Basics of ROOM AIR DISTRIBUTION and ADPI

Dan Int-Hout

Chief Engineer / Krueger

Richardson Texas

And

Keith Miller

Samuel Tepp Associates

Office: 732-548-7398

Cell: 201-638-6591

Paul Cenci, P. E.-Principal

Brian England-Principal

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Agenda

- Diffuser performance terminology
- Thermal comfort and ASHRAE Air Diffusion Performance Index (ADPI)
- LEED V3 air distribution prerequisites
- Selecting air distribution components and system parameters for effective air mixing.
- ASHRAE Standard 55-2010Thermal Comfort and determining optimum occupant comfort strategies
- Predicting end use acoustic environments
- Ventilation requirements of ASHRAE Standard 62.1-2010 and air distribution component selection
- Effects of diffuser selection on project cost

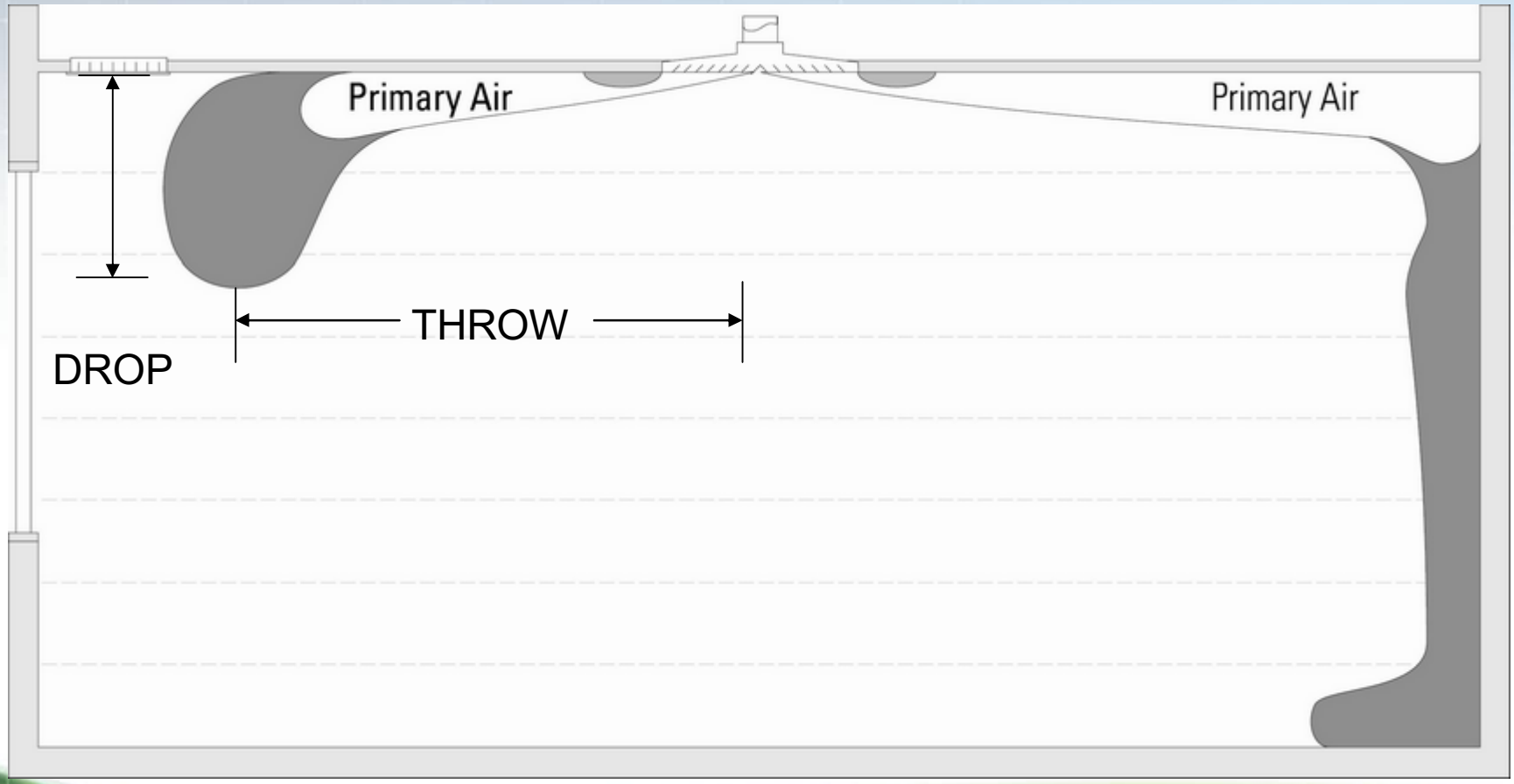
Terminology

Understanding The Terminology

Primary Air Jets - Air jets from free round openings, grilles, perforated panels, ceiling diffusers and other outlets can be defined by three variables.

- Throw
- Drop
- Spread

Understanding The Terminology



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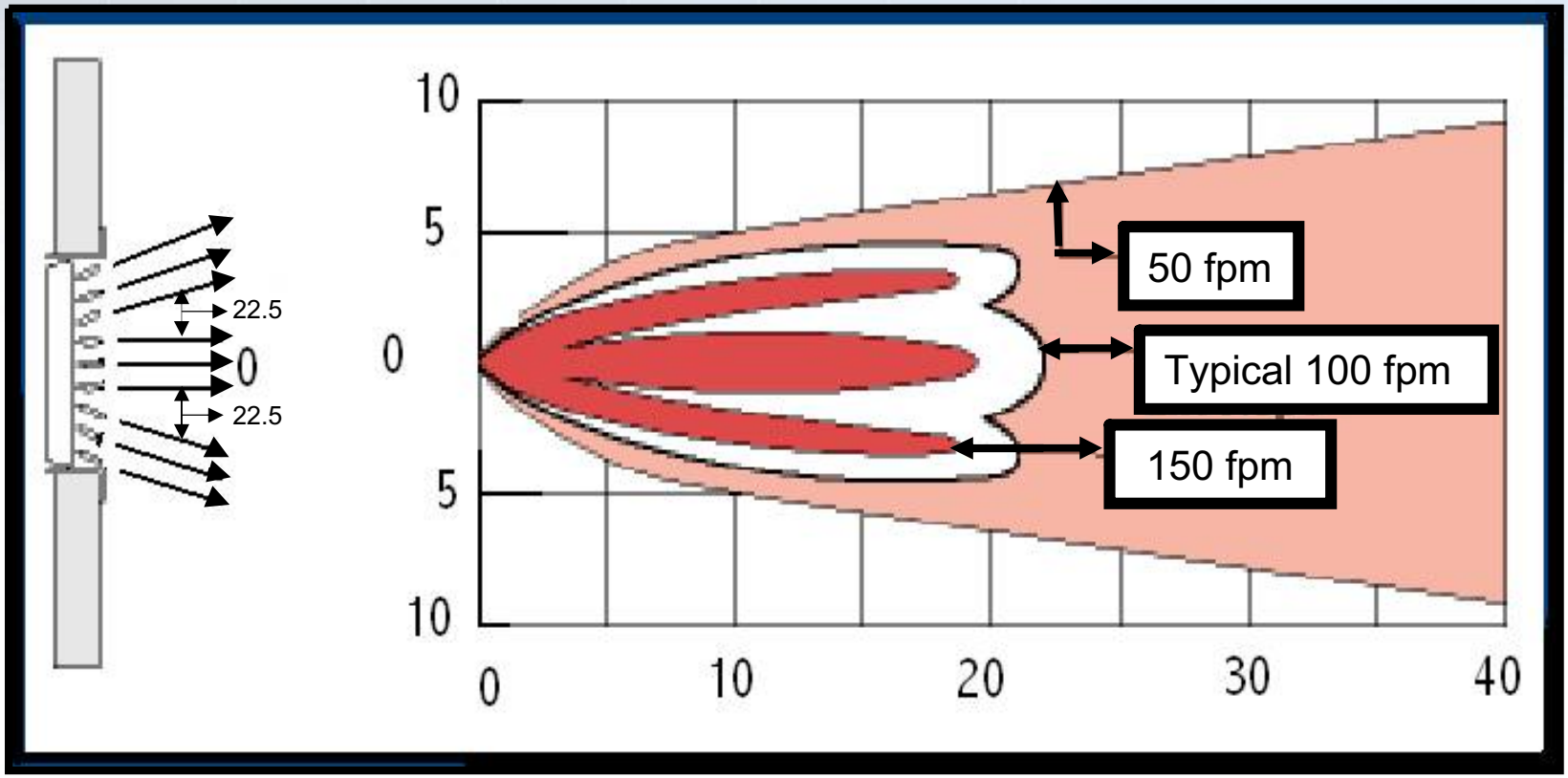
Understanding The Terminology

Spread - is defined as the divergence of the airstream in a horizontal or vertical plane after it leaves the outlet.



