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A Case to Displace: Comparing Overhead Air Supply with Displacement Ventilation

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Presenters

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- 110 Education Projects

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Agenda

01 What is it?

02 Comfort and IAQ

03 Energy

04 Integration

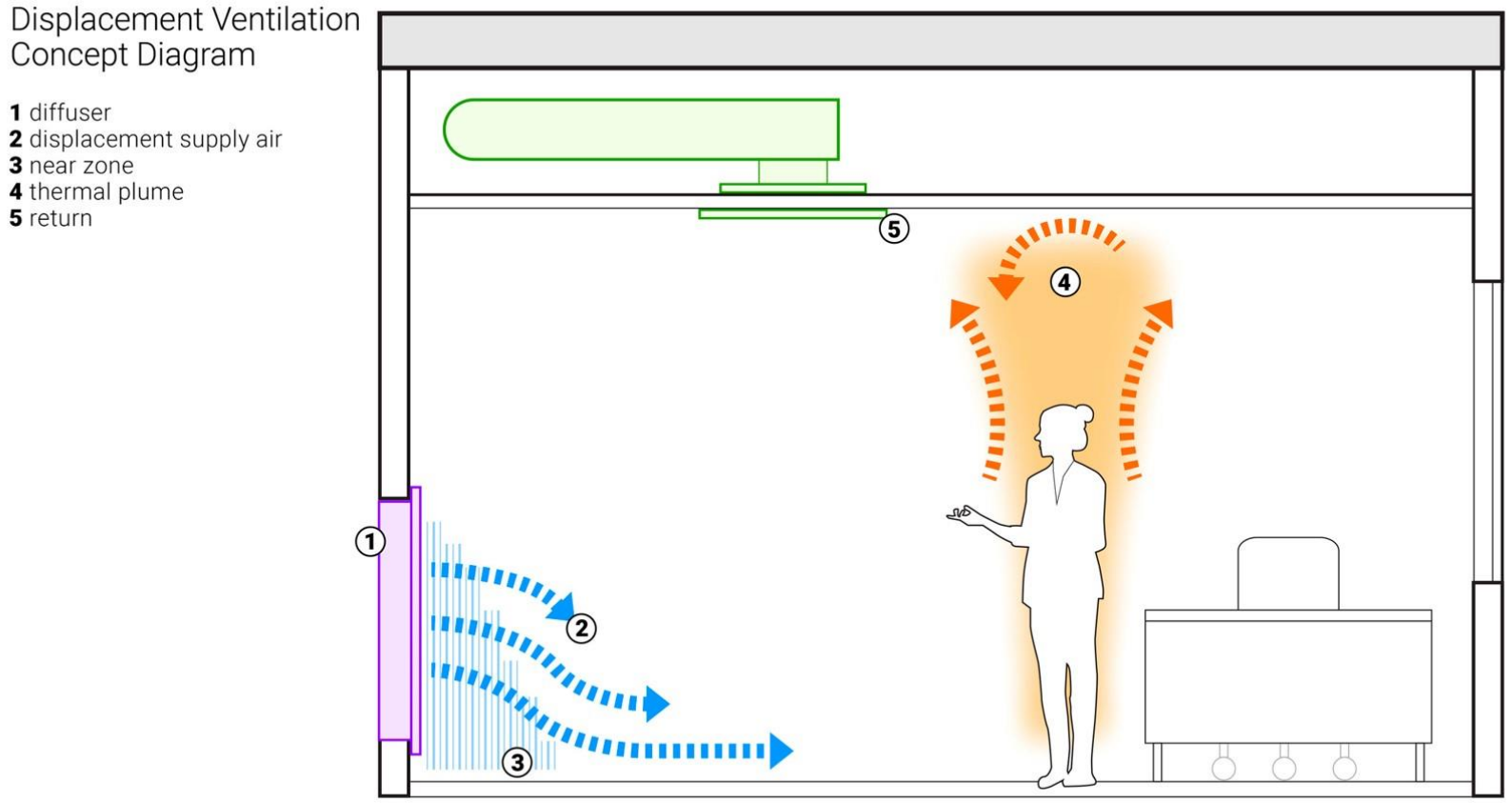
05 Limitations

06 Wrap Up

What is displacement?

What is Displacement

- Relies on gravity to distribute air to a space.
  - Low Velocity at Floor Level.
  - Displaces warmer, less dense air
  - Creates a vertical temperature gradient.
- ASHRAE : Fully Stratified System
  - No mixing in occupied zone.



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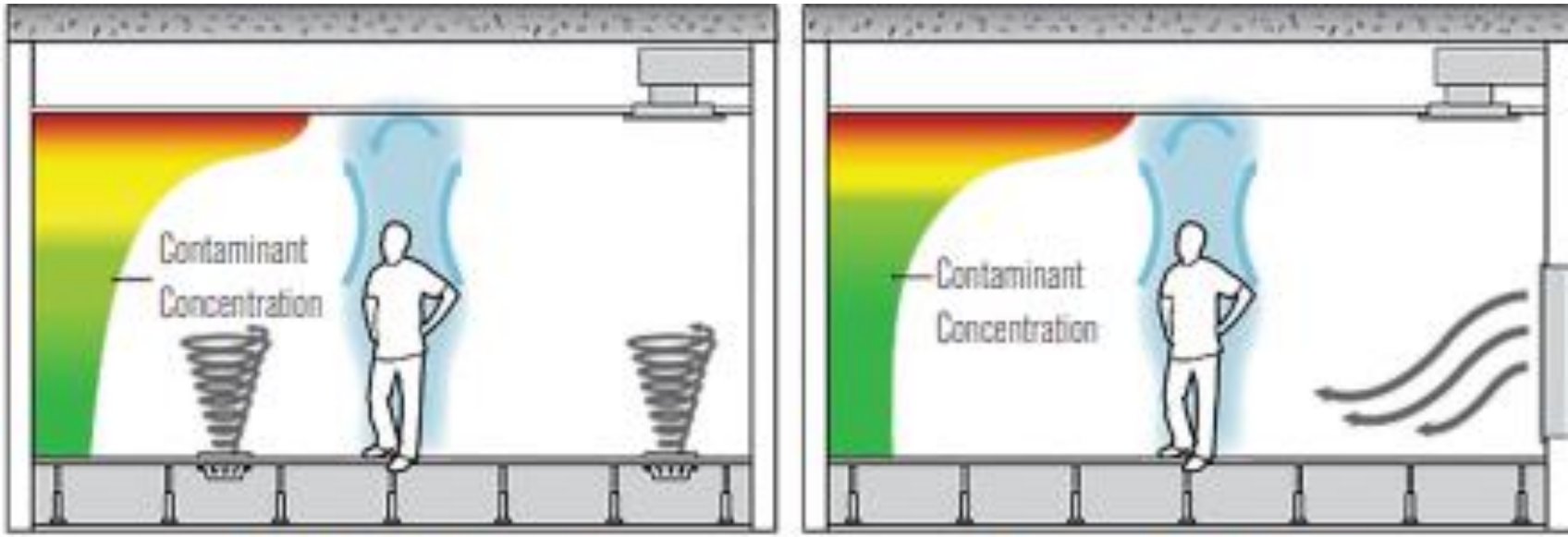
What is Displacement?

Floor Applications

- Office, Large Volume Spaces

Sidewall Applications

- Ideal for Classrooms
- Integrated into Architecture
  - Free up ceiling space
  - Heavy-duty construction
  - Various options for locations, colors, sizes



What is Displacement?

What are the comfort and IAQ benefits?

