



Modeling Chilled Beam Systems in HAP

This HAP e-Help provides a high-level overview of chilled beams, the different types available, how they work and how to model them in HAP. Please consult specific manufacturers' application and product literature for application and design information. Carrier offers the 36CB series chilled beam system. Application information is available for downloading at www.commercial.carrier.com or by contacting your local Carrier sales representative.

Europe has successfully applied Chilled Beam systems for a decade even though it is relatively new technology in North America. The inherent design and operational advantages influenced the popularity of chilled beam systems in North America. We discuss these advantages later in this e-Help.

There are two types of Chilled beam systems: active and passive.

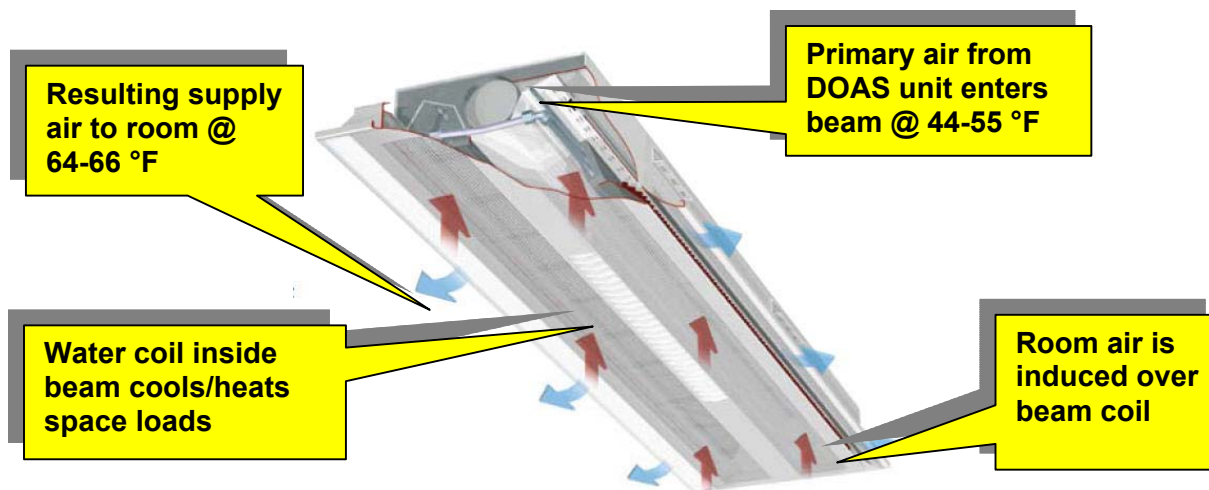


Figure 1 – Active Chilled Beam

Active chilled beams (ACB) use pre-cooled (and dehumidified) primary air using chilled water in a quantity necessary to meet the room latent load and ensure good air quality for the occupied area. The cooled and dehumidified primary air absorbs the space latent load; resulting in the chilled beam coil operating without condensation. The chilled beam then cools or heats the induced air to meet the room sensible load and respond to the room thermostat requirements.

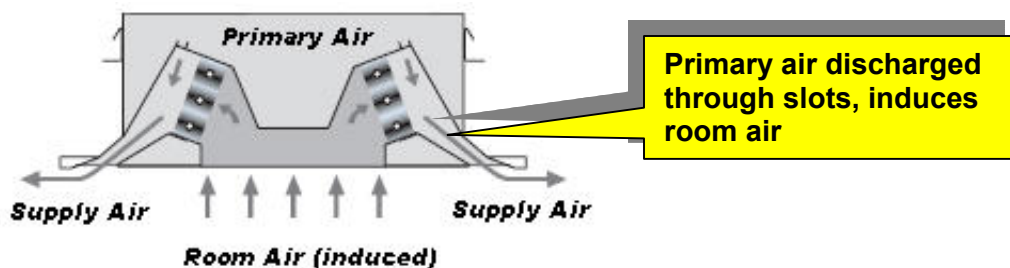


Figure 2 – Active Chilled Beam Cut Away



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Active chilled beams operate using the induction process. During induction, the primary air discharges under pressure through nozzles located within the device as illustrated in Figure 2. This high velocity incoming primary air creates a negative pressure in the inlet portion of the beam thereby inducing room air through the beam coil where it mixes with the cold primary air. This mixed air is then discharged through the outlet slot of the beam into the room, resulting in a total airflow quantity 3 to 4 times greater than the primary airflow. We refer to this ratio of total air to primary air as the induction ratio.

