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Design Bulletin 2

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Considerations for Active Chilled Beam Designs

What About Primary Air?

This design bulletin deals with considerations in the design of **Primary Air** for Active Chilled Beams

How much Primary Air is needed for each ACB?

a. Minimum primary air quantity is equal to the fresh air requirement for the space to be served by each ACB. i.e. If each ACB on the perimeter zone is to serve 13m² and the design ventilation strategy is 2.5 L/s/m², minimum target primary air quantity is 32 L/s.

Reason: Let's assume the perimeter zone is to eventually be churned out into small offices of roughly 13m² each. It is therefore fair to assume that 13m² is a reasonable multiplier for determining primary air quantity per beam.

b. Primary air will ideally deliver approximately 30% of the sensible cooling load for the design space.

Reason: For load diversity, if 30% cooling load is experienced at the ACB, the secondary water can be isolated leaving the primary air (alone) to deliver the limited 30% part-load cooling without risking the primary air will over-cool the space. If the primary air is too warm, this limits the active chilled beam total sensible cooling capacity and places a greater proportion of the sensible cooling load on the secondary cooling coil, thereby limiting part-load cooling turn-down capability of the Active Chilled Beam.

For example, if the room condition is 23ºC and the sensible cooling load per ACB unit is 1345W

1345W x 30% = 403W as a target primary air capacity

Using the standard energy equation (q = M*cp*Δt), we can calculate the primary air value once the room and primary air temperatures are known.

Room 23ºC - 12ºC Primary air = 11ºC delta T

$$\left(\frac{W / cp}{\Delta t}\right) = L/s \quad \text{or} \quad \left(\frac{4.3W / 1.213}{11^{\circ}C\ (\Delta t)}\right) = 30\ L/s$$

If the ventilation strategy suggests 32 L/s primary air, or a higher value, use the ventilation strategy value.

c. If the primary air quantity is too high for a given primary air temperature, more primary air cooling than is really necessary will be delivered; lowering the potential fan energy savings and reducing the ability of the ACB to respond efficiently to part-load conditions without over-cooling the space. In addition, too much primary air may lead to air velocity problems as discussed in Design Bulletin 4.

d. If primary air quantity is too low to deliver the required sensible cooling per unit, the primary air quantity will have to be increased to reach the target sensible cooling capacity per unit or an increased number of ACB units will have to be selected to reach the total sensible cooling target.

Reason: The amount of secondary air that can be induced over the coil to deliver secondary sensible cooling is a function of the primary air quantity, thereby influencing the sensible capacity delivered by the ACB.

Choosing too low a primary air quantity limits the sensible cooling capacity per unit forcing an increased number of units to be selected for a given sensible cooling load.

e. The primary air quantity <u>must</u> deliver all required latent capacity. Insufficient primary air will fail to deliver adequate latent cooling increasing the risk of unwanted condensation. Refer to more detailed latent load comments on page 2 of this bulleting and in Design Bulletin 6.

f. Primary air will probably need to deliver all heating capacity from the ACB. If the primary air quantity is too low, the resulting heating air temperature from the primary air handlers will be unnecessarily high. Refer to more detailed heating comments in Design Bulletin 5.

THIS ISSUE:

Considerations for Active Chilled Beam Designs

What primary air temperature should be used?

It can be any value, but:

a. The primary air must deliver all required latent capacity to the space.

Note: Warmer primary air is unlikely to deliver adequate latent capacity unless the air has been cooled down to say 10-11ºC to achieve a low enough absolute humidity value then reheated to a higher temperature. Therefore, 12ºC primary air is considered a reasonable starting value for primary air design.

Assume the primary air latent capacity requirement for a given perimeter zone being served by 14 ACB units is 1420W for a primary air quantity of 448 L/s (32 L/s per unit) where the room condition is 23ºC & 50%rh and the design primary air condition is 12ºC & 88%rh.

23ºC & 50%rh room air has an absolute humidity value of 8.80 g/Kg

12ºC & 90%rh primary air has an absolute humidity value of 7.71 g/Kg

The absolute humidity differential (Δ*w*) is therefore 1.09 g/Kg

The (Δ*w*) of 1.09 g/Kg is required to ensure design latent capacity is delivered for 448 L/s primary air

If primary air design condition is 12ºC & 88%rh, the air handler control logic must simply be scheduled to deliver a primary air absolute humidity value of 7.71 g/Kg (the corresponding absolute humidity value to 12ºC & 88%rh) to ensure the design latent capacity is delivered.

Note the absolute humidity differential (Δ*w*) between primary air and room air conditions at the right vertical axis of the psychrometric chart below.