Comfort and Indoor Air Quality

Comfort: Thermal Comfort

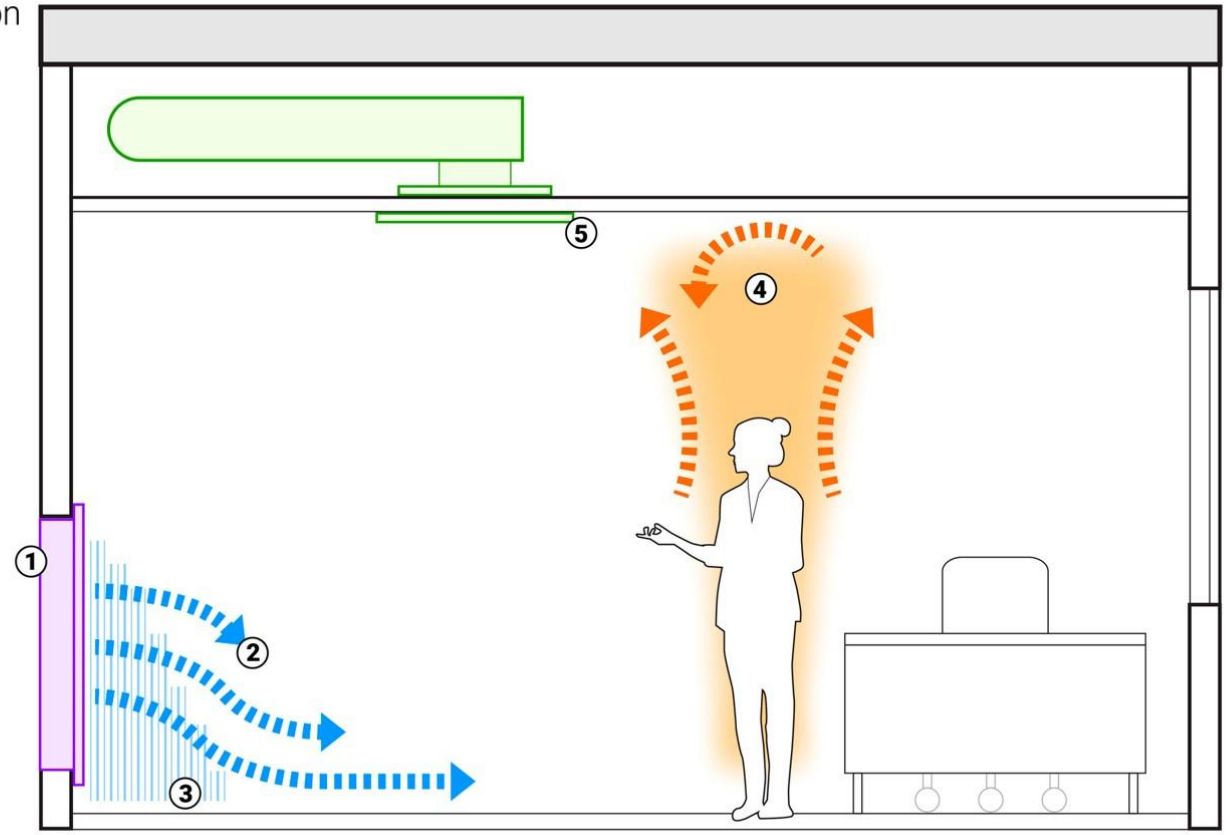
- Less drafty.
- Reduces cold spots.

Comfort: Acoustics

- Low velocities → Less Noise
- Positive impact on student performance

Displacement Ventilation Concept Diagram

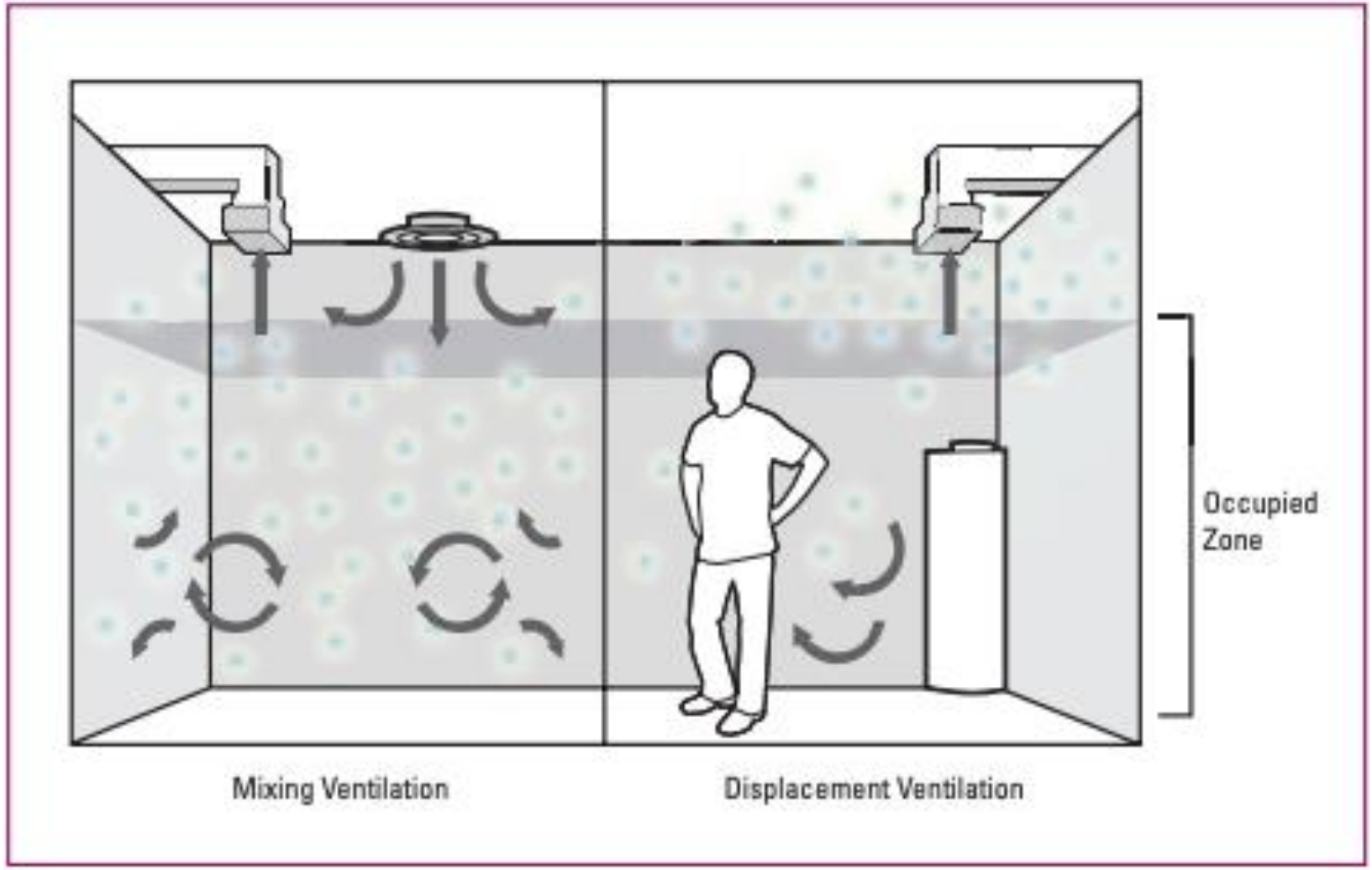
1 diffuser
2 displacement supply air
3 near zone
4 thermal plume
5 return



