HVAC Optimization with Cold Air Distribution

An Online Continuing Education Course for Engineers

Course Number: HV-2003

Credit: 2 Hours / 2 PDH / 2 CPD

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Most conventional air conditioning designs are based on supplying 55°F air to the space. This temperature generally provides the required humidity ratio to maintain space conditions at 75°F with in reasonable humidity control range of 55 ± 5%. Over many years, it has become a standard design parameter upon which equipment selection specifications and rules-of-thumb are based. Designers repeatedly use this norm simply because they know it works, even though it may not necessarily offer the best economics in terms of energy performance, cost or air quality.

What if we design a HVAC system to supply air below 55°F!! Several questions will come in mind.

1. Is this been used elsewhere?
2. What are the benefits?
3. What are the drawbacks?

The answer to the first question is yes. The cold air design has been in use in many applications including industrial, manufacturing, control rooms, cold rooms, pharmaceutical and medical facilities and even in the commercial buildings. We will find the answers to the remaining questions in this course.

What is cold air distribution?

The "conventional approach" to design the HVAC system is based on estimating the heat load and computing the air volume for delta temperature (ΔT) between the room setpoint minus the supply air temperature. For comfort applications, the room setpoint temperature is 75°F and the supply air temperature is designed for 55°F, therefore the ΔT is taken as 20°F.

The "cold air systems" distribute air at a temperature much lower than 55°F. The coldest practical air temperature is about 38°F, with most cold air designs using 42-48°F.

Why cold air distribution?

For a given air-conditioning load, as the supply air temperature is reduced, the supply air volume is reduced proportionally. Let's check this for 1 ton of air-conditioning load.

The sensible heat gain equation is $Q = 1.08 \times CFM \times \Delta T$

Where

Q is sensible heat in Btu/hr. *(Note that 1 ton of refrigeration, Q is equivalent to heat extraction rate of 12000 Btus per hour.)*

CFM is the air volume required

ΔT is the temperature differential of the space setpoint minus the supply air temperature

Consider two cases:

Case # 1: The room setpoint temperature is 75°F and the supply air temperature is 55°F

Case # 2: The room setpoint temperature is 75°F and the supply air temperature is 45°F

In case # 1, the ΔT is 20°F and therefore the air volume per ton of air-conditioning load shall be

CFM = 12000 / (1.08 x 20) or = 555/ton

In case # 2, the ΔT is 30°F and therefore the air volume per ton of air-conditioning load shall be

CFM = 12000 / (1.085 x 30) or = 370/ton

This shows that by simply lowering the supply-air temperature from the 55°F to 45°F reduces the supply-air volume by 33%.

What are the Benefits of cold air distribution?

The primary advantage of cold air distribution lies in the dramatic reductions in the supply air volume. What this means is that the HVAC equipment shall use smaller air handling units (AHU's), air ducts, terminal devices, insulation and fittings.

Let's take a closer look at the opportunities extended by considering an example of an office complex requiring 100TR of air-conditioning. On a conventional system design operating at 55°F, this facility shall require 55500 CFM of air while following case # 2 - cold air distribution at 45°F, the supply air volume shall be 37000 CFM.

1) Smaller Air Ducts

Sno.	Parameters	Case #1	Case #2
A	Air volume	55500 CFM	37500 CFM
B	Duct air velocity	1500 FPM	1500 FPM

Sno.	Parameters	Case #1	Case #2
C	Duct cross sectional area (A/B)	37 sq-ft	24.6 sq-ft
D	Assume round duct shape, diameter of duct (d) = Sqrt (C * 4 / 3.14)	6.86 ft	5.6 ft
E	Assuming 100 feet duct length, surface area of duct = (3.14 * D * 100)	2154 sq-ft	1758 sq-ft

Benefits

1. The case #1 shall use 2154 sq-ft of duct work vs. 1758 sq-ft for the case #2. This is 18% reduction in the ductwork. What this means is

   - Lower sheet metal
   - Lower insulation
   - Lower fittings such as volume control dampers, terminal devices, grilles, registers etc.
   - Smaller variable air volume (VAV) boxes

   All this represents a very large capital savings.

2. The duct diameter in the case #1 is 6.86 ft vs. 5.6 ft in case # 2. This saves 1.26 ft of plenum space there by can reduce the total height requirements of the building. More space above the ceiling allows more space for cable trays, control cabling, and fire protection sprinklers.

3. The smaller ducts mean smaller core areas or vertical air shafts providing additional floor space.

4. Shorter floor-to-floor height, attributable to smaller ductwork, may significantly reduce the cost of glass and steel in a multistory building ... perhaps even add a floor of rentable space.

5. Smaller ductwork means smaller penetrations on the structural elements, easy installation, transportation and labor handling.