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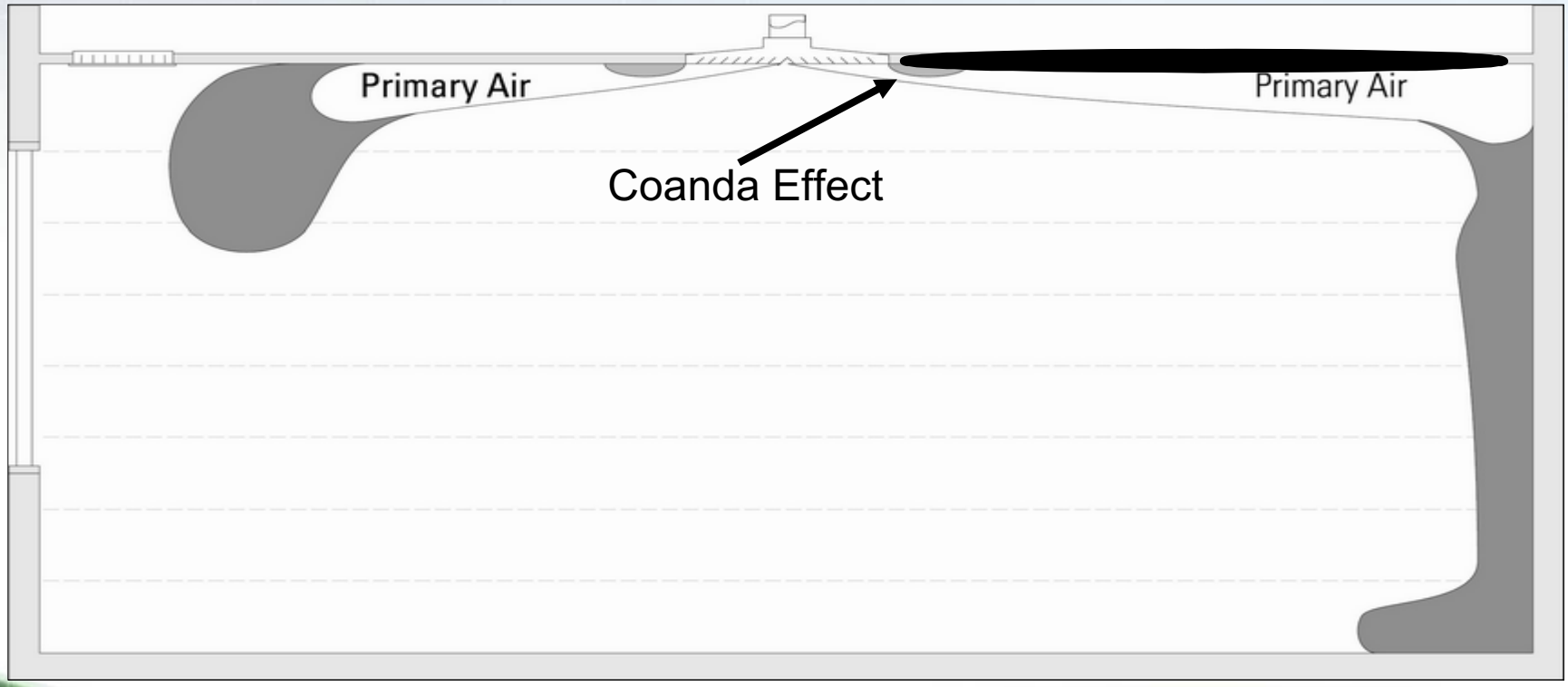
Understanding The Terminology

Coanda Effect - a negative or low pressure area is created between the moving air mass and the ceiling at or near the supply air outlet. This low pressure area causes the moving air mass to cling to and flow close to the ceiling surface and increases the throw.



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Understanding The Terminology

Understanding primary air jet variables enables

- Accurate prediction of room air flow
- Improvement of thermal comfort
- Proper selection of grilles, registers and diffusers
- Adherence with ASHRAE Ventilation Std 62.1 as a Leed **PREREQUISITE**

Understanding The Terminology

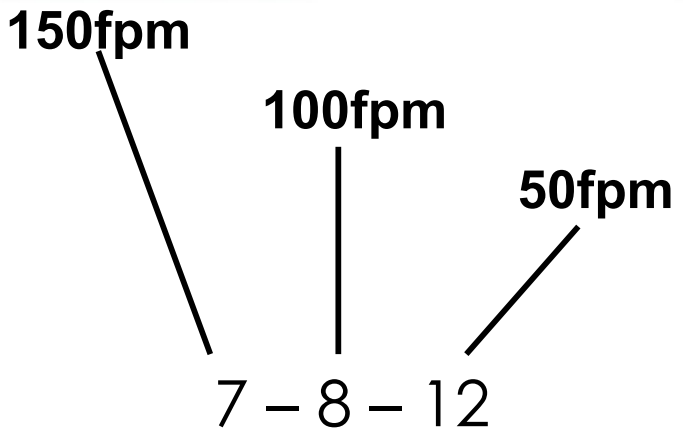
The Basis of Catalog Performance Data

- **Throw – The horizontal or vertical axial distance an airstream travels after leaving an air outlet, usually assumes a surface adjacent to the air outlet**
- **Pressure – Can be total pressure or static pressure**
- **Sound – Can be either NC or Octave Band data**

Throw

- **Throws are cataloged for 150, 100 and 50 fpm terminal velocities.**
- **Throws should be selected so that jets do not collide, but have sufficient projection for the area to be served.**

	IP Data					
	Neck Vel	Air Flow	Pt	Ps	Throw	NC
	FPM	CFM	"WG	"WG	ft	
6" Dia.	200	39	0.004	0.002	1 - 1 - 4	-
	300	59	0.009	0.004	1 - 3 - 6	-
	500	98	0.026	0.010	3 - 5 - 8	-
	600	118	0.037	0.015	4 - 6 - 9	-
	700	137	0.050	0.020	4 - 6 - 10	-
	800	157	0.066	0.026	5 - 7 - 10	12
	900	177	0.083	0.033	6 - 8 - 11	16
	1000	196	0.103	0.041	6 - 8 - 11	19
	1100	216	0.124	0.049	7 - 8 - 12	22



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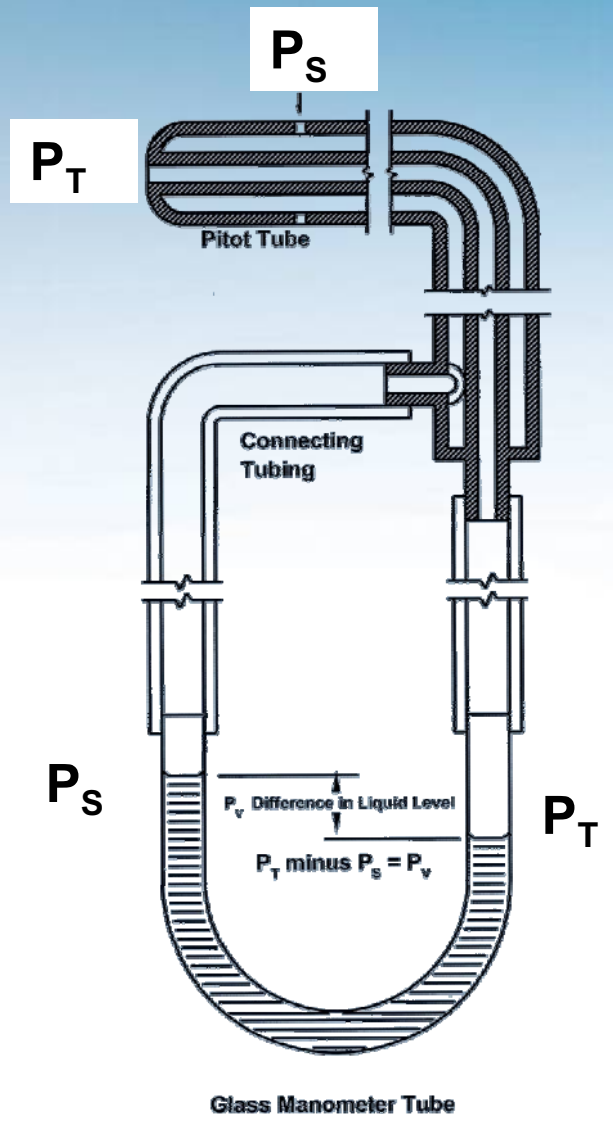
Pressure

Pressure – Air outlet pressure data is required to properly size the air delivery system within a building.