Comfort and Indoor Air Quality

IAQ: Removal of Contaminants

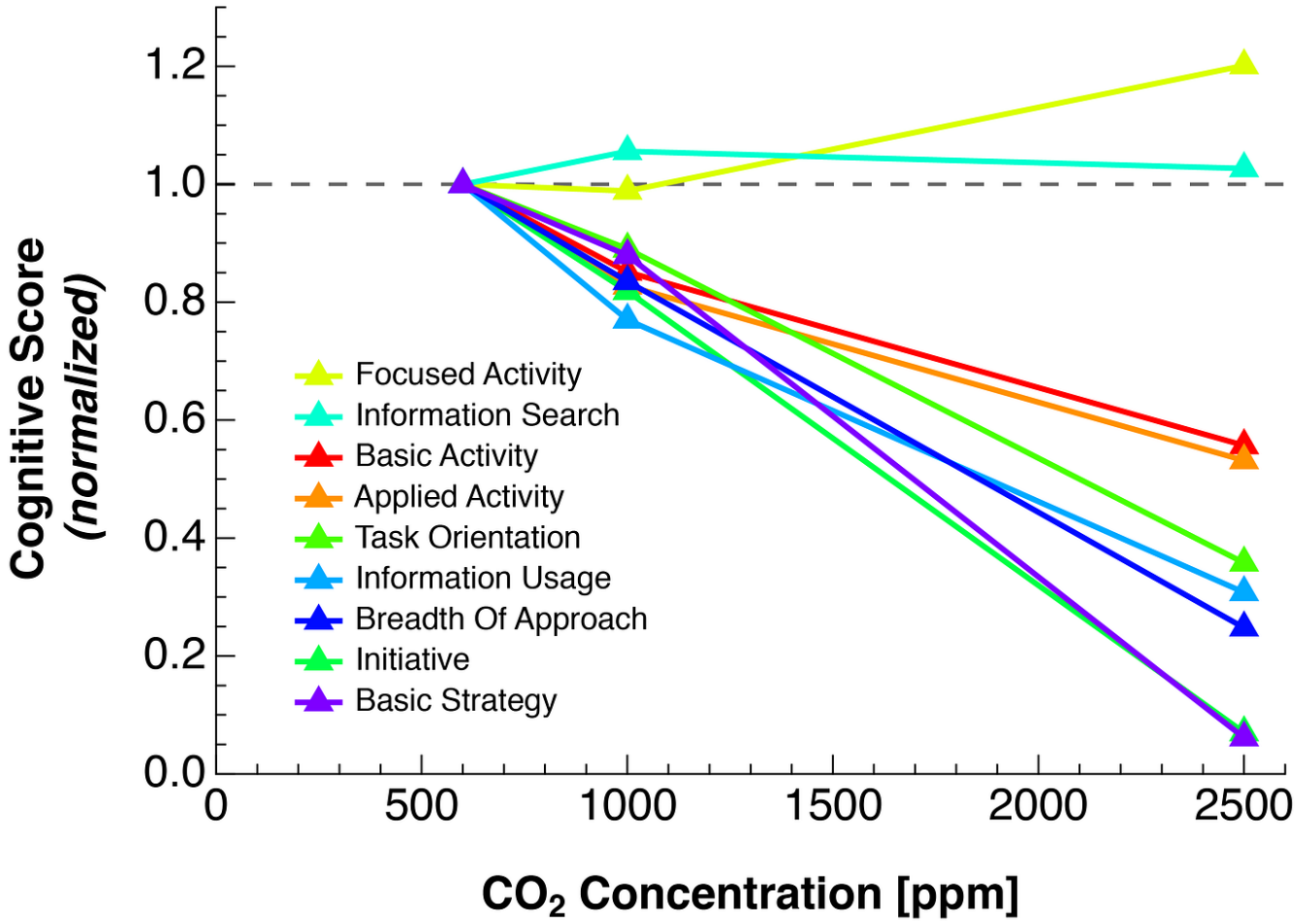
- Displacement is more effective at reducing exposure.
- Less time for contagions to remain in air.
- Leads to less illness/absentees.
- Overhead mixing fights stratification.



Comfort and IAQ

IAQ: Lower CO2

- Studies correlate CO2 levels with occupant cognitive performance.
- More evident for strategic/creative activities.



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What are the energy consumption benefits?

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Supply Air is warmer than an overhead mixing system.

55°F vs 64°F

Increased Economizer Hours (Free Cooling)

Lower Velocities (Fan HP)

Overhead Mixing: ~400-500 fpm

Displacement: ~50-90 fpm

Improved Ventilation Effectiveness

Less Outdoor Air (ASHRAE 62.1)

Outside Air Heating/Cooling

$$\textbf{358 CFM} \begin{cases} 900\ ft^2 \times 0.12\ \frac{CFM}{ft^2} = \ 108\ CFM \\ 25\ Persons \times 10\ \frac{CFM}{Persons} = \ 250\ CFM \end{cases}$$

Outdoor Air Required (Poorly Mixed)

- $358\ CFM \div \mathbf{0.8}\ (\boldsymbol{E_Z}) = \ 448\ CFM$

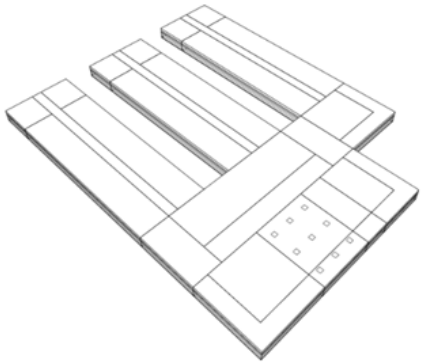
Outdoor Air Required (Well Mixed)

- $358\ CFM \div \mathbf{1.0}\ (\boldsymbol{E_Z}) =$ 358 CFM

Outdoor Air Required (DV)

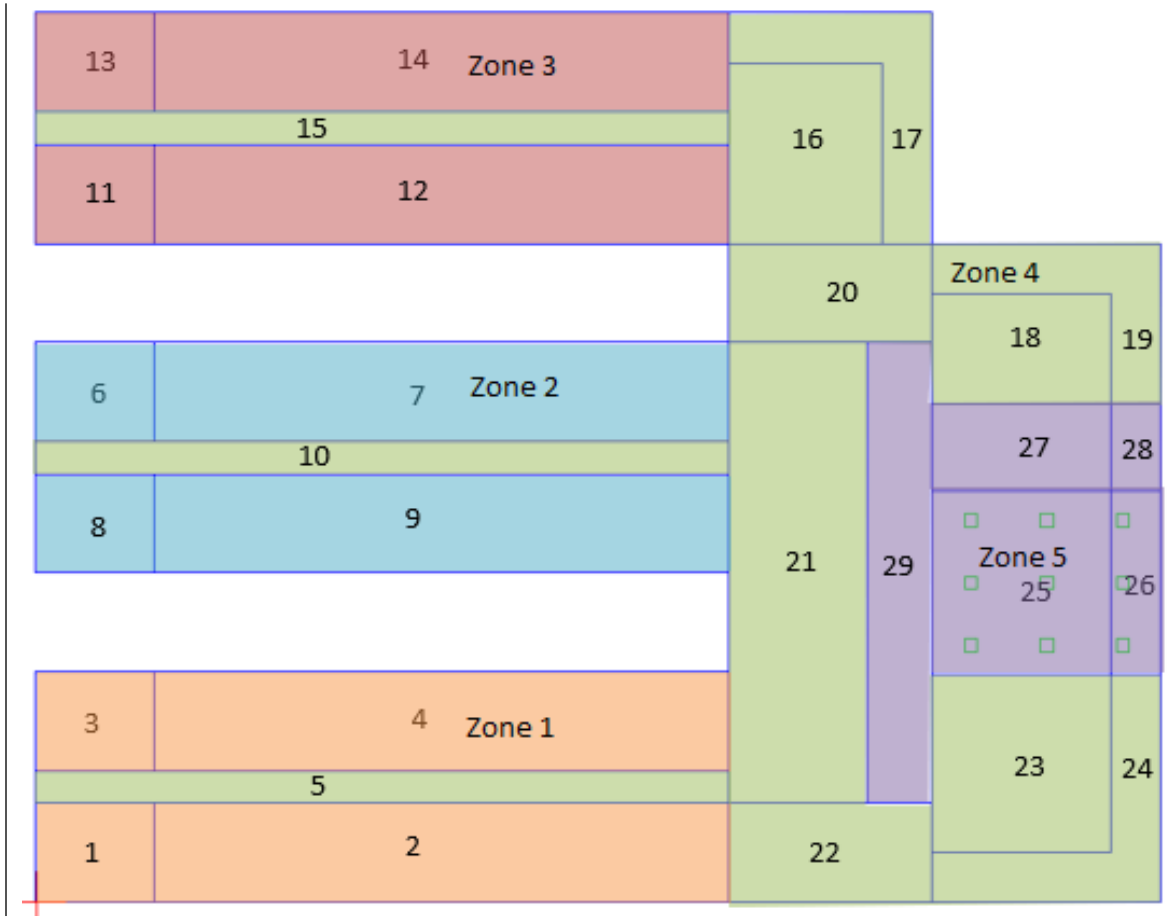
- $358\ CFM \div \mathbf{1.2}\ (\boldsymbol{E_Z}) = \ 298\ CFM$

- Cooling for 15 classrooms
  - Poor Overhead – 45 tons
  - Well Designed Overhead – 36 tons
  - Displacement – 30 tons
- Heating for 15 classrooms
  - Poor Overhead – 578 MBH
  - Well Designed Overhead – 462 MBH
  - Displacement – 385 MBH
- 20% - 50% more OA needed



What are the energy consumption benefits?

