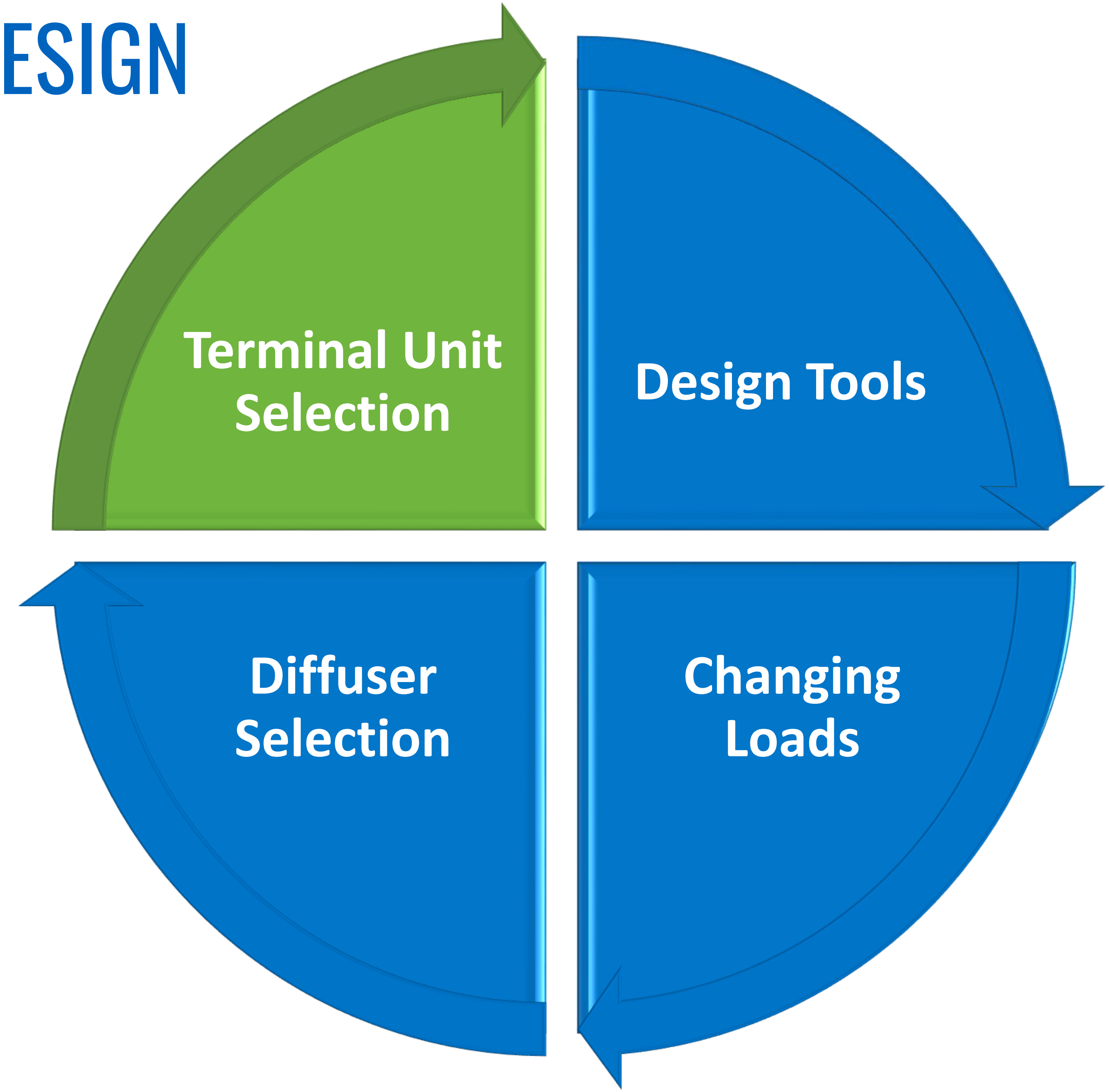
PERIMETER DIFFUSERS

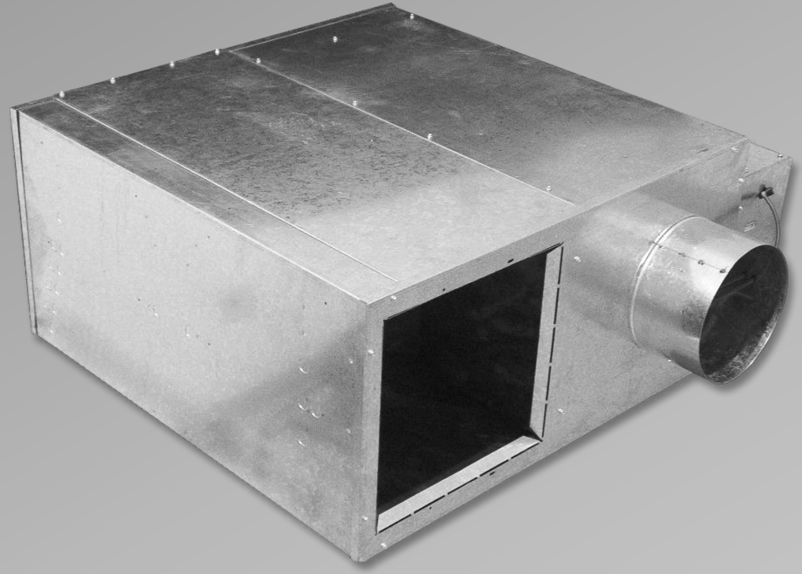
- Perimeter outlets must be close enough that the 150 fpm throw, at the heating CFM, will project down the window

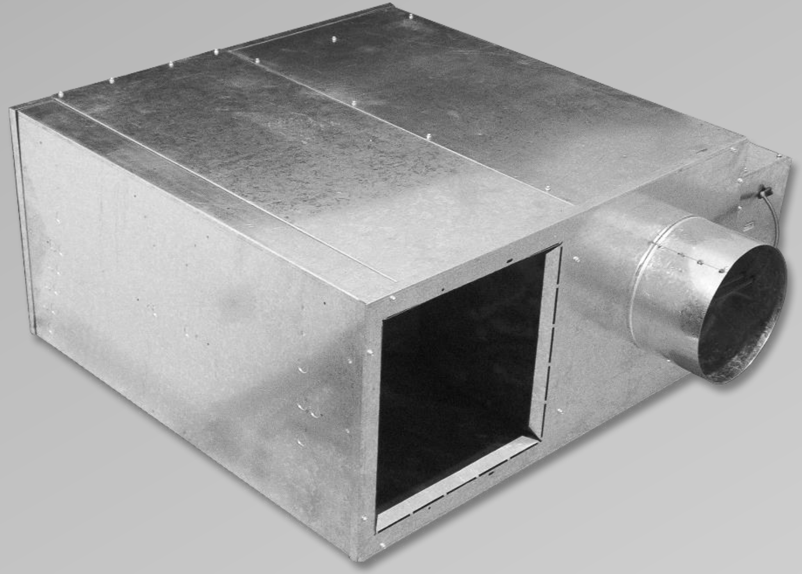