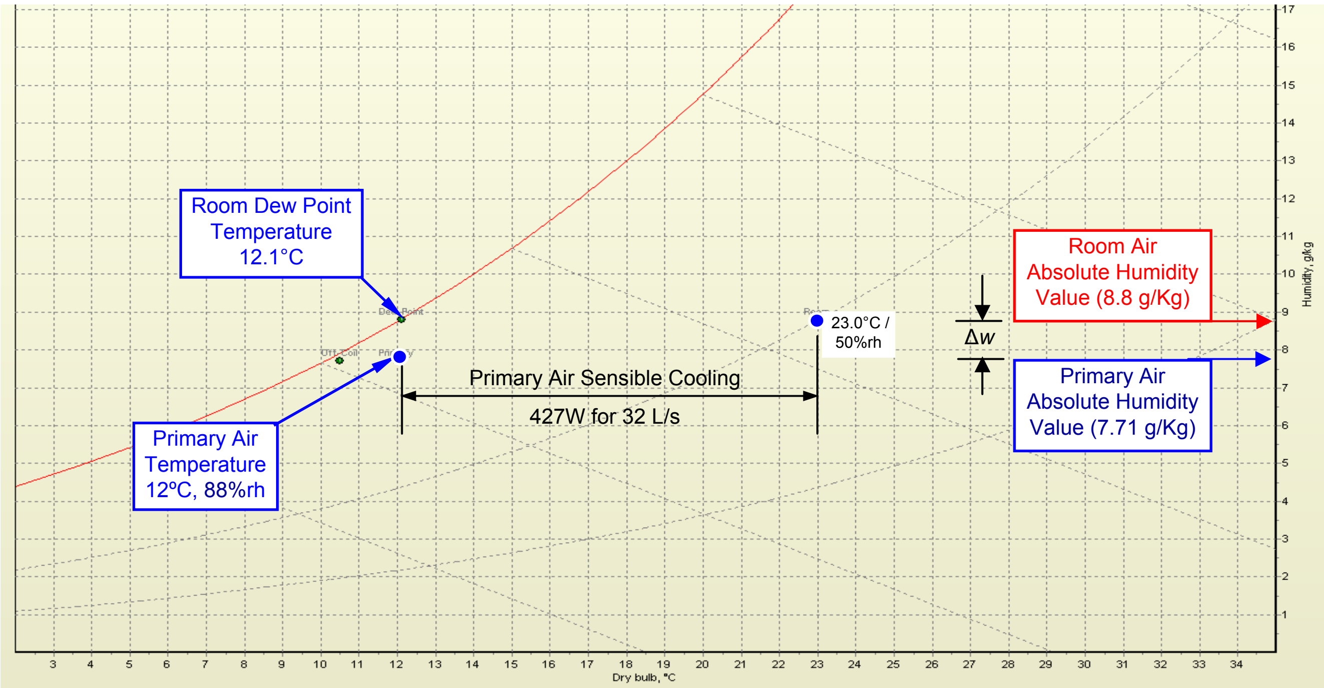
These values will be referred to later in discussing warmer primary air design temperatures.

b. Primary air will ideally deliver approximately 30% of the sensible cooling load for the design space as discussed on page 1 of this design bulletin.

If the cooling load per ACB unit is 1345W …1345W x 30% = 403W as a target primary air capacity

403W of sensible cooling at the design conditions of 12ºC & 88%rh primary air and 23ºC & 50%rh room condition equates to 30 L/s per ACB unit as described on page 1 of this design bulletin.

Since a higher design primary air quantity than 30 L/s was concluded earlier by the design ventilation strategy, 32 L/s will deliver 427W of sensible cooling which satisfies the basic design consideration of 403W while allowing for a part-load cooling scenario turn down capability in the order of 32%.