Passive chilled beams Passive chilled beams (PCB) work using natural convection. Air cooled by the coil inside the beam becomes denser than the surrounding room air and therefore flows downward into the room. The difference in density combined with the height of the beam induces room air down through the beam coil. Thus passive beams mainly provide a downward airflow in the room, as shown in Figure 3. This downward flow induces air from the room upward to the ceiling level and then through the beam coil. Unlike an active chilled beam, the passive chilled beam delivers treated primary ventilation air directly to the space and not through the chilled beam. Nevertheless, like the active chilled beam, this ventilation air must be sufficiently dehumidified to meet the entire latent room load.

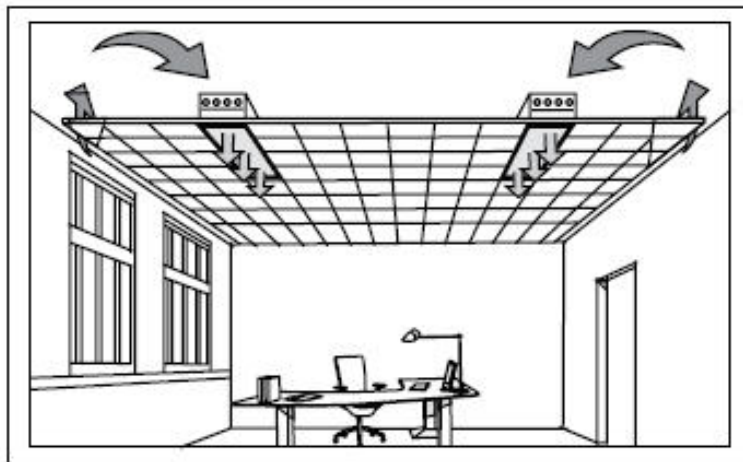


Figure 3 – Passive Chilled Beam Airflow Pattern

To avoid drafts in spaces with low ceilings do not locate passive beams above workstations with sedentary occupants. Both remixing and displacement terminal devices provide good comfort in the room in combination with passive beams.

What are the advantages of chilled beam systems over conventional designs? Chilled beam systems are suitable for use in high sensible cooling load applications or where individual temperature control is required. Compared with a system where the cooling duty is supplied entirely by air (all-air systems), a chilled beam system reduces the fan power requirements and space needed for air-handling plant equipment and ducting. Chilled beam systems have the following advantages:

- High sensible load capacity (offices, schools, computer rooms)
- Decouples ventilation load from room sensible + latent loads resulting in better temperature control and fan energy savings
- Typical supply air temperature is 64-66 °F exiting the chilled beam maximizing occupant comfort. Conventional systems deliver cold air at 55 °F with the potential of creating drafts if poor mixing occurs
- Constant volume ventilation air eliminates potential air dumping as compared to varying airflows in VAV system.
- Reduced fan power requirements (100-250 CFM/ton)
- Increased space ventilation effectiveness (1.0) due to the good mixing (high induction ratio) of room air and supply air
- Reduced plenum space required (units are ~12" tall), good for retrofit applications
- Easily integrates with T-bar (false) ceilings
- Some units incorporate fluorescent lighting fixtures and fire sprinkler heads
- Some units offer directional air flow pattern control, optimizing comfort and preventing drafts



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What are the typical design conditions used for the chilled water and primary air for a chilled beam system and how are they controlled?

Assuming applications with normal ceiling heights (9-10 ft), apply chilled beams in applications with cooling loads of 25-30 Btu/ft² of floor area. This capacity limitation is primarily due to the maximum possible air velocity in the space. Chilled beams use warmer chilled water from the secondary side of the cooling plant (or from mixing of primary and secondary water) at an inlet temperature from 57-61 °F to prevent condensation from occurring on the beam coil. This equates to a primary supply air temperature of approximately 65 °F. Install special humidity (condensation) sensors on the chilled beam coil that close the water control valve if the RH gets to 90% on the incoming chilled water pipe. Alternatively, use an atmospheric RH sensor in combination with an air temperature sensor to reset the supply water temperature upward closer to 60 °F during conditions when condensation might occur.

That is why it is important for the DOAS system to adequately dehumidify the primary ventilation air such that it can absorb all of the latent loads in the zone. The DOAS leaving air temperature (LAT) should be in the 44-55 °F dry bulb range with approximately 44-45 °F dewpoint (DP) to ensure there is no condensation on the beam coil. The lower end of the ranges should be used when the zone latent loads are higher, such as conference rooms, school classrooms, etc. while the higher end of the range may be used in applications with low zone latent loads.