- For perimeter slots, locate them a couple feet away from the window with 2 way discharge – make sure they are adjusted!

- ADPI doesn’t work in heating (yet)

SYSTEM DESIGN







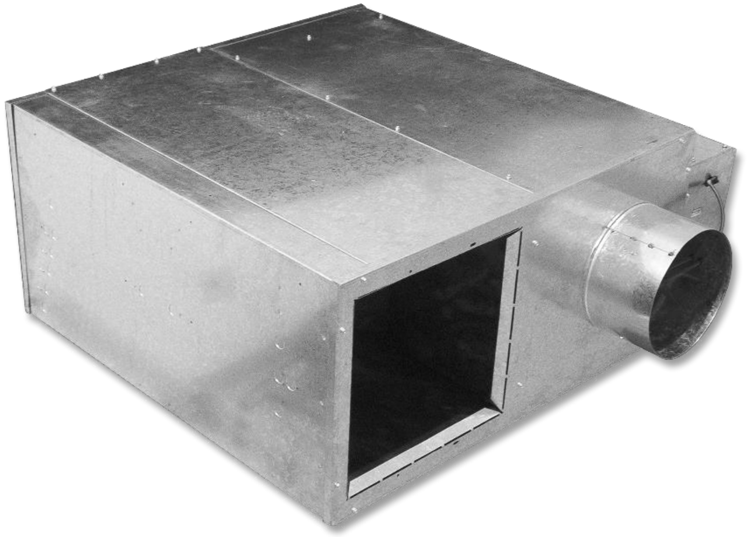
Single Duct vs Parallel FPU vs Series FPU