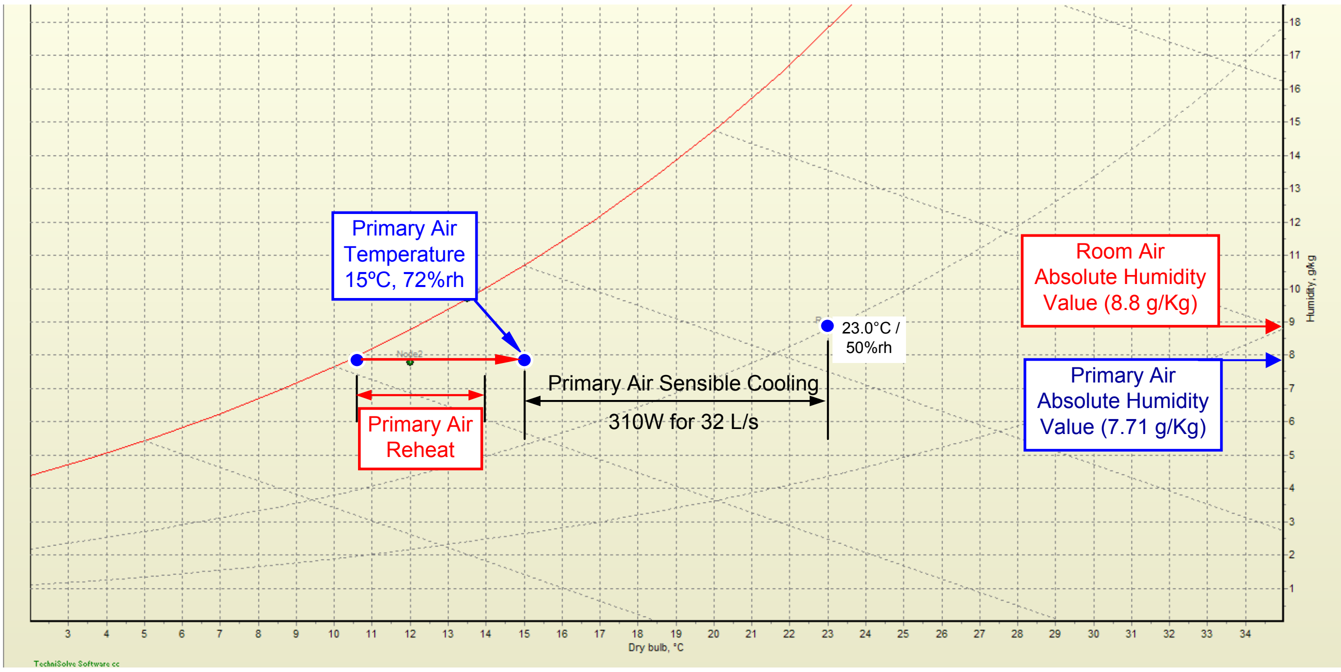
The psychrometric chart above illustrates primary air sensible cooling of 427W for 32 L/s primary air where the primary air condition is 12ºC & 88%rh and room condition is 23ºC & 50%rh.

The absolute humidity differential of 1.09 g/Kg (latent cooling) can be seen on the right vertical axis of the psychrometric chart.

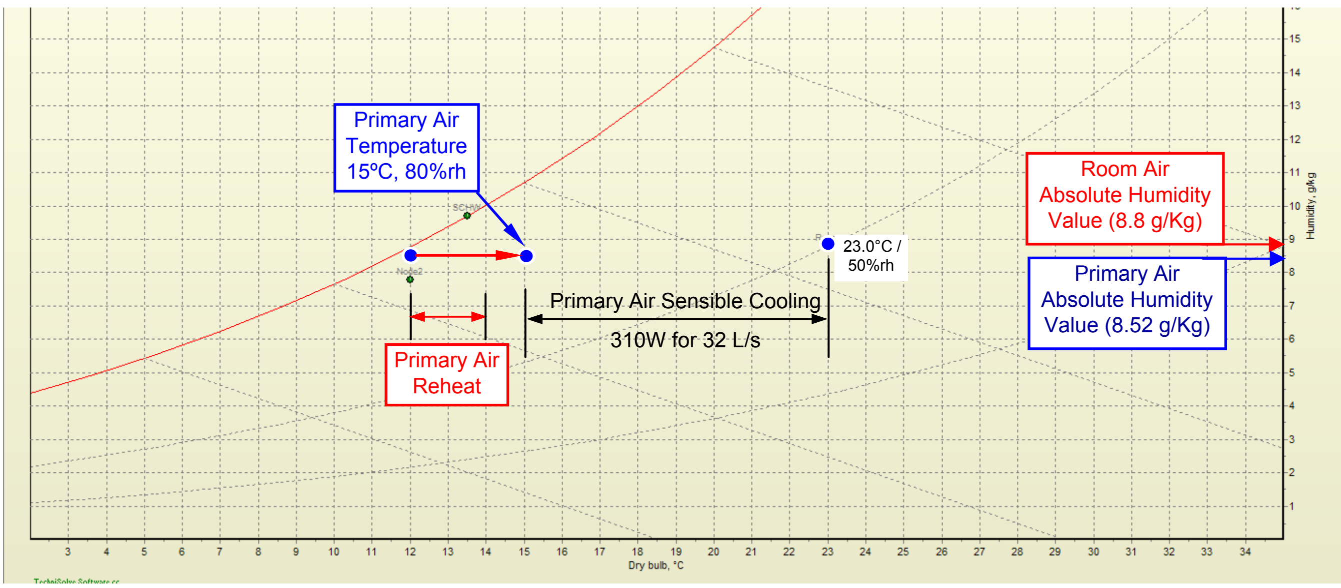
What primary air temperature should be used? *(continued)*

If the primary air design condition is increased to 15ºC, for whatever reason, while maintaining the design absolute humidity differential needed to satisfy the design latent cooling capacity; the new resulting primary air temperature of 15ºC & 72%rh would now deliver 310W of primary air sensible cooling for the design 32 L/s of primary air per ACB unit. This results in a loss of 117W of sensible cooling per ACB unit versus the previous design scenario using 12ºC primary air.