How do you model a chilled beam system in HAP?

An accurate equivalent model for chilled beam systems can be created in HAP using the 4-pipe fan coil system type, as described in the following example. Even though HAP offers a "CAV - 4-Pipe Induction" system, the 4-pipe fan coil system offers some additional features that make it better as an equivalent model for chilled beams.

For our modeling example, assume the chilled beam system is a 4-pipe cooling & heating system with cooling and heating provided in the beam. The system serves four separate office zones. A dedicated outdoor air system (DOAS) preconditions outdoor ventilation air and supplies the treated air to the chilled beam units. The DOAS will also use an air-to-air heat recovery device to increase system energy efficiency.

In the HAP air system properties form, select **Terminal Units** as the Equipment Type and **4-pipe Fan Coil** as the **System Type**. Then select the **Common Ventilation System** radio button as indicated in Figure 4. "Common Ventilation System" is HAP's term for the DOAS unit.



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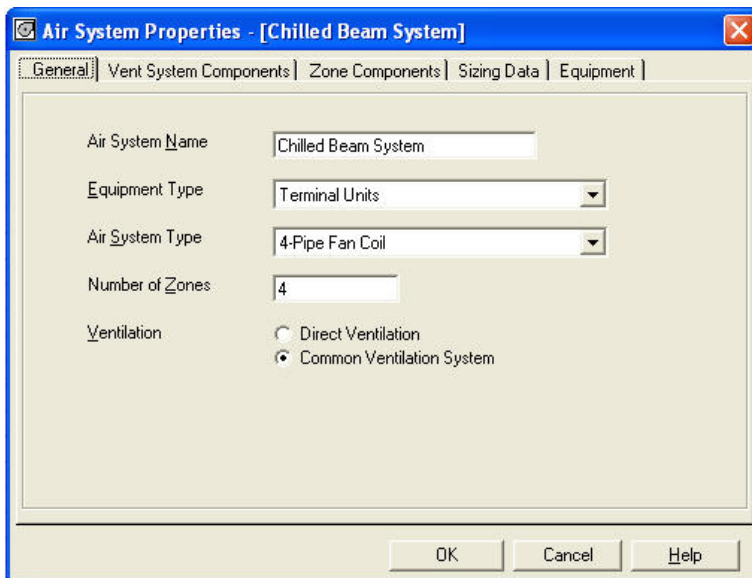


Figure 4 – HAP System General Tab Input Screen

Next, under the **Vent System Components** tab select the items as shown in Figure 5.

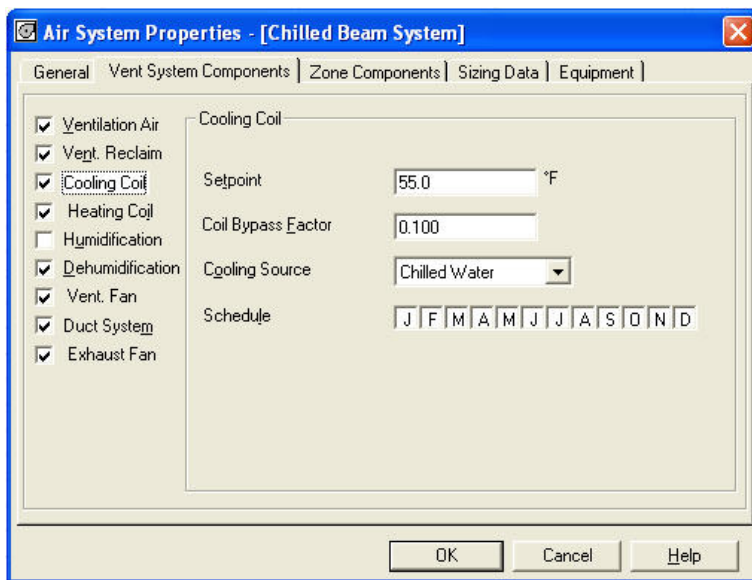


Figure 5 – HAP Vent System Cooling Coil Input Screen

As mentioned previously, chilled beam units operate as sensible-only devices (no latent) therefore the DOAS must supply air to the chilled beams at conditions capable of absorbing all of the zone latent load thereby preventing condensation on the beam coil. This means the DOAS cooling coil LAT must be selected at a dry bulb temperature and dewpoint less than **zone-neutral** conditions. Let us assume a room design setpoint of 75 °F/50% RH (~ 55 °F DP) and use an assumed cooling coil LAT of 55 °F.