SINGLE DUCT TERMINAL UNIT

- Single duct VAV systems have been in common use for over 50 years
- With a reheat coil, it may be able to either control or supplement baseboard or radiant heating of a perimeter zone
- ASHRAE Standard 90.1 limits how much cooling air can be reheated
- ASHRAE Standards 62.1 and 55 limit the discharge temperatures to avoid stratification

PARALLEL FAN POWERED TERMINAL UNIT

- Parallel units induce plenum air on demand for heating, *in parallel* with a VAV damper; airflow rates for fan and VAV damper are independent
- With a parallel unit, the central system fan must deliver air to the diffuser, passing through it
- The fan in the parallel unit is typically off when in cooling demand
- Heat generated by the motor is transmitted into the space, potentially making the fan 100% efficient



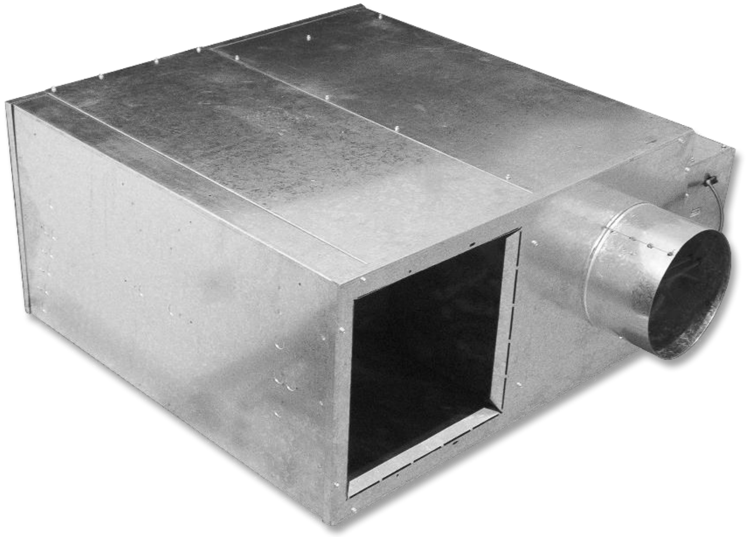
SERIES FAN POWERED TERMINAL UNIT

- Series units induce plenum air, which mixes with primary air from the VAV damper, then passes through the fan; the fan must always deliver more air than the VAV valve to prevent backflow into the ceiling plenum

- The result is a lower supply duct minimum static pressure requirement for series systems than with parallel systems

- Series unit fans must run at all times during occupancy

- **A series unit with an EC motor can be turned down close to the primary (VAV) airflow**



If the fan airflow is varied, rather than operating at constant airflow, energy savings can be significant