- **<u>Static Pressure</u> – The outward force of air within a duct, measured in inches of water column.**
- **<u>Velocity Pressure</u> – The forward moving force of air within a duct, measured in inches of water column.**
- **<u>Total Pressure</u> – The sum of the velocity and static pressures, expressed in inches of water column and can be obtained by use of a pitot tube.**



$$P_T = P_V + P_S$$

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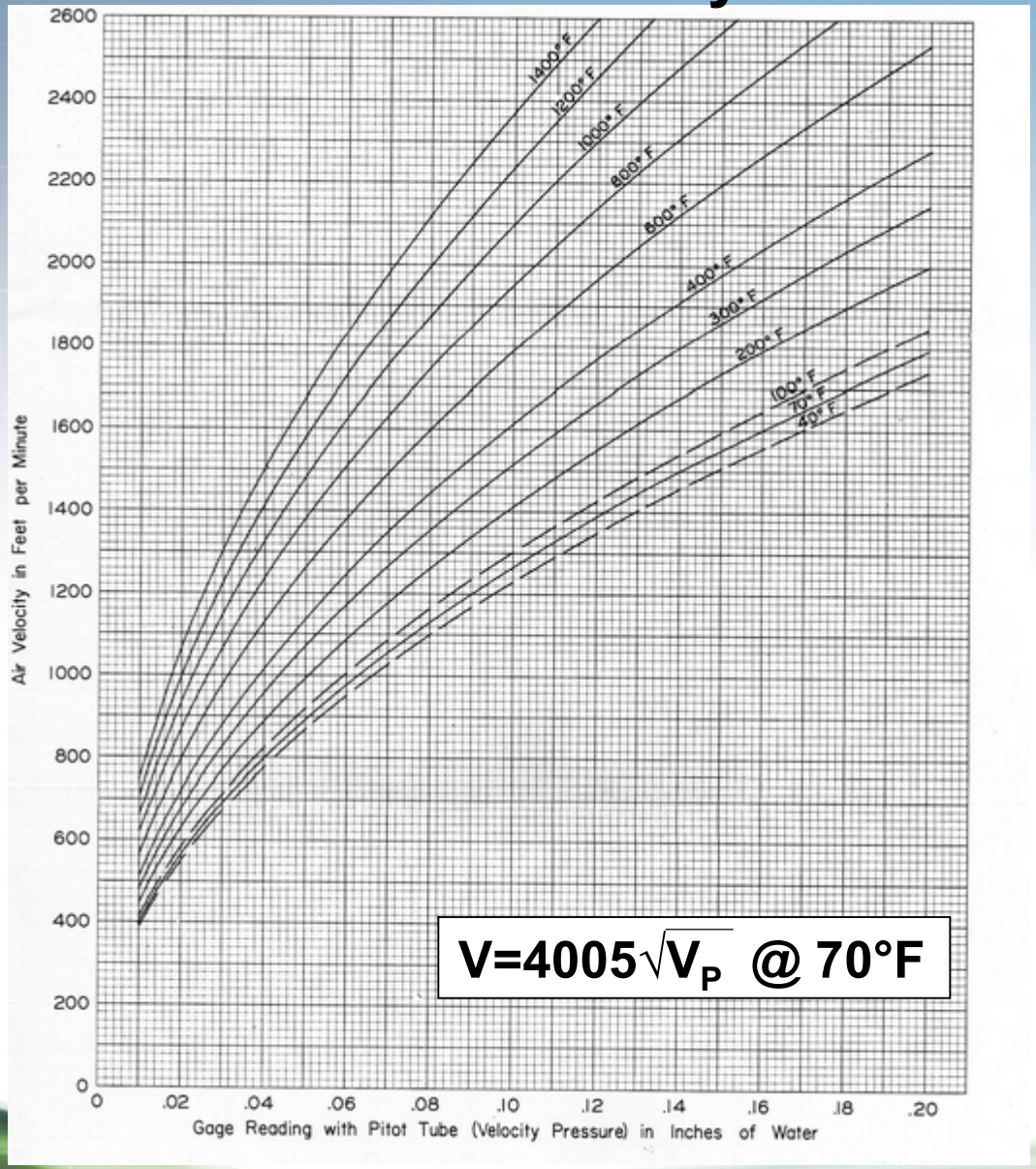
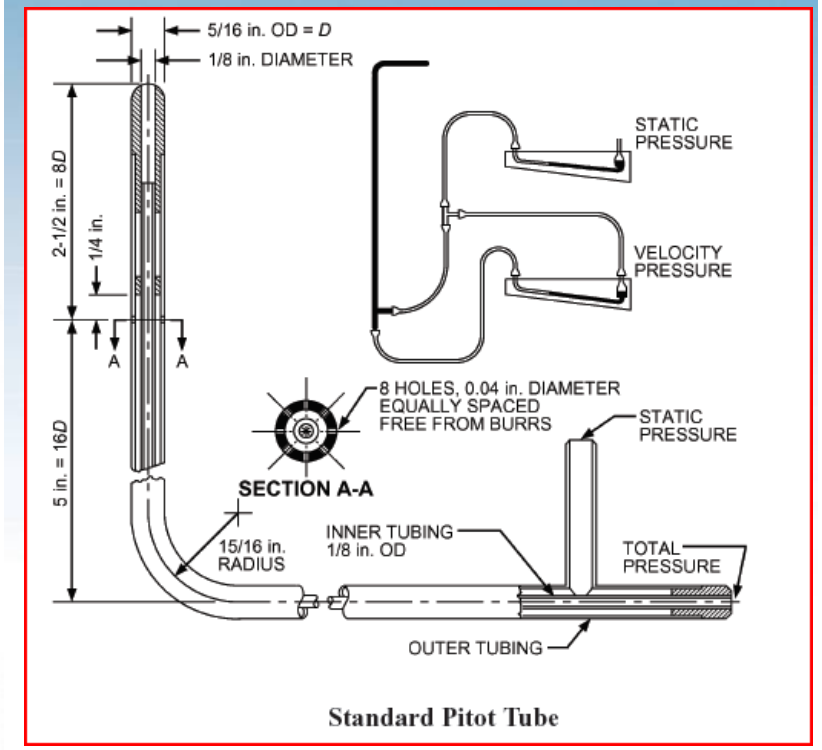
Air Velocity vs. Velocity Pressure



$V=4005\sqrt{V_P}$ @ 70°F



Standard Pitot Tube

CFM = Velocity X Area

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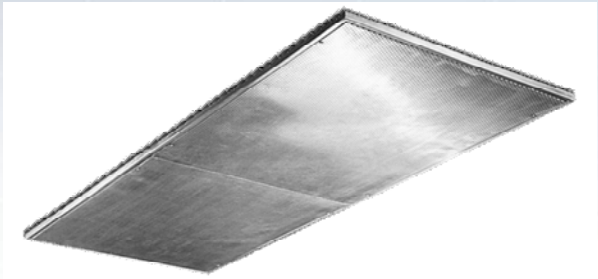
Sound

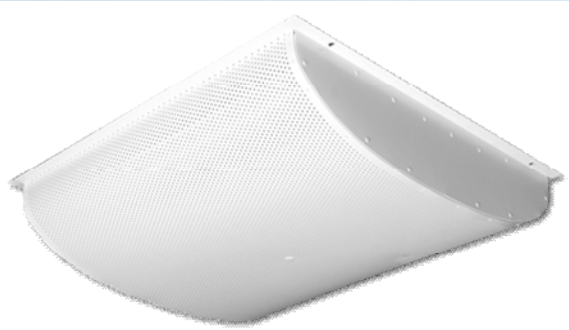
Sound levels reported for diffusers are conducted in accordance with ASHRAE Standard 70.

- **Catalog sound data assumes 10 diameters of straight duct.**
- **Room absorption is assumed to be 10dB in all bands.**
- **In practice however, room sound levels are probably 5 NC higher than reported.**

Non-Inductive Air Distribution- Laminar and Radial Flow Outlets



Laminar Flow



Radial Flow

- Hospital Operating Suites
- Hi-Tech Electronics and other industrial applications
- Clean Rooms
- Laboratories