- Energy Savings in Primary Schools
  - Energy Model comparing Induction Displacement Ventilation with Active Chilled Beams (ACB) to:
    - DOAS w/FCUs
    - VAV Air Handler System.
  - Zones 1-3: Displacement
  - Zone 4: Active Chilled Beam
  - Zone 5: Packaged DX units



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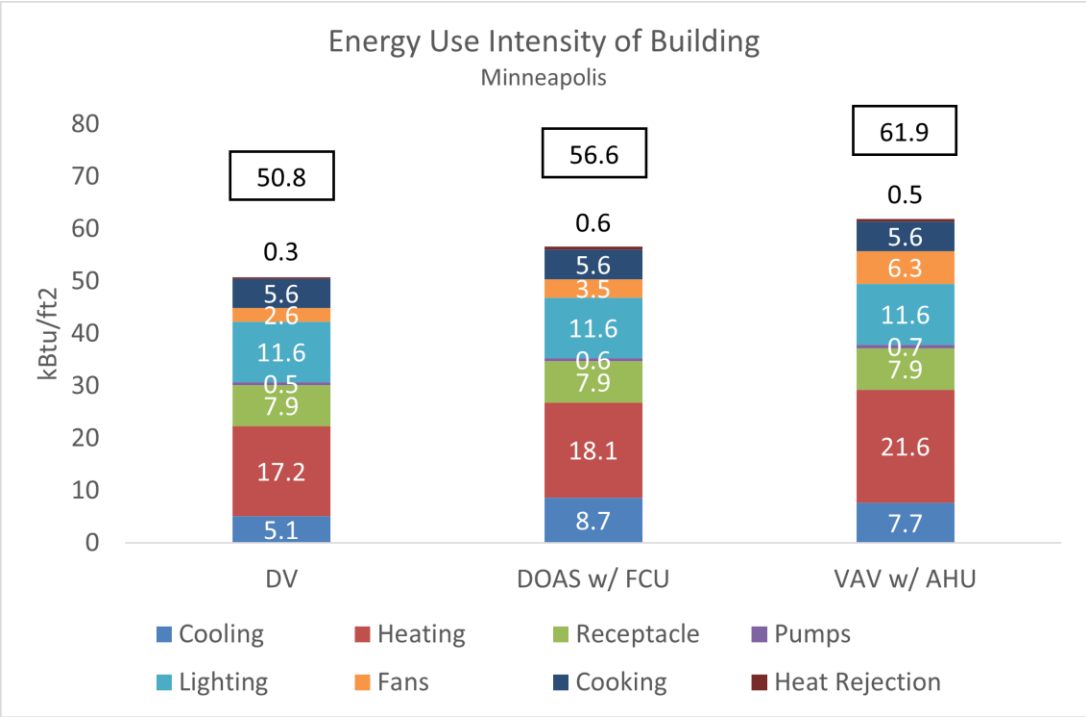
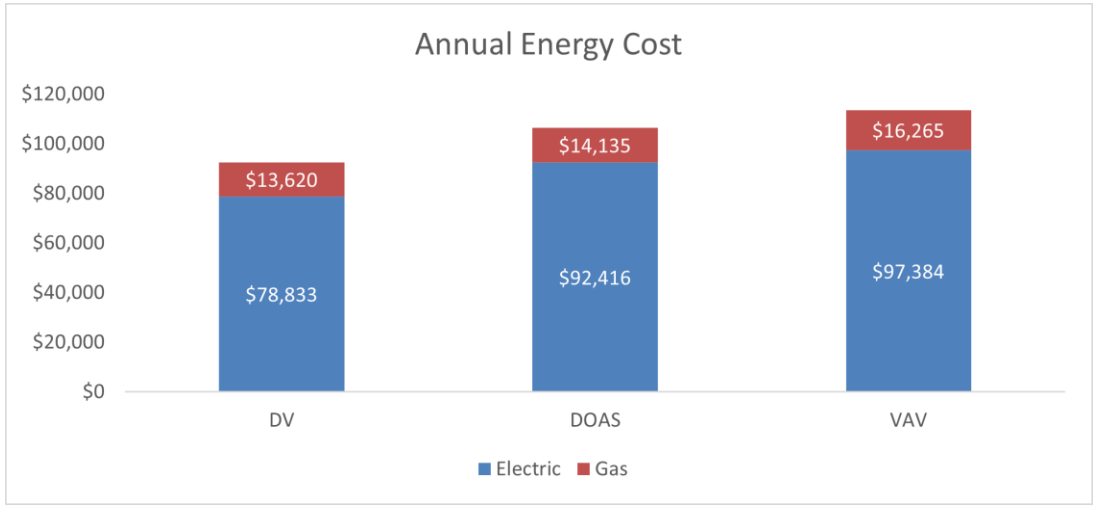
What are the energy consumption benefits?

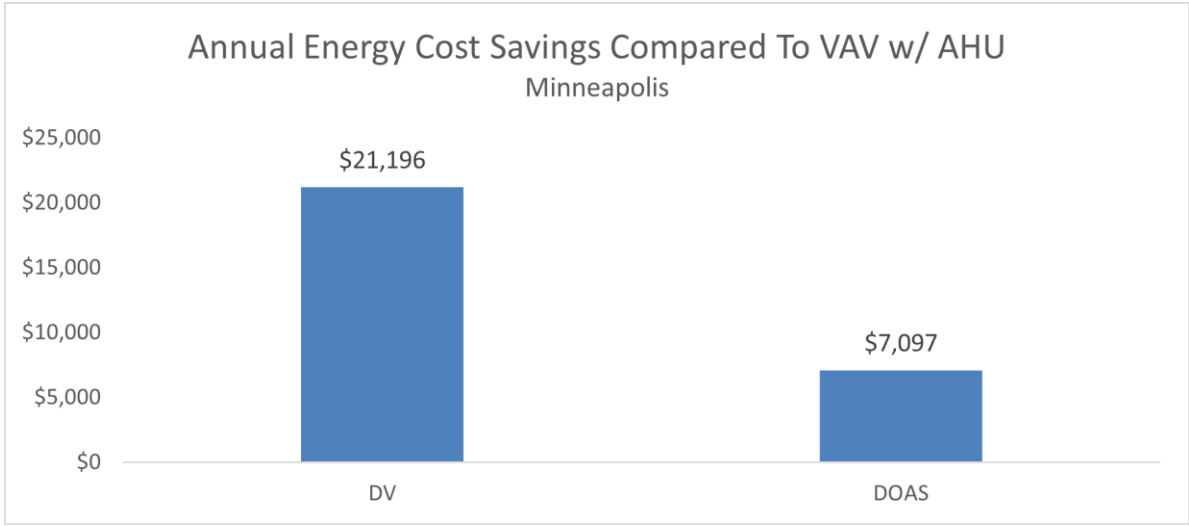


- Reduction in total ventilation required per ASHRAE 62.1-2013
- Reduction in chiller energy due to reduced airflow for ventilation and supply
- Reduction in boiler energy due to reduced airflow for ventilation and supply
- Reduction in fan energy by eliminating FCU fans (DOAS FCU system)
- Reduction in total heating and cooling capacity related to reduction in peak outside air required

What are the energy consumption benefits?

*Flat Energy Rates were applied based on local utility data (MN)





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Integration into Buildings

Wall Integrated

Thickened wall

Bump out

In stud space

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Surface Mounted

Rectangular

Quarter round

Half round

Chamfered corner

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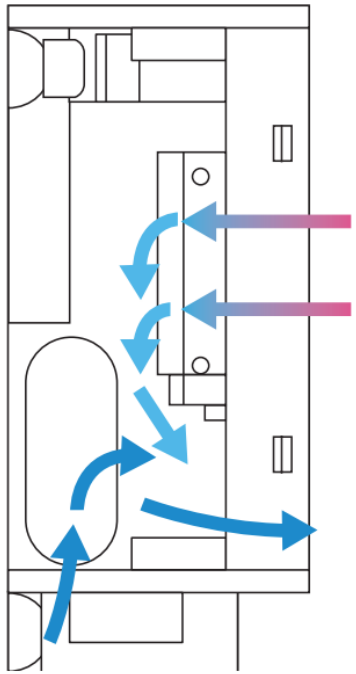
Induction Displacement