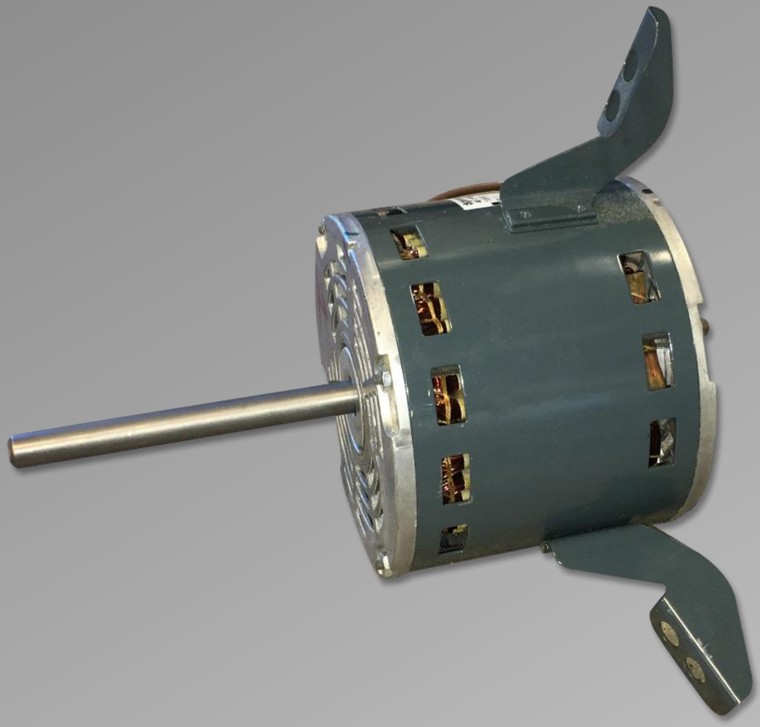
MINIMUM AIRFLOW AT THE INLET

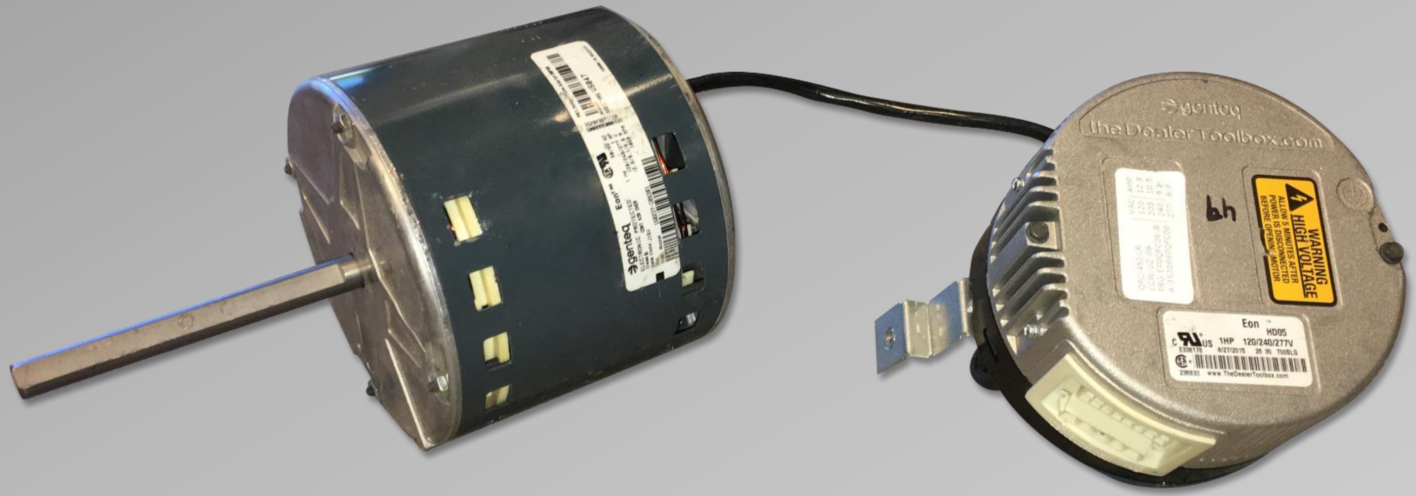
- The primary airflow sensor on a VAV box, typically a multi-point averaging sensor, has been shown to be repeatable down to very low airflows

- The probe is designed so that signal is greater than a pitot tube, different for each manufacturer

- A probe signal of 0.03" has traditionally been a lower design limit, based on pneumatic control capabilities; DDC controllers are capable of operation at much lower signal pressures

- A signal of 0.01" is now reasonable minimum, although some DDC manufacturers claim acceptable performance down to 0.004"