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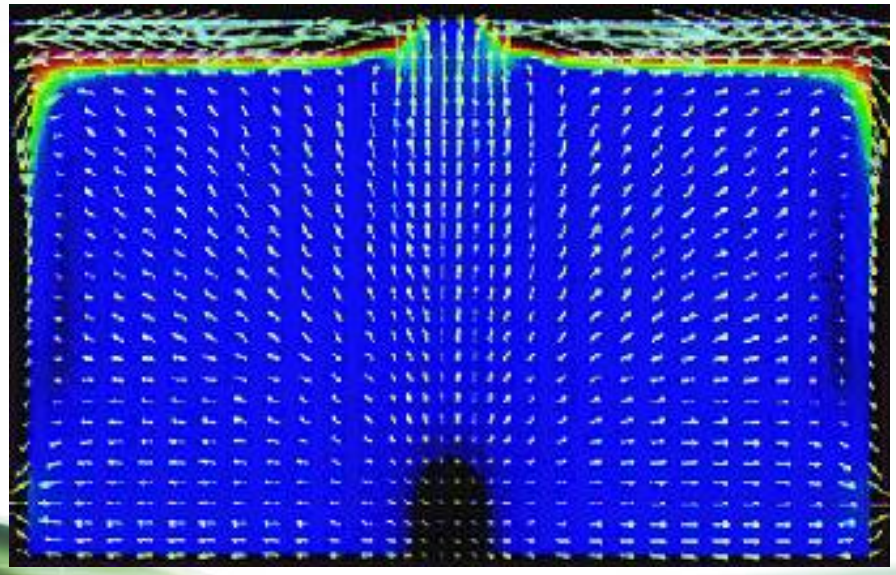
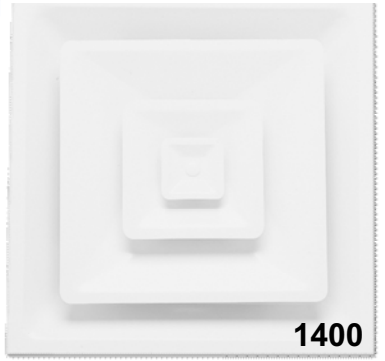
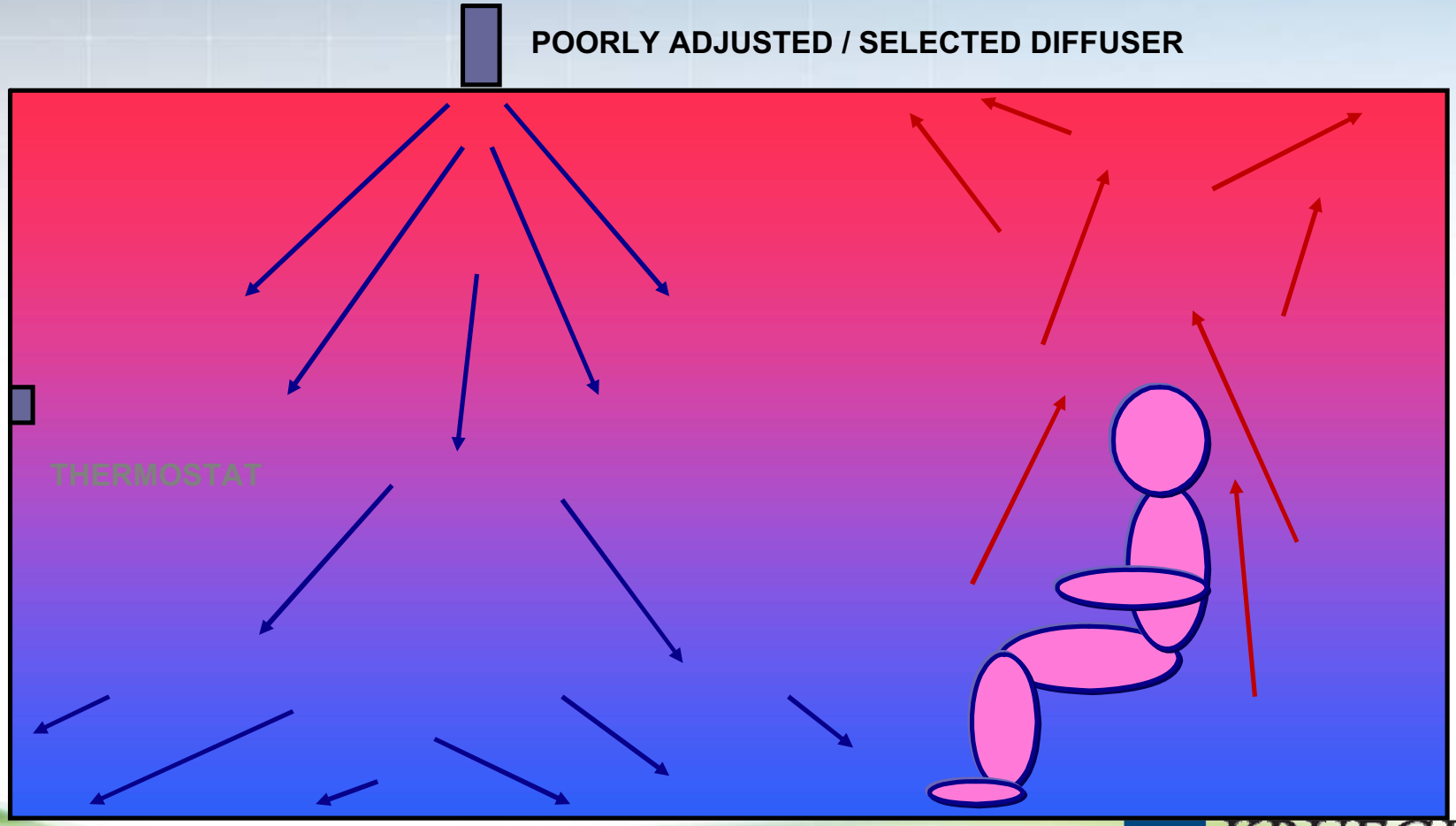
Well Mixed-High Induction Diffusers

- Commercial Office Spaces
- High Velocity Jets
- Long Throw
- Designed to Mix in Zone





Air Distribution, Poor Pattern



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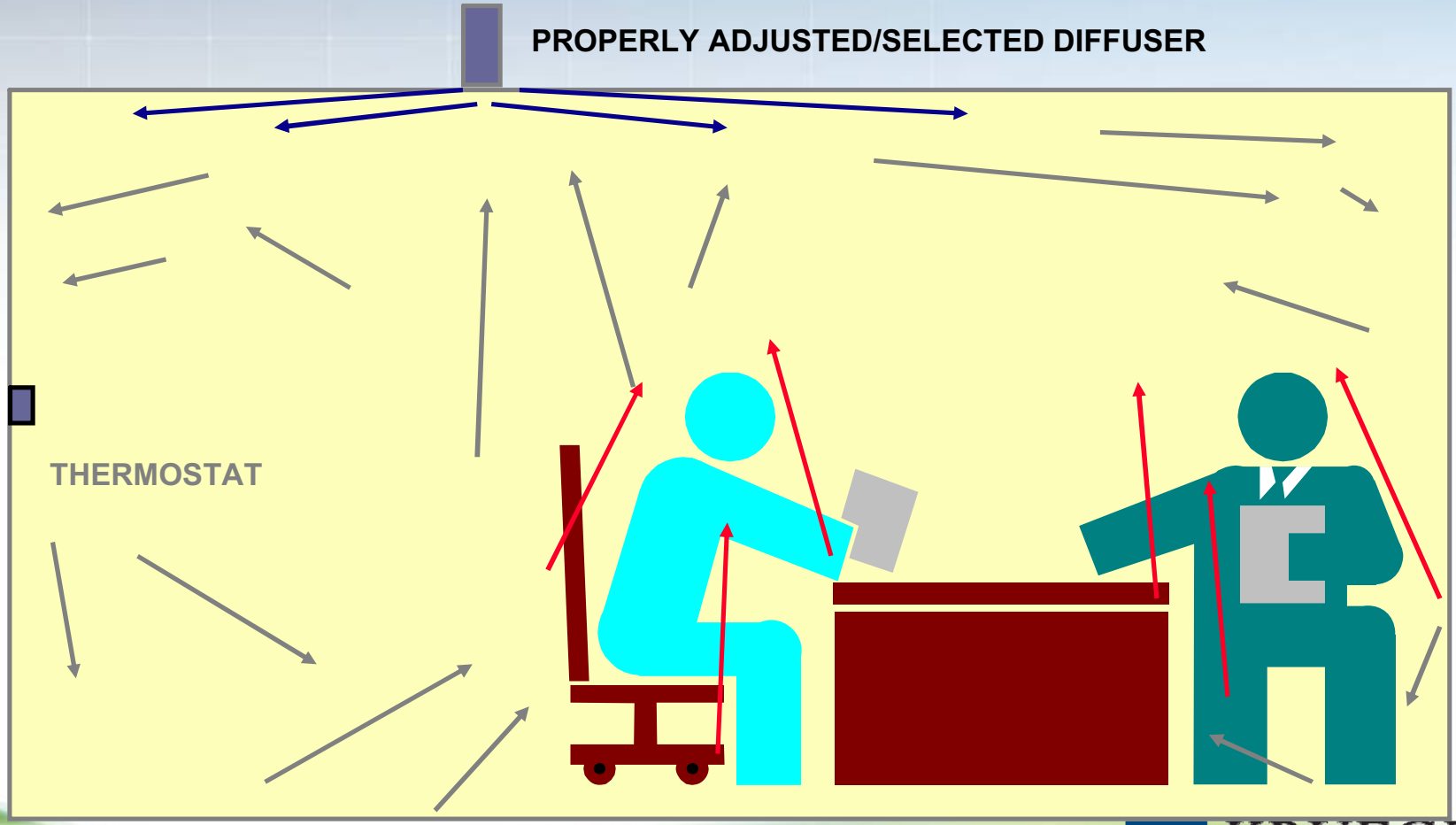
Air Distribution, Good Pattern