Floor mounted chilled beam

Four manufacturers



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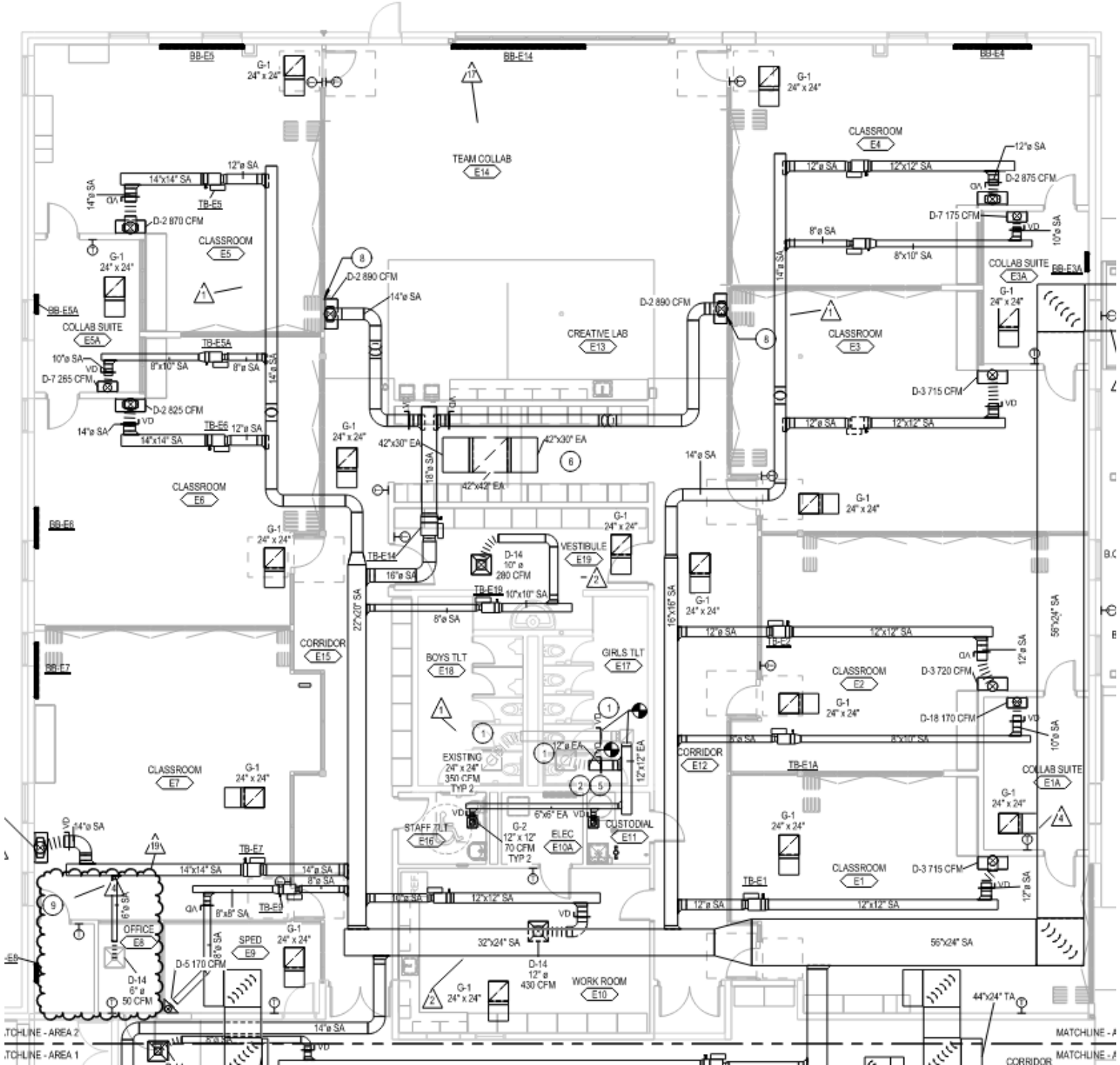

Above the Ceiling

All air system

Similar VAV and duct sizing to overhead mixing

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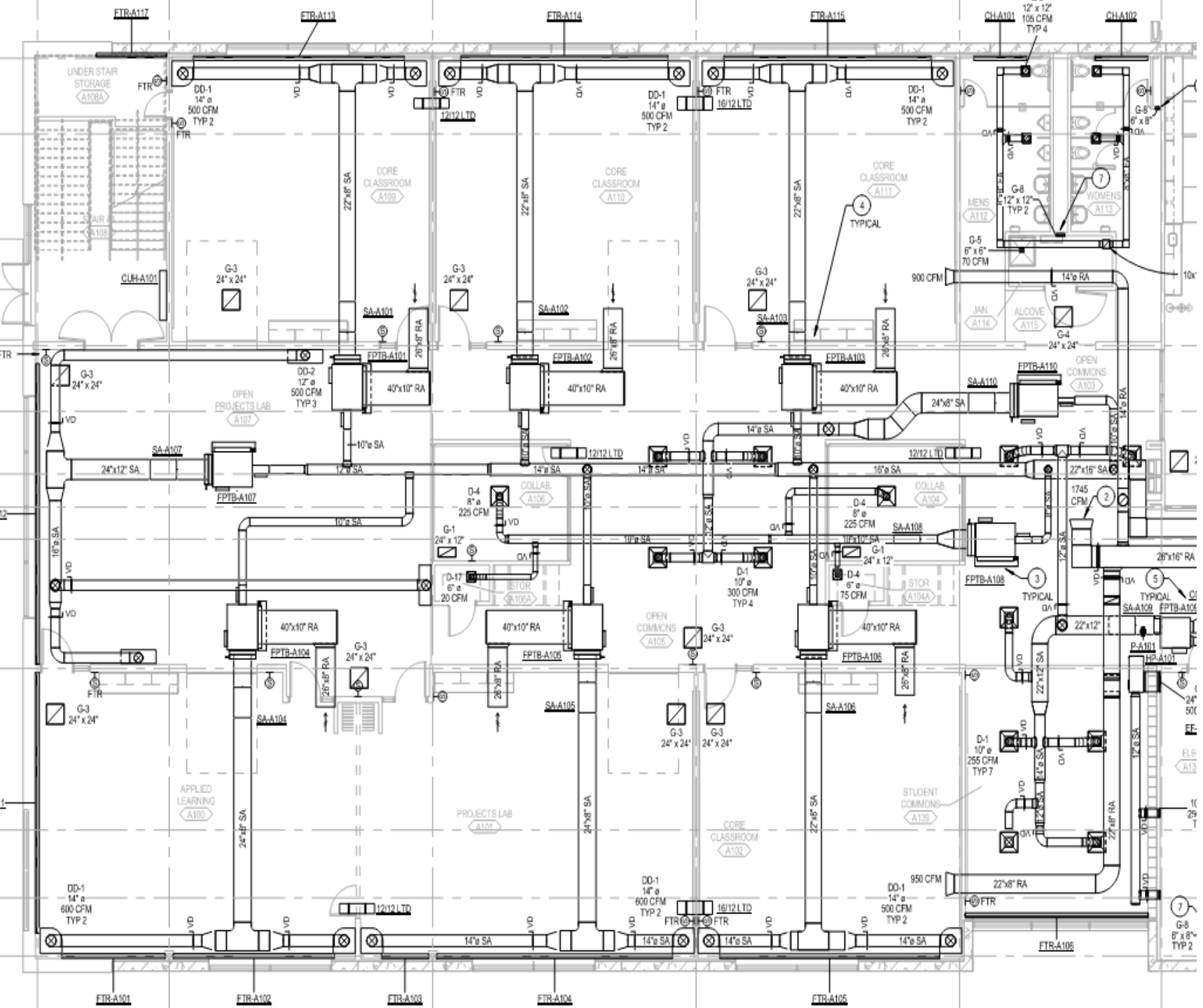