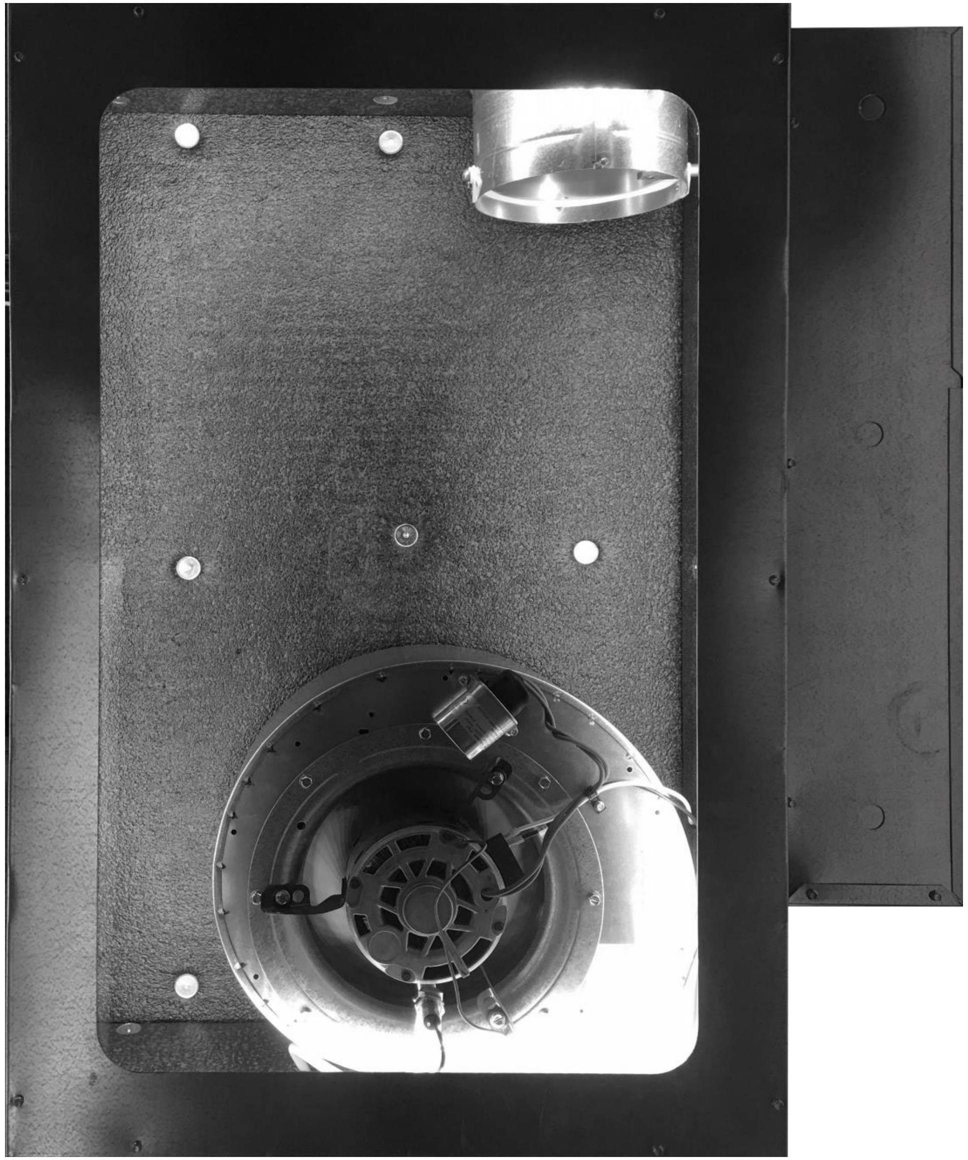




PSC Motor **vs** **EC Motor**

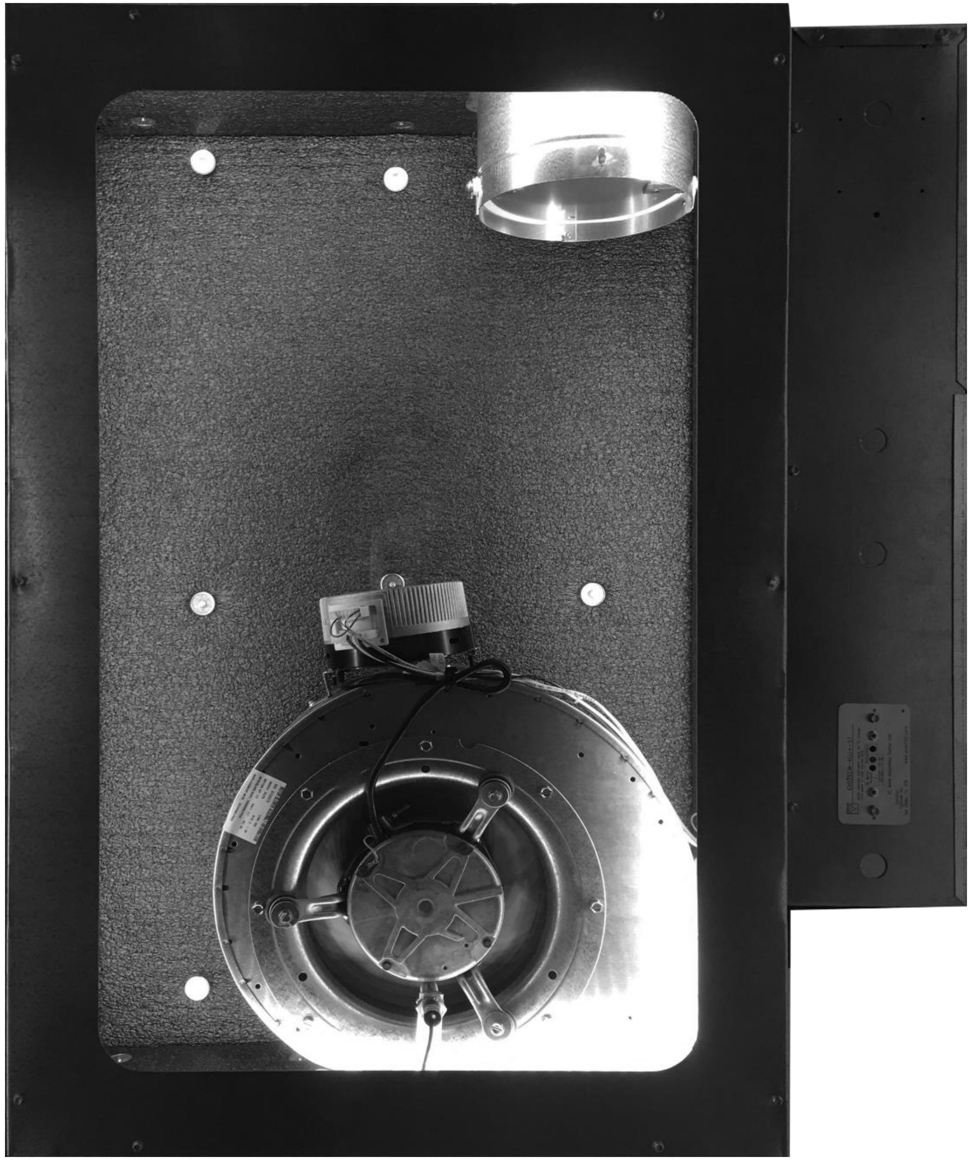
PSC MOTOR

- The PSC motor is a constant speed capacitor start induction type motor
- Some are wired for “three speed” operation, although in practice they are “three torque” motors
- The addition of an SCR speed controller can reduce a motor’s speed, but not significantly enough to reduce energy consumption