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For the Heating Coil setpoint from the common ventilation unit, assume a LAT slightly less (2-3 °F) than the cooling coil, otherwise the cooling and heating coils will fight each other and operate simultaneously anytime the DOAS is operating. See Figure 6.

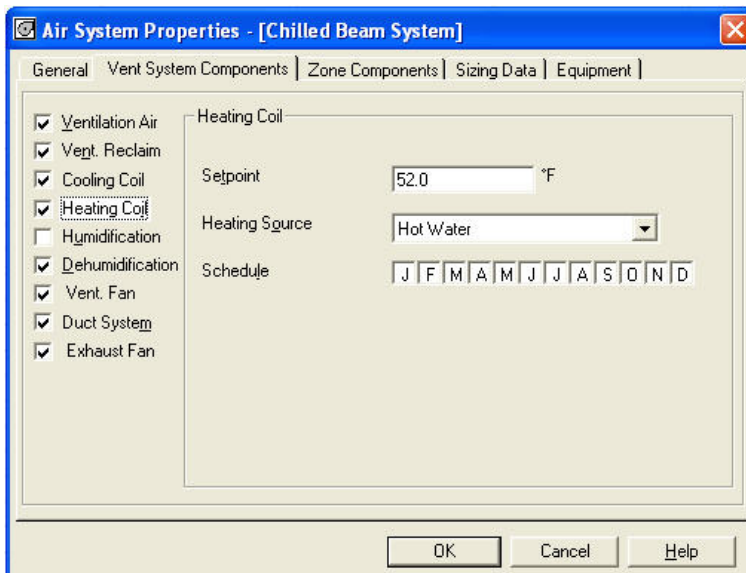


Figure 6 – HAP Vent System Heating Coil Input Screen

Since the cooling coil LAT approaches saturation, (90-100% RH) additional dehumidification of the ventilation air is often required. This is basically a reheat coil as modeled in HAP. On the **Vent System Components** tab, check the box labeled **Dehumidification**, and specify 80% supply air RH, as indicated in Figure 7.

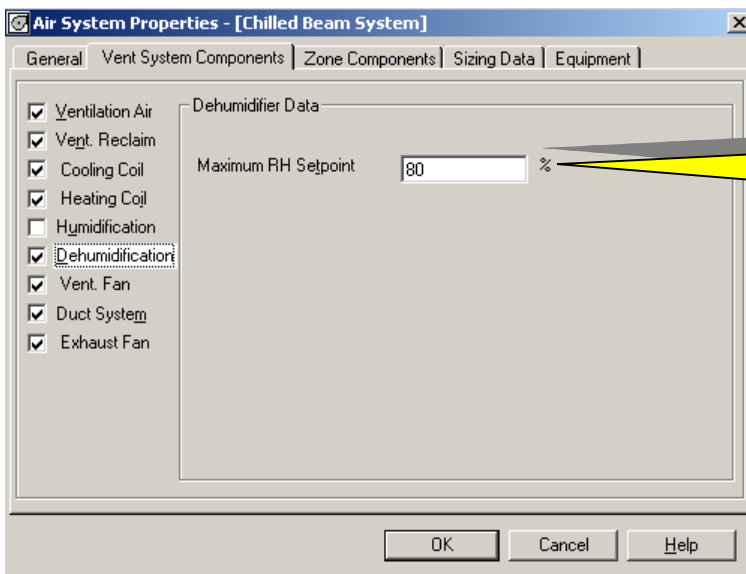


Figure 7 – HAP Vent System Dehumidification Input Screen



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Keep in mind that for a Common Ventilation System the dehumidification maximum RH% input is for the supply airstream, not the relative humidity setpoint for the zone. The 80% RH setpoint means anytime the supply air RH% goes above 80% the cooling coil will be activated to further dehumidify the air while the heating coil in the reheat position will be activated to maintain no greater than 80% RH in the supply air.

You might have to use a trial-and-error approach and change the cooling LAT and dehumidification RH% values until you arrive at an optimum and reasonable result. As a general rule, use the highest LAT and RH% that maintains the zone at 40-50% RH, which ensures no condensation and minimizes energy usage.

The Hourly Zone Loads Report shown in Figure 8 displays the resulting room relative humidity and zone dry bulb temperatures for each hour in each zone. This report should be used to check these values for each zone.

For our example 4-zone building, we generated the Hourly Zone report for the peak design month. Also consider checking the zone RH% during off-design times like September or October. This report can be generated for any off-design month. If the Hourly Zone reports indicate a maintained zone 40-50% RH, then the common vent system LAT and RH are acceptable.