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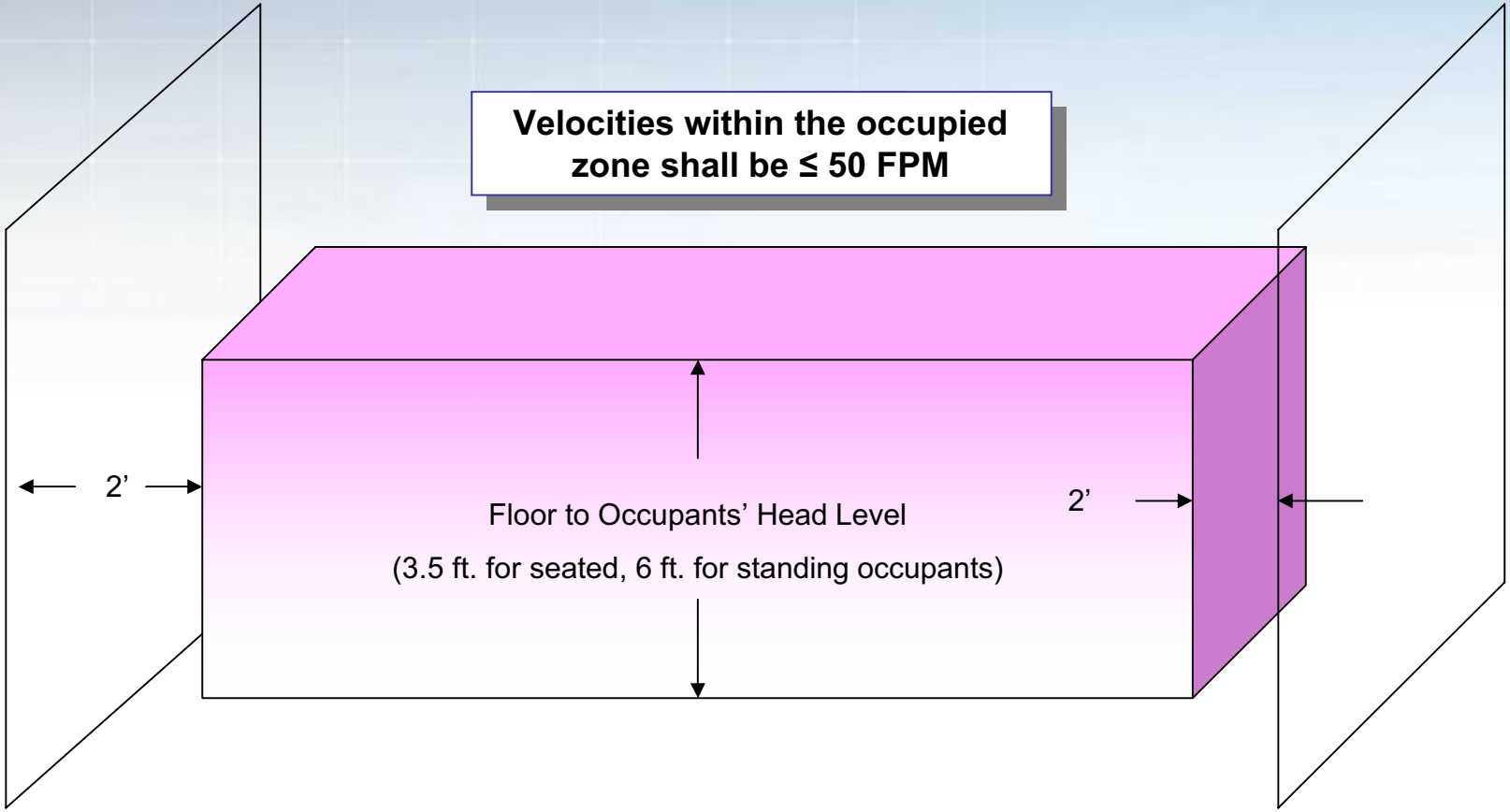
Thermal Comfort

ASHRAE Standard 55-2010 mandates a maximum 5.4°F vertical temperature stratification in Occupied Zone



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Understanding ADPI

ADPI

- ADPI is the percentage of points within the occupied zone having a range of effective draft temperatures of -3° to +2° of average room temperature at a coincident air velocity less than 70 FPM.
- ADPI is essentially a measure of the degree of mixing in zones served by overhead cooling systems.
- When air distribution is designed with a minimum ADPI of 80% the probability of vertical temperature stratification or horizontal temperature non-uniformity is low and conformance with ASHRAE Standard 55 (Thermal Comfort) requirements is high.
- ADPI does not apply to heating situations or ventilation-related mixing.

ASHRAE Fundamentals Chapter 20, Table 3

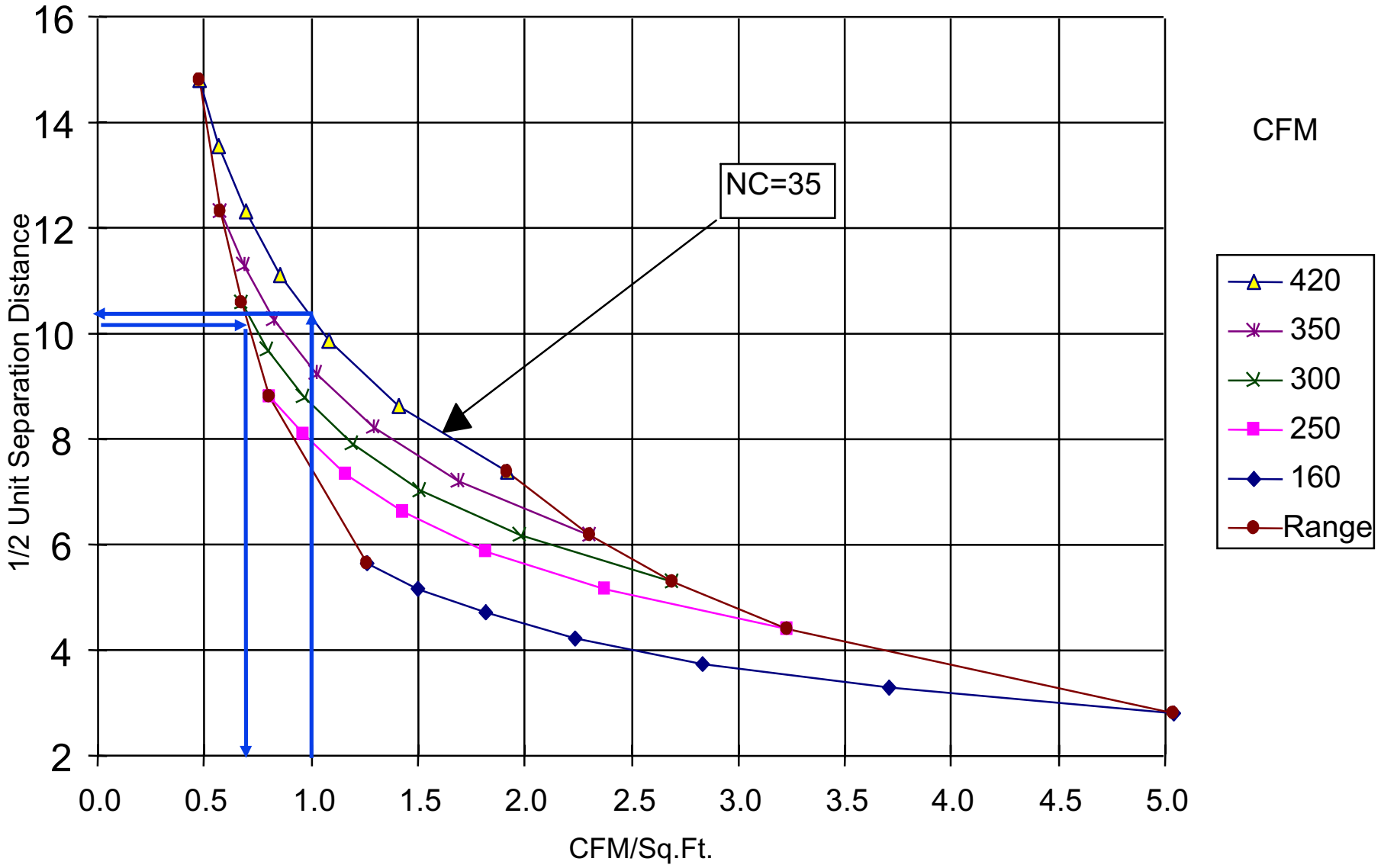
- ADPI selection using T_{50} / L was developed in the '60s where L is the distance to the nearest wall or halfway to the nearest air outlet. See Fundamentals Chapter 20 table 2 for more details on definition of L.
- A relationship was found between 50 FPM/min isothermal throw and cooling throw, and built into the selection charts included in ASHRAE Fundamentals, Chapter 20, table 3.
- Using this table engineers can assure clients that diffuser selections will provide acceptable mixing and air change effectiveness.

Air Diffusion Performance Index (ADPI) Selection Guide

Terminal Device	Room Load, Btu/h·ft²	T_{50}/L for Maximum ADPI	Maximum ADPI	For ADPI Greater than	Range of T_{50}/L
High sidewall grilles	80	1.8	68	—	—
	60	1.8	72	70	1.5–2.2
	40	1.6	78	70	1.2–2.3
	20	1.5	85	80	1.0–1.9
Circular ceiling diffusers	80	0.8	76	70	0.7–1.3
	60	0.8	83	80	0.7–1.2
	40	0.8	88	80	0.5–1.5
	20	0.8	93	90	0.7–1.3
Sill grille, straight vanes	80	1.7	61	60	1.5–1.7
	60	1.7	72	70	1.4–1.7
	40	1.3	86	80	1.2–1.8
	20	0.9	95	90	0.8–1.3
Sill grille, spread vanes	80	0.7	94	90	0.6–1.5
	60	0.7	94	80	0.6–1.7
	40	0.7	94	—	—
	20	0.7	94	—	—
Ceiling slot diffusers (for T_{100}/L)	80	0.3	85	80	0.3–0.7
	60	0.3	88	80	0.3–0.8
	40	0.3	91	80	0.3–1.1
	20	0.3	92	80	0.3–1.5
Light troffer diffusers	60	2.5	86	80	<3.8
	40	1.0	92	90	<3.0
	20	1.0	95	90	<4.5
Perforated, louvered ceiling diffusers	11–50	2.0	96	90	1.4–2.7
				80	1.0–3.4

Perforated 24X24, 10” inlet, 4 way, 20° Delta-T

Spacing for 80% ADPI



Prism, 24”x24”, 10” inlet, 20°ΔT
Spacing for 80% ADPI

Room Air Speed
Issues and Factors

- Standard 55 says thermal comfort can be achieved with 0 fpm air motion.
- Uniform air temperatures indicate good mixing when loads are present.
- With conventional (well-mixed) systems, room air speed is driven primarily by room loads when air supply is below 0.9 CFM/sq. ft. and air diffusion is adequate per ASHRAE sponsored research
- Partitions can provide excellent comfort with ceiling diffusers when cooling.