As illustrated in the psychrometric chart below, the primary air condition of 15ºC & 72%rh would require reheat to the 15ºC condition if we assume an air-off condition at the AHU of 10.5ºC to achieve the design primary air absolute humidity condition needed to satisfy the design latent cooling requirement for the design primary air quantity of 32 L/s per ACB unit.



As illustrated in the psychrometric chart below, if the 15ºC primary air condition is delivered by a higher AHU off-coil absolute humidity condition than the original 7.63 g/Kg, the absolute humidity differential reduces requiring a higher primary air volume to satisfy the design latent cooling requirement or a compromised latent cooling performance if the primary air quantity remains the same.



Assuming a higher primary air condition of 15ºC & 80%rh with a new corresponding absolute humidity value of 8.52 g/Kg, an AHU off-coil condition in the order of 12ºC would probably be required and primary air reheat would still be necessary to achieve the 15ºC condition. Although slightly less reheat would be needed than with 11ºC off-coil condition, to satisfy the original design latent cooling requirement of 1420W would now require 125L/s per ACB unit, an air quantity not deliverable by Active Chilled Beams, due to the reduced absolute humidity differential created by using 15ºC & 80%rh primary air.

While less primary air reheat is now used due to a higher AHU off-coil condition, a significantly higher primary air quantity is now required to satisfy the design latent load if a lower absolute humidity differential (Δ*w*) is used.

Considerations for Active Chilled Beam Designs

The preceding information comparing 12ºC and 15ºC primary air temperatures clearly indicates 12ºC primary air makes a favourable contribution to sensible cooling capacity delivered and simplifies the task of delivering latent cooling performance.

Where warmer primary air temperatures are used:

- Sensible cooling capacity is reduced, placing more of the cooling load on the secondary water coil
- Latent cooling capacity is potentially reduced if a high absolute humidity differential is not maintained
- Higher primary air quantity may be needed to deliver latent cooling requirements
- Part-load cooling scenario turn down capability must be controlled through secondary water only

Must the primary air be all outside air?

No. Primary air can be all outside air or a mixture of fresh air and return air. It is up to the designer.

An all-outside air system often uses more than the recommended code ventilation requirement to achieve higher Green Star points and deliver improved Indoor Environmental Quality (IEQ) by providing higher levels of fresh air dilution rather than relying on filtration of air. An all-outside air system also eliminates return air infrastructure resulting in mechanical services installed cost savings.

All outside air designs will likely incur higher primary air chilled water capacity but this is generally offset by reductions in air quantity versus conventional all-air system designs.

Does the primary air system need VAV control?

No. The primary air system can easily be constant volume (CAV) as the amount of air in question is quite small compared to a conventional VAV system design.

In some designs for larger buildings even greater fan power savings can be realised by incorporating VAV strategies into the primary air but it is not considered essential to a successful design.

In multi-purpose use buildings requiring different primary air temperatures or quantities per floor or zone, a VAV strategy can be useful in overcoming problems related to over-cooling or over-heating through primary air.

What degree of primary air temperature control needs to be considered?

Generally, primary air can be constant volume and constant temperature for cooling applications.

Where needed or preferred, primary air temperature can be allowed to 'glide' to warmer temperatures where sensible loads are reduced but care must be taken to ensure that latent capacity is always being delivered. Warmer primary air temperatures often do not provide for adequate latent performance in the primary air stream as discussed earlier in this design bulletin.

If primary air temperature is allowed to glide upward during part load conditions, when sensible loads increase during a part-load scenario, primary air temperature should be reduced to the lower design temperature (maximum latent cooling) first before allowing the secondary water flow to resume.

With this strategy, increases in cooling requirement can be dealt with in the primary air and latent capacity will be restored to the maximum design value before secondary water is enabled thereby avoiding unwanted dew point conflicts.

For more design considerations, see other issues of the Design Bulletin

This series of design bulletins is provided by Dadanco in the interest of sharing design experience with those interested in learning more about Active Chilled Beam design fundamentals

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