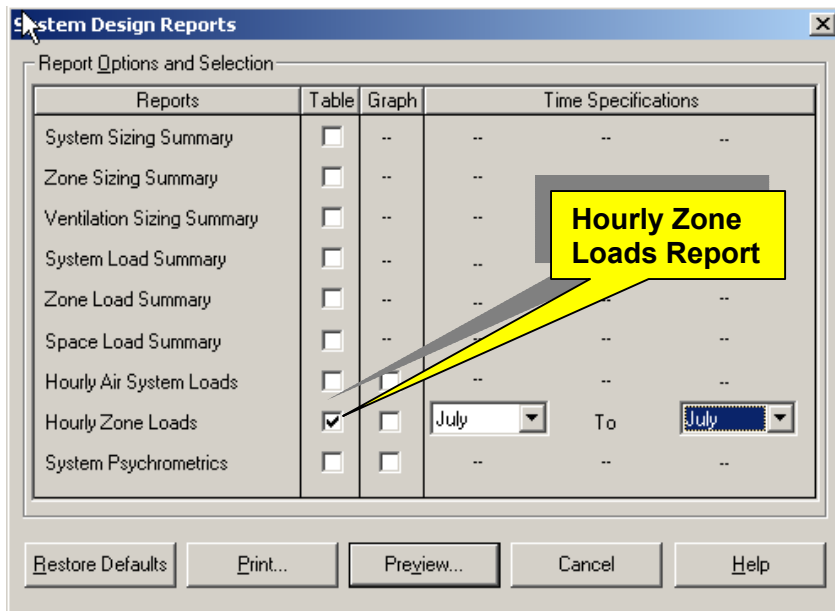


Figure 8 – Ask For HAP System Design Hourly Zone Loads Report

ZONE: Zone 1
DESIGN MONTH: NOVEMBER

Hour	OA TEMP (°F)	ZONE TEMP (°F)	RH (%)	ZONE AIRFLOW (CFM)	ZONE SENSIBLE LOAD (BTU/hr)	ZONE COHD (BTU/hr)
0000	63.8	76.7	-	0.0	1816.3	0.0
0100	62.9	76.7	-	0.0	1505.0	0.0
0200	62.1	76.6	-	0.0	1201.7	0.0
0300	61.4	76.5	-	0.0	916.0	0.0
0400	60.9	76.4	-	0.0	649.8	0.0
0500	60.7	76.3	-	0.0	417.8	0.0
0600	61.0	76.2	-	0.0	236.7	0.0
0700	61.9	75.0	50	1613.6	4634.8	2493.8
0800	63.5	75.1	50	1613.6	4917.1	6400.6
0900	65.7	75.2	50	1613.6	5200.0	6536.4
1000	68.3	75.5	50	1613.6	5483.5	6661.7
1100	71.3	75.2	50	1613.6	7233.8	8031.5
1200	74.0	75.1	51	1613.6	8043.4	9030.8
1300	76.1	75.5	50	1613.6	9059.7	9136.7
1400	77.5	75.4	51	1613.6	10181.4	10389.6
1500	78.0	75.4	51	1613.6	11017.1	11232.9
1600	77.5	75.4	51	1613.6	10899.5	11099.5
1700	76.3	75.7	50	1613.6	9328.5	8909.8
1800	74.4	75.4	46	1613.6	4672.1	4794.6
1900	72.1	75.2	46	1613.6	4118.4	4608.5
2000	69.9	75.3	46	1613.6	3676.7	4006.4
2100	68.0	75.2	46	1613.6	3286.7	3614.4
2200	66.2	76.8	-	0.0	2508.8	0.0
2300	64.9	76.8	-	0.0	2116.3	0.0

Hourly Zone Load Report Displays Resulting Zone RH

Figure 9 – HAP System Design Hourly Zone Loads Report



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The last three settings for the Vent System should be entered appropriately for your conditions. The vent fan and exhaust fans are the fans inside the DOAS, not the zone terminals (which have no fans in our case). The fan power settings must include all static losses including the recovery unit, the supply/return duct losses and the static losses through the beam units.

Next we move to the Zone Components tab, as shown in Figure 10. Here you assign the spaces to the zones. In our case we have four zones, each with one space. Also set the thermostat settings and schedule.

Under Common Data, we will enter a cooling supply air temperature of 65 °F, which is typical for a chilled beam system. The heating coil setting will be 90 °F, which will minimize stratification during heating and maximize the ventilation efficiency.