Above the Ceiling

DOAS AHU feeding FPVAV with sensible cooling coils

Smaller ducts

All air back to mechanical room is exhausted – no mixing between rooms

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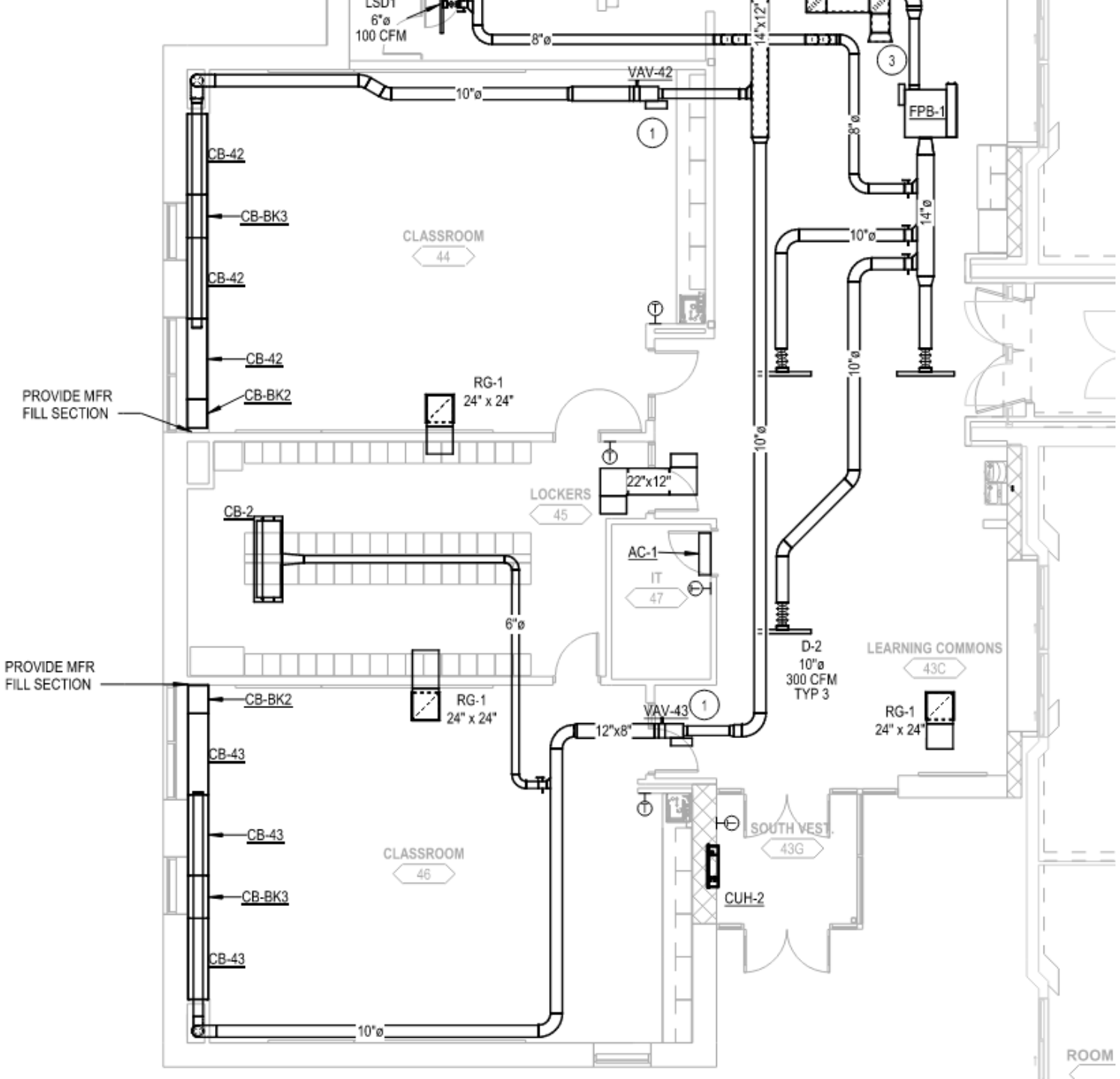

Above the Ceiling

Induction displacement fed from DOAS

Smaller ducts and VAV boxes

More piping

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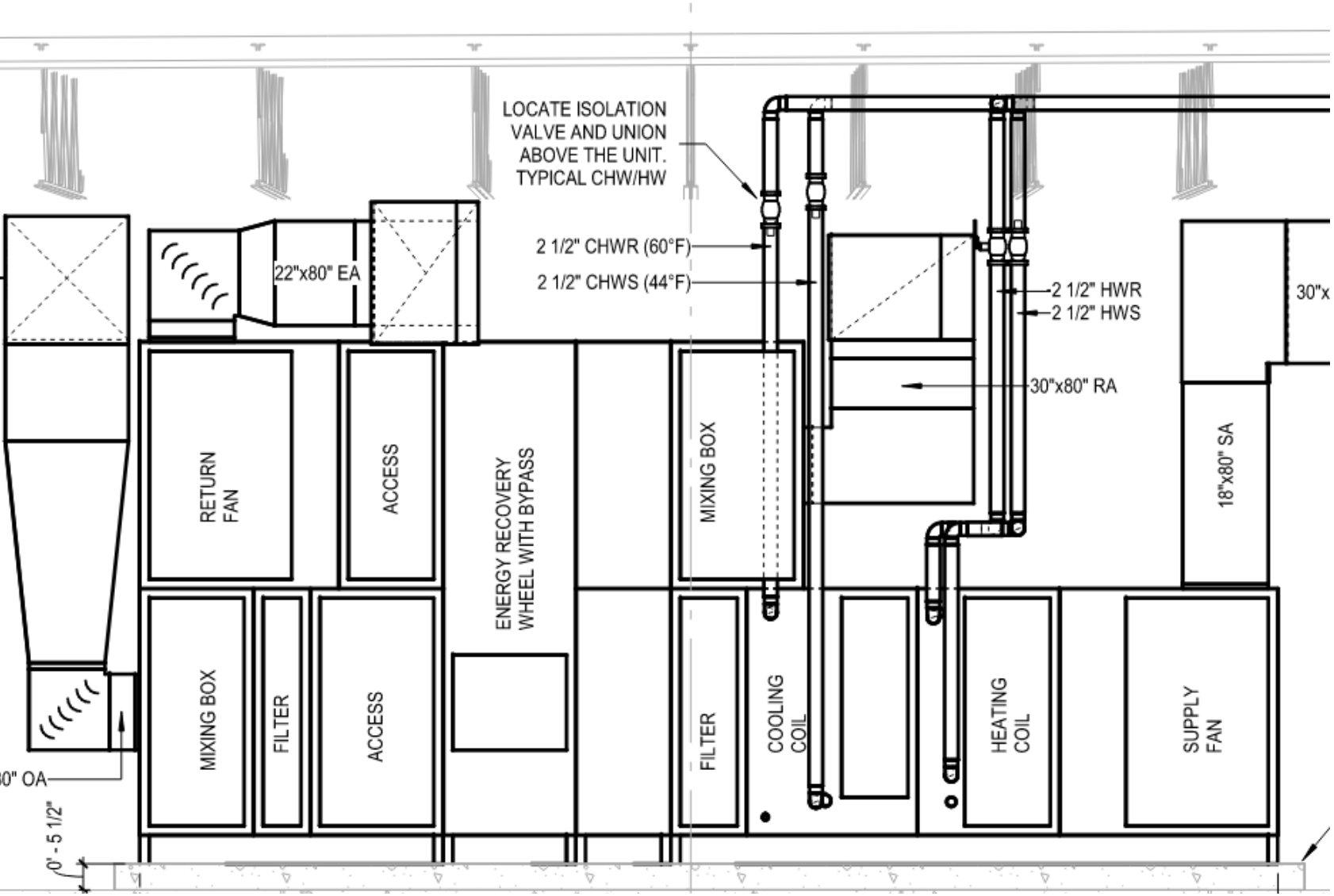

Mechanical Room

"Standard" DOAS AHU serving half of the classrooms in a 100k SF elementary.