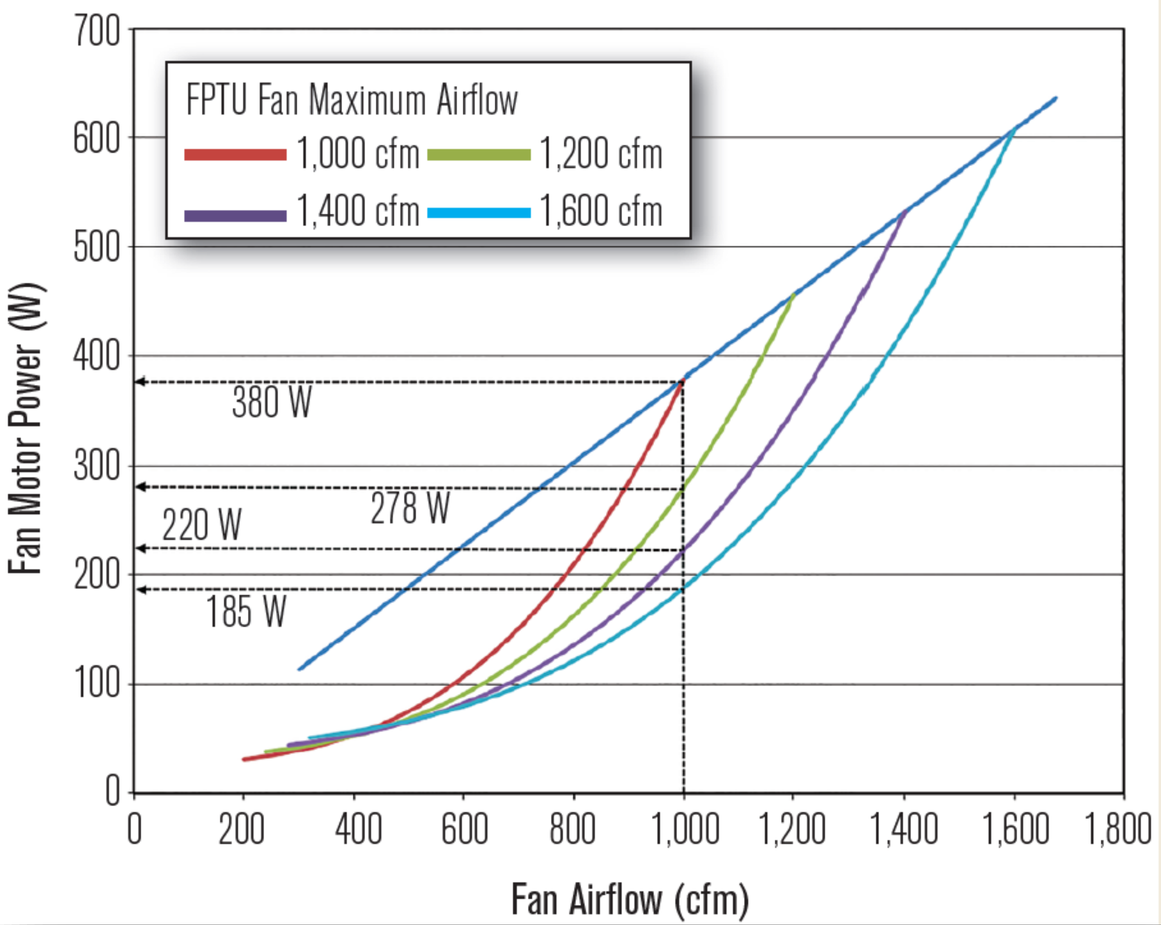
EC MOTOR

- The Electrically Commutated Motor is controlled by an embedded DDC controller, which regulates the speed
- The energy data from an ASHRAE/AHRI research project shows that (in most situations) series units with EC motors will use less energy than a parallel box with either type of motor
- **Combined with the lower system pressure drop of a series unit configuration, it is usually the lower energy use solution**



MEASURED ENERGY CONSUMPTION

FIGURE 4 Sample plot showing how sizing ECM FPTUs affect fan power.



WHY MINIMUM AIRFLOW INTO THE SPACE?

- It will use significantly less energy when turned down, compared to design airflow
- The choice and spacing of diffusers is a major determinant in how far units can be turned down
- If a series unit is coupled with a sensible cooling coil on the induction port, further gains in efficiency will be realized with extended economizer operation

SUMMARY

- Diffuser spacing, turndown, and ADPI
- Considerations with environment changes
- Considerations in diffuser selection
- Considerations in VAV selection

QUESTIONS & CONTACT INFORMATION

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Read my HVAC Blog!