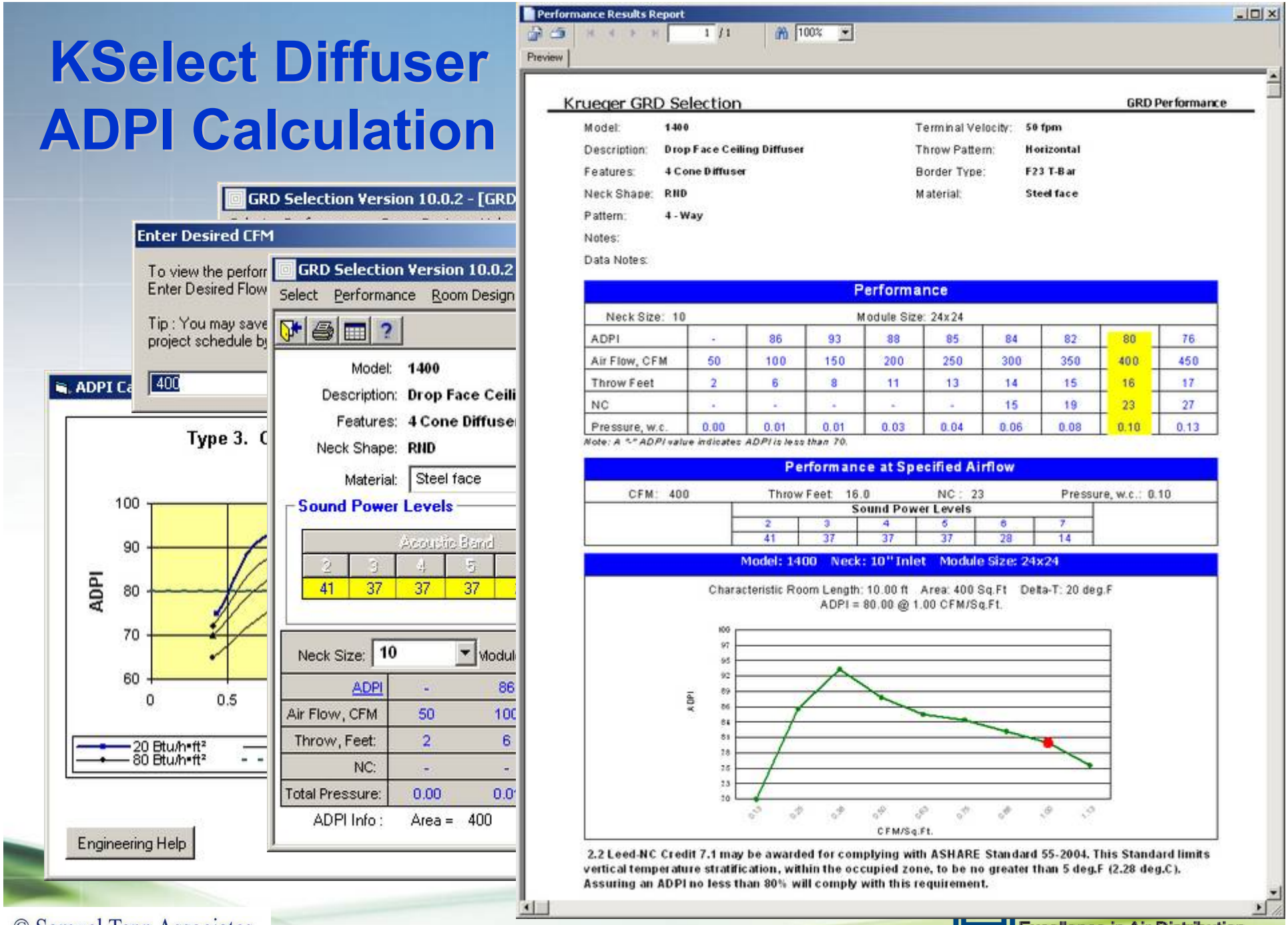
ADPI, LEED, and Thermal Comfort

- **One can get a LEED point for meeting ASHRAE Standard 55 (Comfort).**
- **Currently, the only way to prove compliance to Standard 55's vertical temperature stratification limitation, at the design stage, is through the use of ADPI.**

LEED & ASHRAE Code Compliance

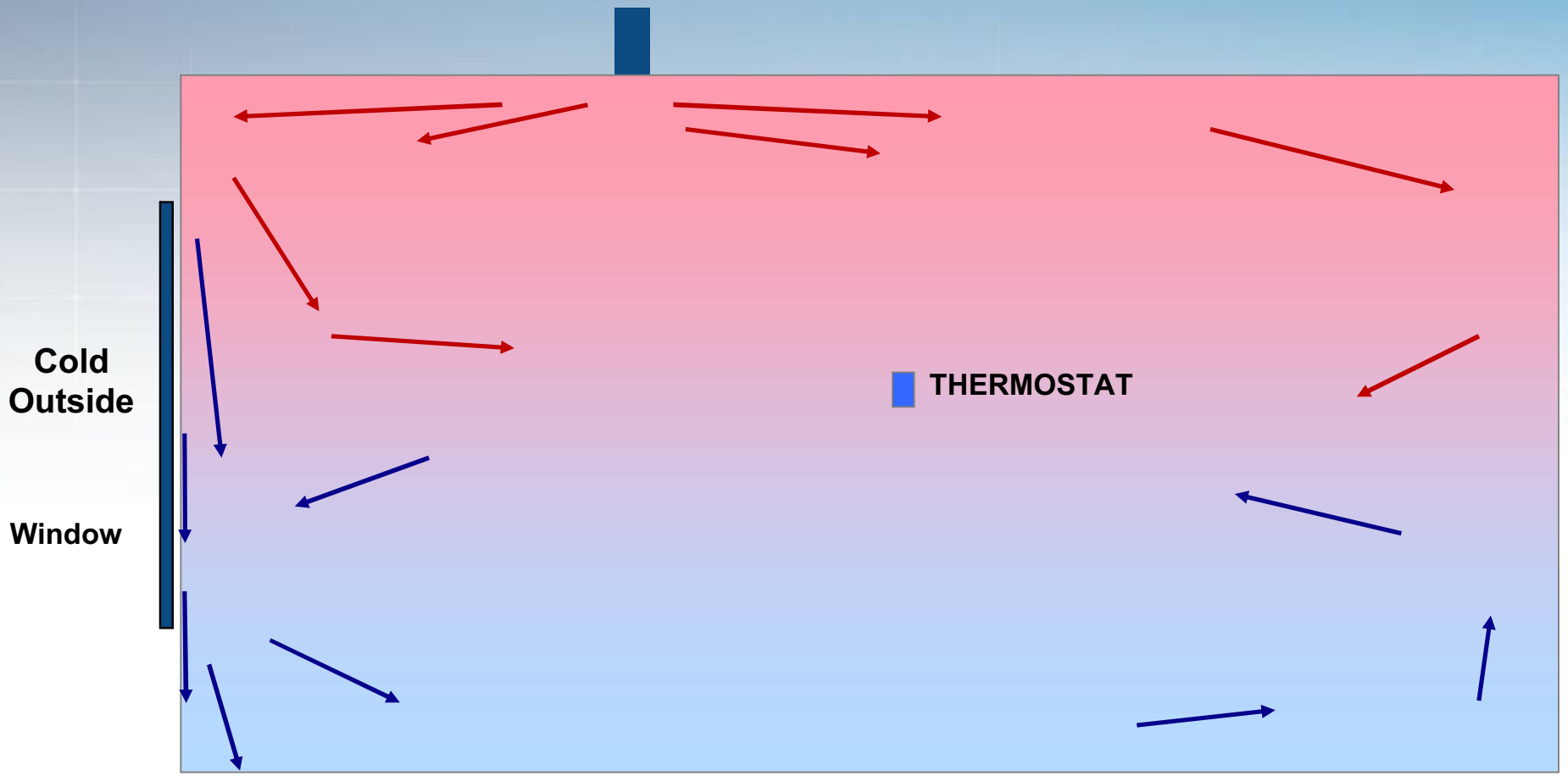
- In LEED V3, in order to get ANY LEED points, one must fully meet the Ventilation Rate Procedure calculation in ASHRAE Standards 62.1 (Ventilation)
- ASHRAE 62.1-2010 VRP requires that if heating air supplied from the ceiling is less than 15° above room temperature but does not reach within 4.5 feet of the floor at 150FPM the outdoor air supply must be increased by 25%.
- ASHRAE 62.1-2010 VRP requires that if the heating air supplied from the ceiling is greater than 15° above room temperature the outdoor air supply must also be increased by 25%.
- LEED Ventilation points are gained by increased ventilation