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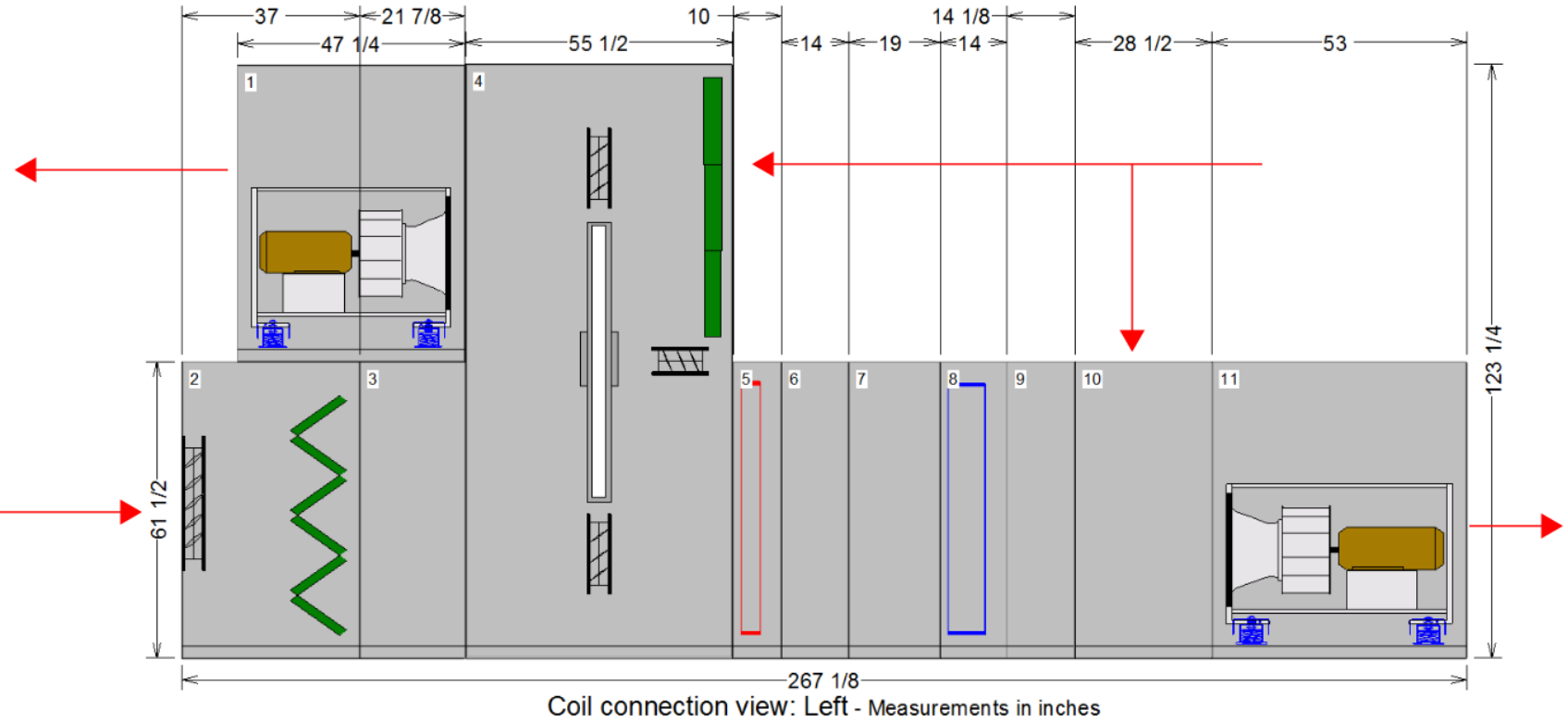
Mechanical room

AHU with RA bypass for reheat



Coil connection view: Left - Measurements in inches

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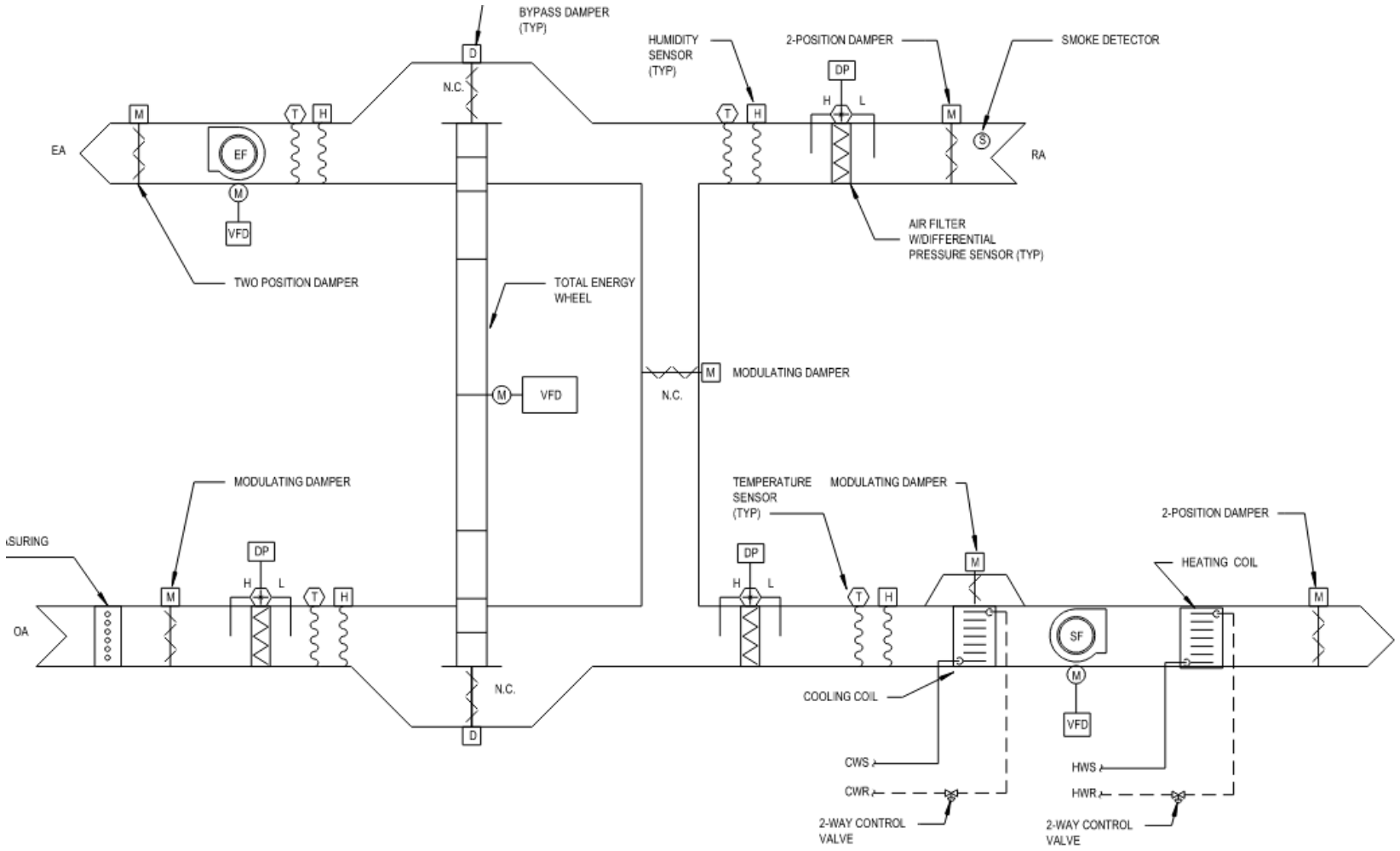
Limitations

Not Business As Usual

Get all stakeholders on same page



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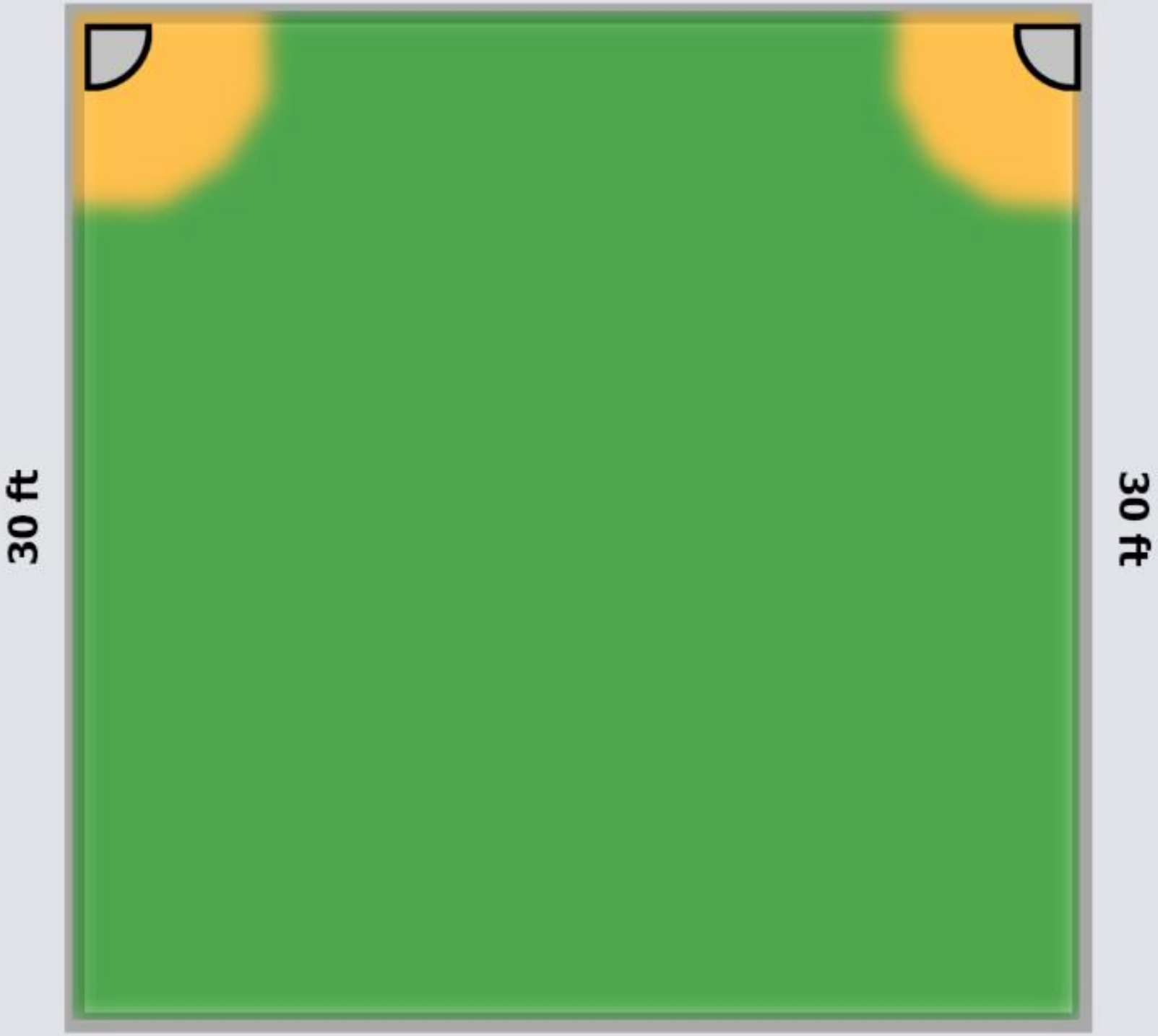
Heating