2) Smaller Air-Handling Units (AHUs)

Sno.	Parameters	Case #1	Case #2
A	Air volume	55500 CFM	37500 CFM
B	Face velocity across coil	500 FPM	500 FPM
C	Coil Face Area(A/B) or [Air volume (CFM)÷ 500 (FPM)]	111 sq-ft	74 sq-ft

Benefits

1. The case #1 shall use 111 sq-ft of cooling coil vs. 74 sq-ft for the case #2 at 500 feet per minute face velocity. This is 33% reduction in the size of AHU. What this means is
    - Less sheet metal for the AHU
    - Less insulation and painting requirements
    - Smaller filters and dampers
    - Smaller Fan/s and motor/s
2. Note that the cooling coil has to be designed for 100 TR (1.2 MBH) heat extraction capacity. Since the face area of cooling coil is reduced, the increased heat transfer area shall be compensated by increasing the depth of the coil i.e. by adding rows to the cooling coil. This shall have negligible impact on the size of the AHU length though it shall affect the air pressure drop across the coil. The fan power requirement shall however reduce as the supply air volume reduction shall far offset the marginal increase in fan static.
3. Smaller AHU means lesser foot print area in the mechanical room. The savings on the mechanical spaces could create significant extra useable/rentable floor space. The cost benefits shall be tremendous particularly in the premium real estate buildings.
4. Or the extra space made available by the smaller air-handler footprint can be used for attenuation in sound-sensitive applications.
5. The noise, vibration and the structural loading on account of smaller AHU shall be considerable.

6. The double panel insulation on the smaller AHU shall be significantly lower. Epoxy painting requirements shall also be lower.

7. Smaller air-handling equipment lessens capital expense. If architectural space can be reduced due to the smaller system components, additional construction cost savings can be realized.

3) Reduced Fan Energy Consumption

Spe…		…2
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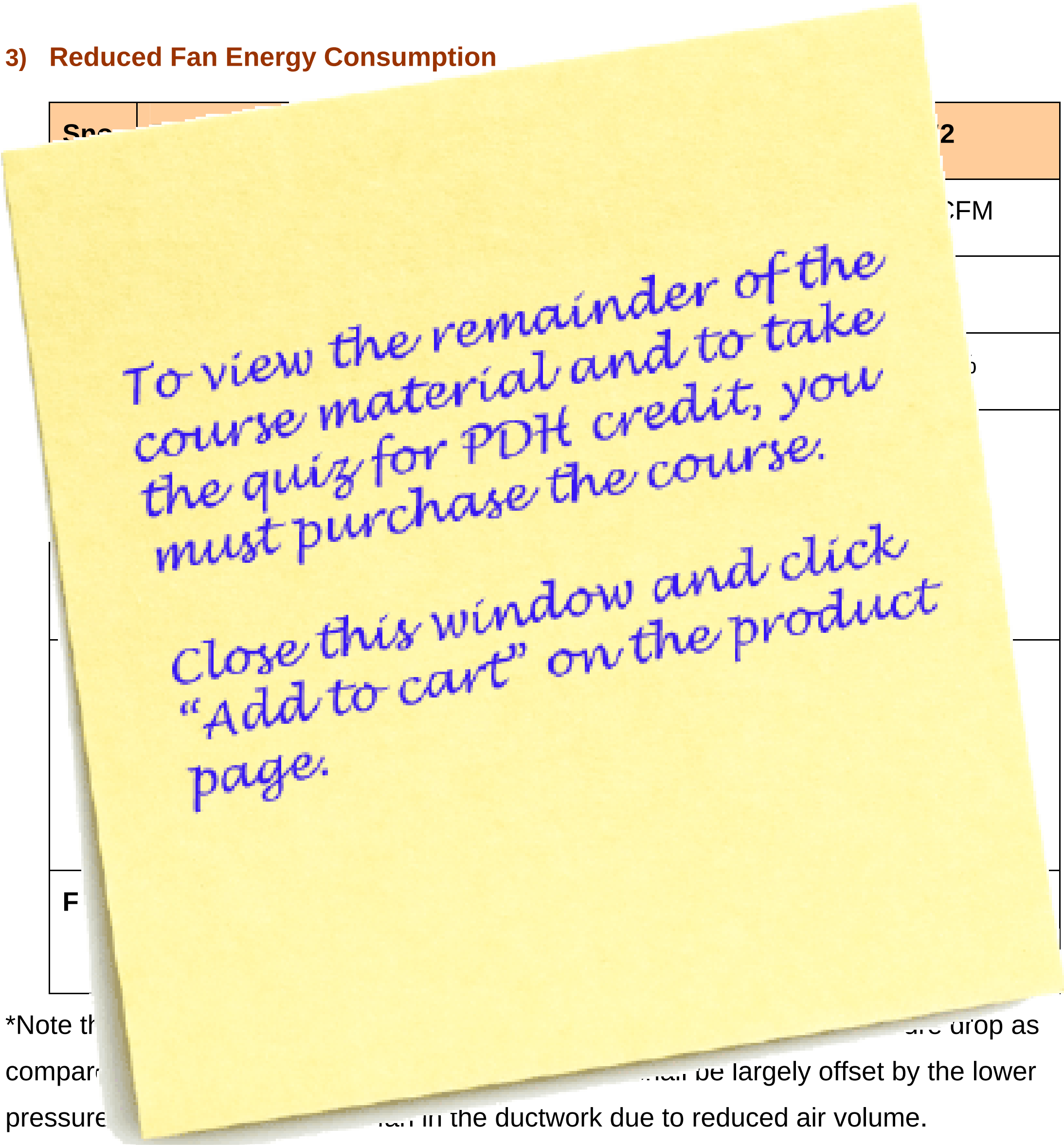

*Note th… …re drop as compar… …hall be largely offset by the lower pressure… …an in the ductwork due to reduced air volume.

Benefits

1. The case # 1 shall use 25 BHP vs. 16.6 BHP for the case #2. This represents 33% reduction in the fan power savings.

2. The case # 2 represents a saving of approx 45000 kWh of electrical energy or $ 3600 per annum.