KSelect Diffuser ADPI Calculation



Proper Overhead Heating Design

Common Overhead Heating Design



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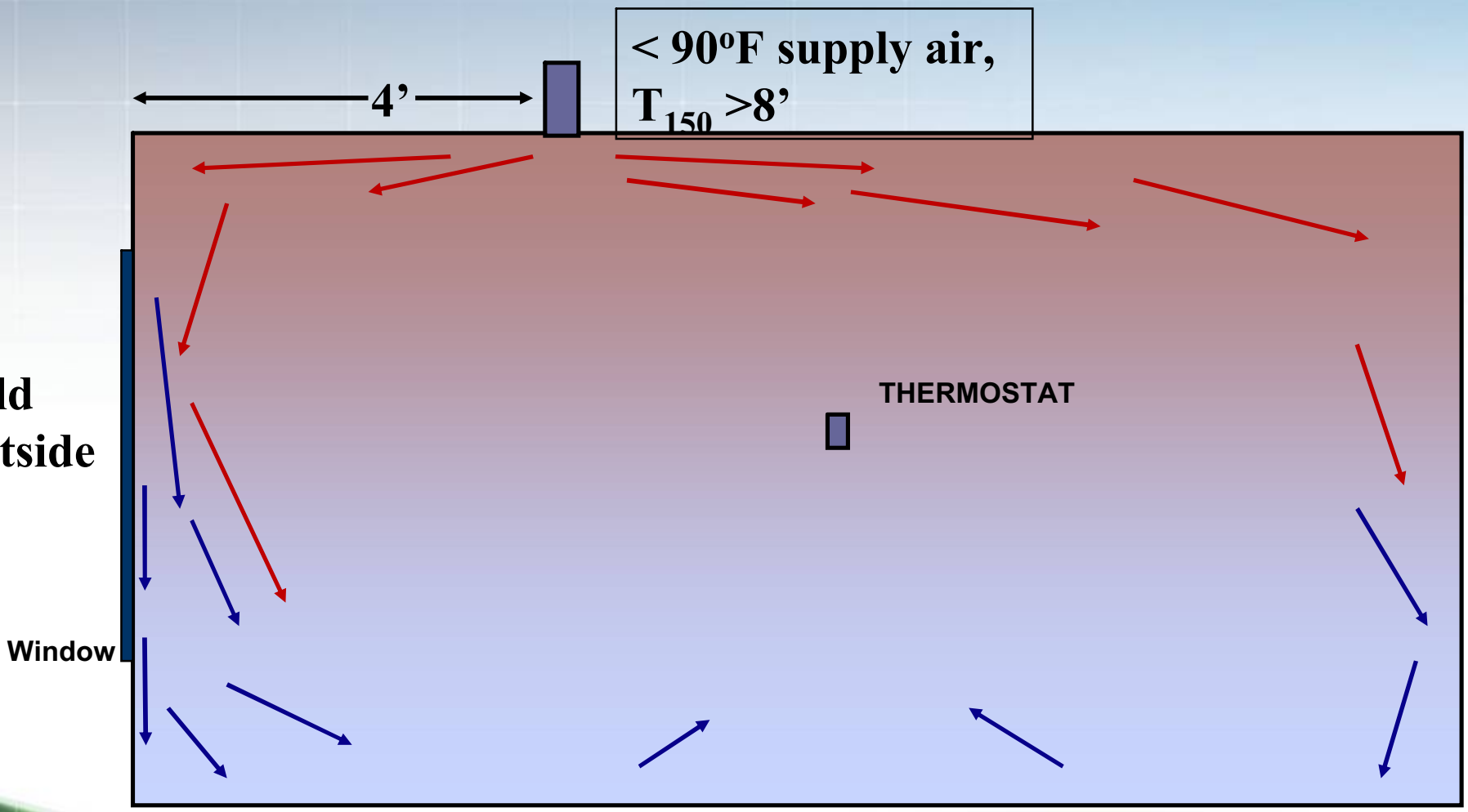
Perimeter Considerations:

- Maximum temperature difference between supply air and room temperature for effective mixing when heating, per ASHRAE handbook = 15°F (90°F discharge), continuous operation.
- Throw toward and away from glass.
- 150 FPM must reach 4.5 feet from the floor or less.
- ASHRAE 62.1 requires that ventilation be increased by 25% when heating, if the above rules are not followed.

Proper Perimeter Example



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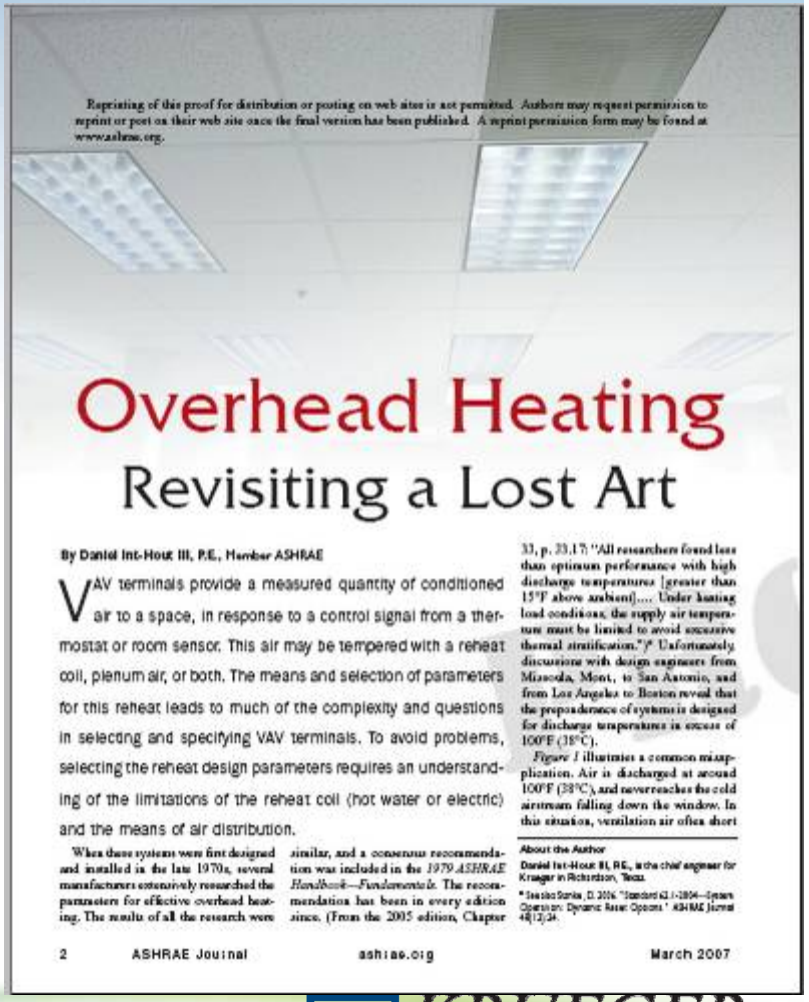
Perimeter Considerations:

See March 2007 ASHRAE Journal:



Overhead Heating

Revisiting a Lost Art

By Daniel Int-Hout III, P.E., Member ASHRAE

VAV terminals provide a measured quantity of conditioned air to a space, in response to a control signal from a thermostat or room sensor. This air may be tempered with a reheat coil, plenum air, or both. The means and selection of parameters for this reheat leads to much of the complexity and questions in selecting and specifying VAV terminals. To avoid problems, selecting the reheat design parameters requires an understanding of the limitations of the reheat coil (hot water or electric) and the means of air distribution.

When these systems were first designed and installed in the late 1970s, several manufacturers extensively researched the parameters for effective overhead heating. The results of all the research were similar, and a consensus recommendation was included in the *1979 ASHRAE Handbook—Fundamentals*. The recommendation has been in every edition since. (From the 2005 edition, Chapter 33, p. 33.17: "All researchers found less than optimum performance with high discharge temperatures [greater than 15°F above ambient].... Under heating load conditions, the supply air temperature must be limited to avoid excessive thermal stratification."[4] Unfortunately, discussions with design engineers from Missoula, Mont., to San Antonio, and from Los Angeles to Boston reveal that the preponderance of systems is designed for discharge temperatures in excess of 100°F (38°C).

Figure 1 illustrates a common misapplication. Air is discharged at around 100°F (38°C), and never reaches the cold airstream falling down the window. In this situation, ventilation air often short

About the Author

Daniel Int-Hout III, P.E., is the chief engineer for Krueger in Richardson, Texas.

* See also Stanke, D. 2006. "Standard 62.1-2004—System Operation: Dynamic Reset Options." ASHRAE Journal 48(12):34.