Should not heat with displacement

- Top heating
- Face heating
- Radiant ceiling panels
- Finned tube



Near Zone

Coordinate layout with furniture and occupants to avoid drafts immediately next to diffuser.

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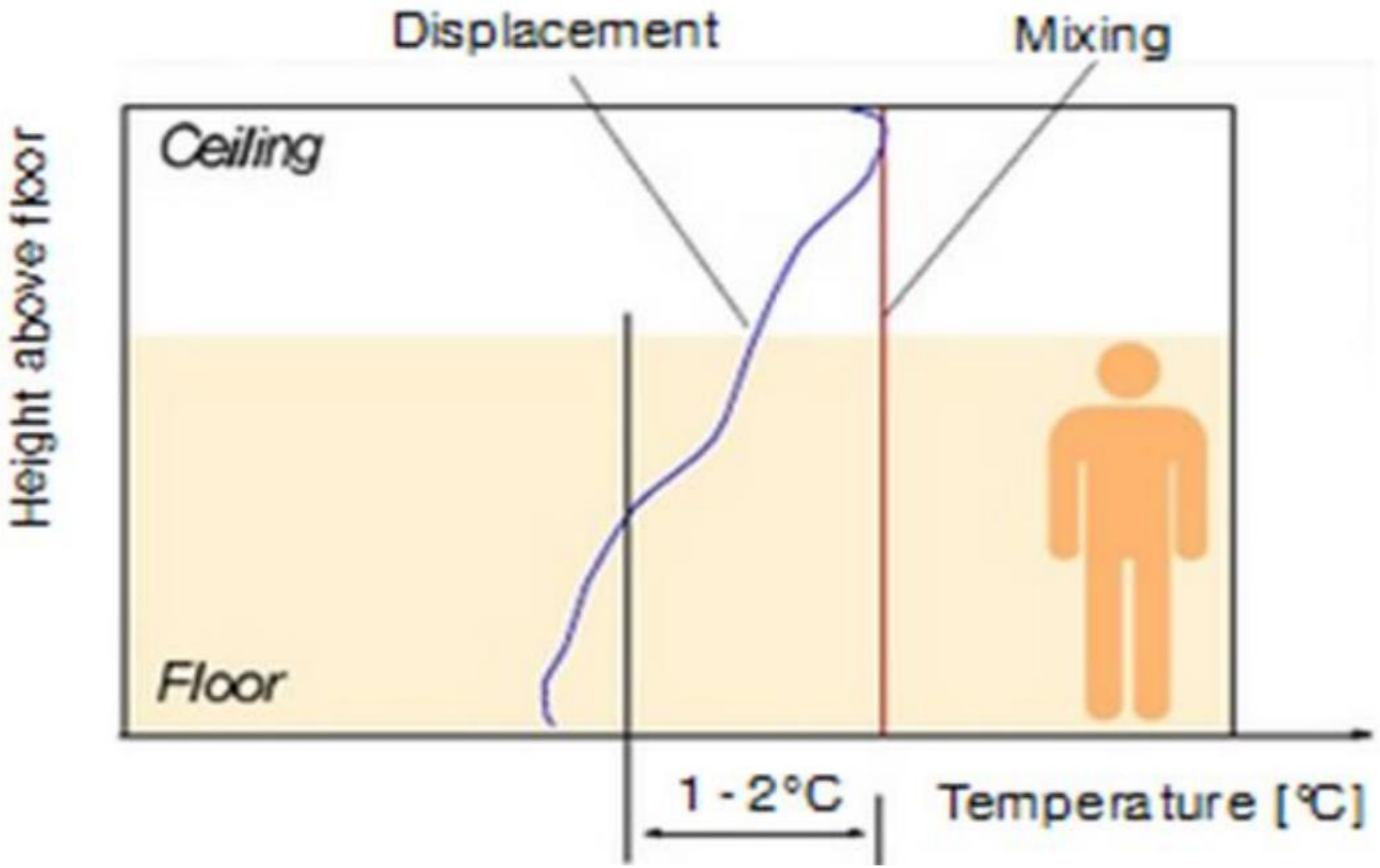


Low Ceilings

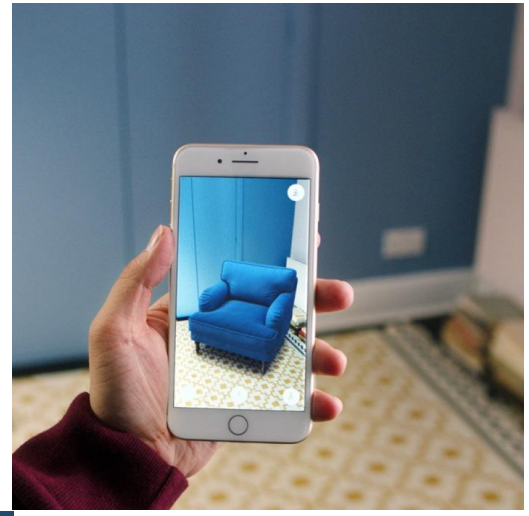
Need space to stratify – about 1°F -1.8°F per foot height.

Too low of a ceiling – noticeable temperature gradient

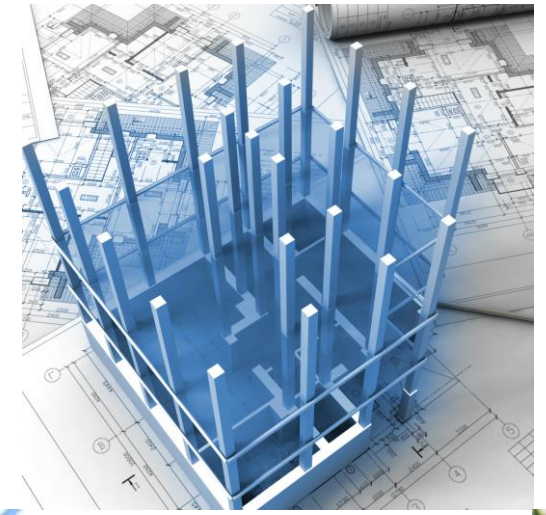
Wrap Up

Summary

Stratified System– Helps reduce probability of contagions due to non-mixing.



Flexible Integration– Can be applied in a variety of manners and spaces.



Effective in Minnesota – Energy models show cost savings in northern climates.

Low Velocities – Air is delivered at lower velocities resulting in comfort benefits.

Energy Consumption– Ventilation effectiveness, supply temperatures help reduce energy consumption.

References

- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9310363/figure/Fig1/
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Questions?
Answers