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Non Typical Throw Analysis

Special Applications

High bay application - Ceilings over 12’ high

- Heating is a challenge due to buoyancy.
  - Take advantage of vertical stratification where possible
  - Required Heating airflow rate may exceed cooling airflow rate.
  - Keep heating supply air temperature to room temperature ΔT to a minimum
- If supplying air distribution from the ceiling, consider using round diffusers, drum louvers, or diffusers with some vertical projection.
- One cannot use ADPI to predict heating performance.
- Consider Displacement Ventilation

Diffuser Selection & Buoyancy

- ADPI isn't always the best way to analyze, select and place diffusers, especially with heating and high bay applications.
- One can estimate Throw as a function of ΔT and buoyancy.
- Simple rule: Distance to 75ft/min is affected by 1%/degree(F) ΔT.

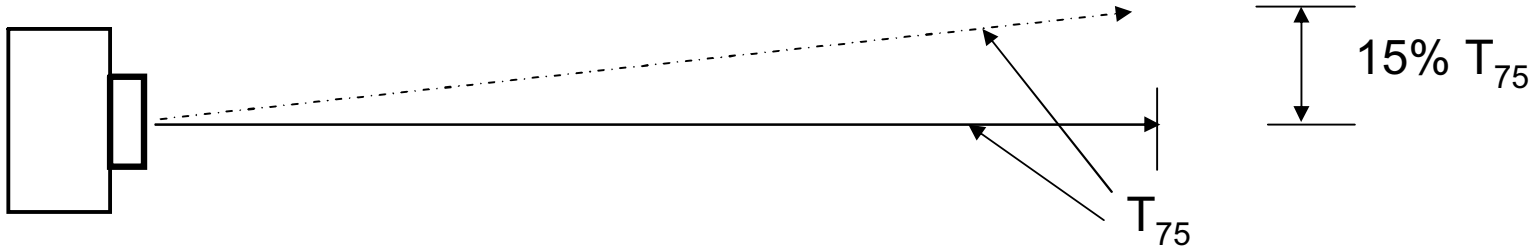
Example:

1. 20°ΔT Cooling, Vertical Down = +20% projection
2. 20°ΔT Heating, Vertical Down = -20% projection
3. 20°ΔT Heating, Along Ceiling = +20% projection

Side Wall Register Selection & Buoyancy

- Horizontal free jet:
- Vertical change @ 75ft/min is affected by 1% of 75fpm throw/F^0 ΔT.

Example: 15^{o}F Delta T heating



Note: T_{150} is not affected by Delta-t

Entrained vs. Free Jets

- Most catalog throw data assumes jet is along a surface.
- Exceptions include drum louvers, duct mounted grilles and vertical linear diffusers.
- A free jet will be shorter than an entrained jet because it has more surface area to induce surrounding air, which shortens throw.

Special Applications

Continuous Duct Application Suggestions:

- Use multiple drum louvers, duct mounted grilles and continuous linear applications (longer than 10').
- Size duct as large a possible (Duct inlet velocity < 1000fpm).
- If inlet velocities are less than 1000fpm, maintain constant duct size through entire length of run and balancing will be minimal.

Returns

- Typically, returns are located in the ceiling in offices.
- Returns have an almost immeasurable effect on room air flows below 1.5 cfm/sf.
- Suspended ceilings typically leak 1cfm/sf at 0.1” differential pressure.
- Spaces with high airflow rates can benefit from low returns.

Value Engineering

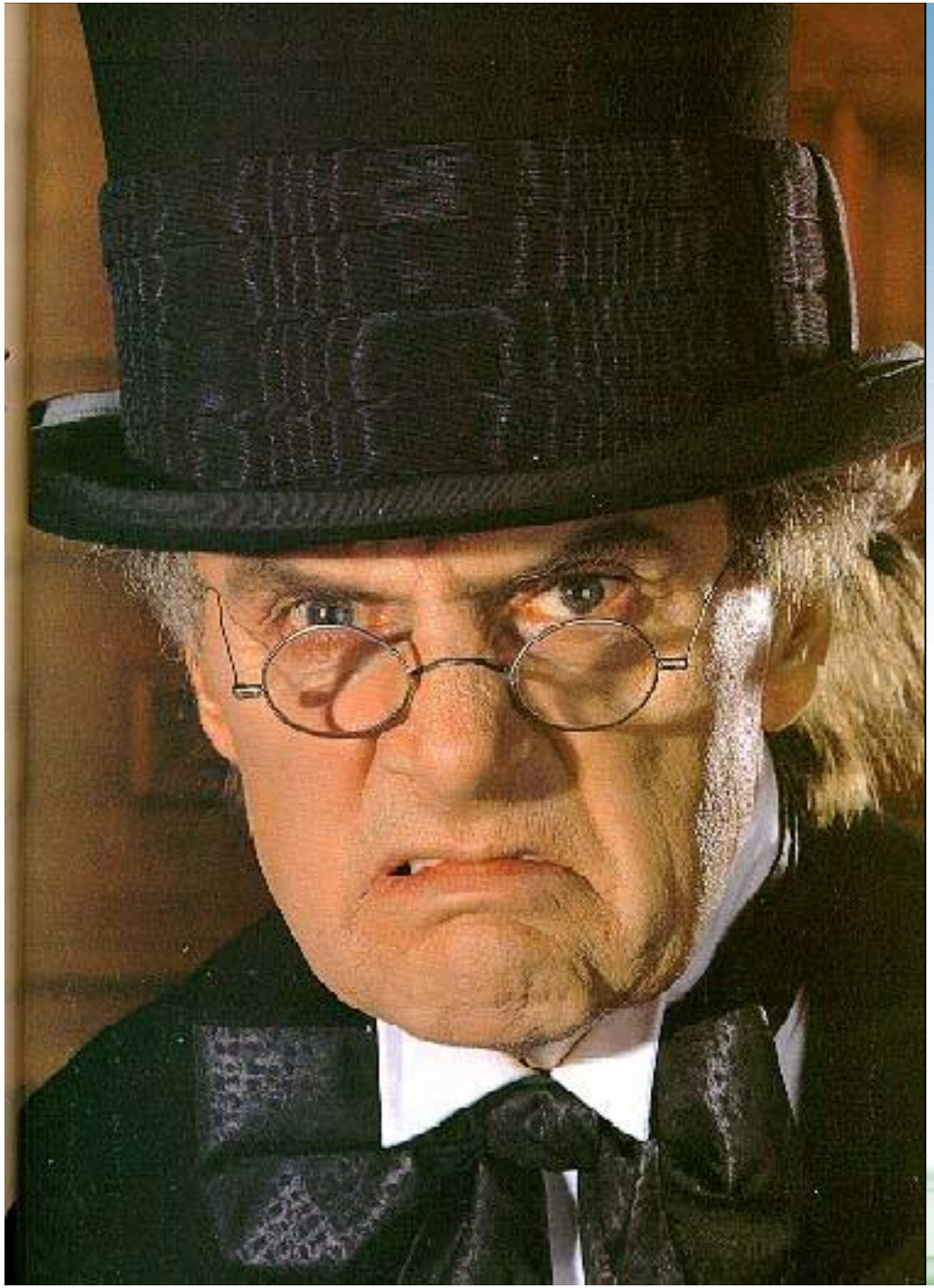
Installed Cost of Diffuser Selection

Based on 10,000 sq. ft. office space at optimum ADPI & 8,000 CFM

Type	4 Cone 12" Ø Neck	Perforated Face-12" Ø Neck	Prism-12" Ø Neck	Plaque-12" Ø Neck	Flush Louver Face-12" Ø Neck	Flush Louver Face-12 x12 Neck
CFM @ NC=35	670	615	850	850	970	970
Minimum CFM @ ADPI=80	160	325	180	220	420	420
CFM Turndown Ratio	0.24	0.53	0.21	0.26	0.43	0.43
Number of Diffusers	12	13	10	10	9	9
Unit Diffuser Cost Comparison, 4 Cone as Base Cost	1.00	0.76	0.96	1.10	1.7-2.39 depending upon module size	1.43-1.97 depending upon module size
Total branch & diffuser installed cost/sq. ft.-10,000 sq. ft. space	$0.318	$0.327	$0.263	$0.271	$0.274-$0.308 depending upon module size	$0.497-$0.524 depending upon module size

ERAD, ADPI Summary

- LEED 2009 requires meeting Standard 62.1 for project approval-**No compliance=No Leed project designation!**
- Documented use of ADPI is the ONLY way to assure compliance to ASHRAE Std. 55 in the design phase for cooling.
- Reheat needs to be carefully considered in terms of discharge temperatures and velocities. High heating supply temperatures will void meeting Standard 55 (and loose a potential LEED point).
- Software is available to assist in selecting the best mix of products.
- LEED rules are under review.
- If you wish to load KSelect – please get the latest version from the web www.Krueger-hvac.com



ANY QUESTIONS?

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Contacts:

Dan Int-Hout

Dint-hout@krueger-HVAC.com

www.krueger-hvac.com

Keith Miller

Samuel Tepp Associates

Cell 201-638-6591 kmiller@samtepp.com

www.samtepp.com

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