Finally, for the Terminal Units settings you can leave the Terminal Units minimum zone airflow at zero. The primary airflow will be set properly based on space ventilation requirements. Because we are modeling the chilled beam as a fan coil system, the fan static must be entered as zero. This eliminates the effect of the fan from the system. While the program will calculate supply airflow thinking the system is a fan coil, the sensible BTU/h provided will be the same no matter what this supply airflow is and there is no impact on fan heat or energy use because there is no fan.

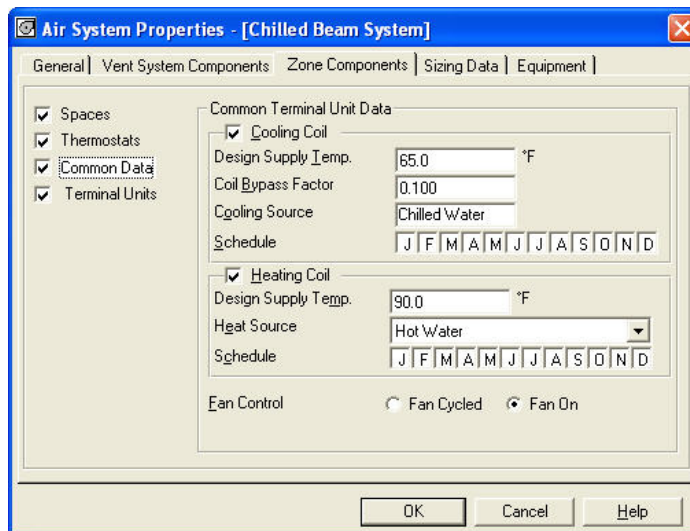


Figure 10 – HAP Zone Components Common Data Input Screen

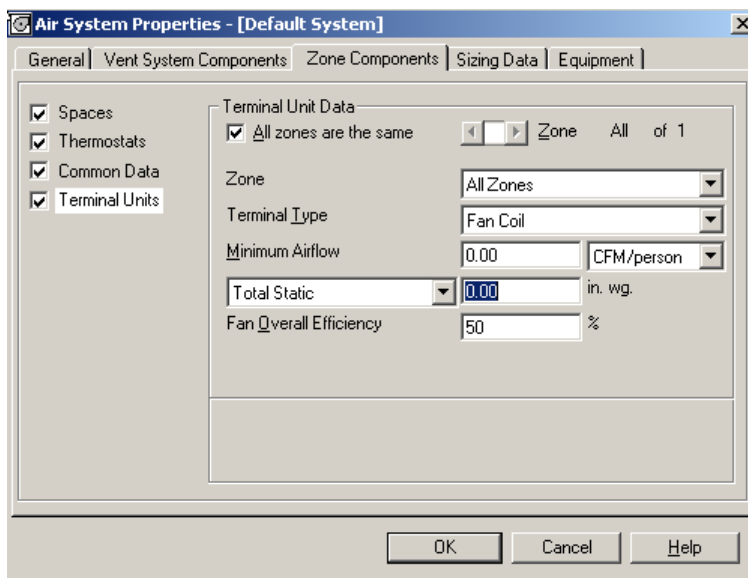


Figure 11 – HAP Zone Components Terminal Units Input Screen



Modeling Chilled Beam Systems in HAP

What about the Chilled water Plant Model?

The chilled water plant for chilled beam systems needs to operate at two supply water temperatures. The DOAS needs to receive cold water at a supply temperature like 44 °F in order to condense sufficient moisture out of the outdoor air stream to handle the space latent load. The chilled beam units need to receive warmer water, typically in the 57 to 61 °F range. This is achieved by producing cold chilled water at 44 °F LCHWT and supplying it first to the DOAS coil. Outlet water from the DOAS unit is then typically blended with water from the return side of the plant to reach the desired 57 to 61 °F temperature for supply to the chilled beam units.

To develop an equivalent plant model for this configuration in HAP, first define the chillers according to actual system specifications. That is, supplying 44 °F LCHWT and with flow rates appropriate for the actual delta-T. This delta-T is often in the range 16 to 20 °F. Connect the chillers to a chilled water plant. Specify the plant design LCHWT as 44 °F. On the Distribution Tab (Figure 12) the best results are obtained by specifying "Primary Only/Constant Speed" or "Primary Only/Variable Speed" as the system type. Specify the Coil Delta-T at design as your overall system design delta-T - such as the 16 to 20 °F value.

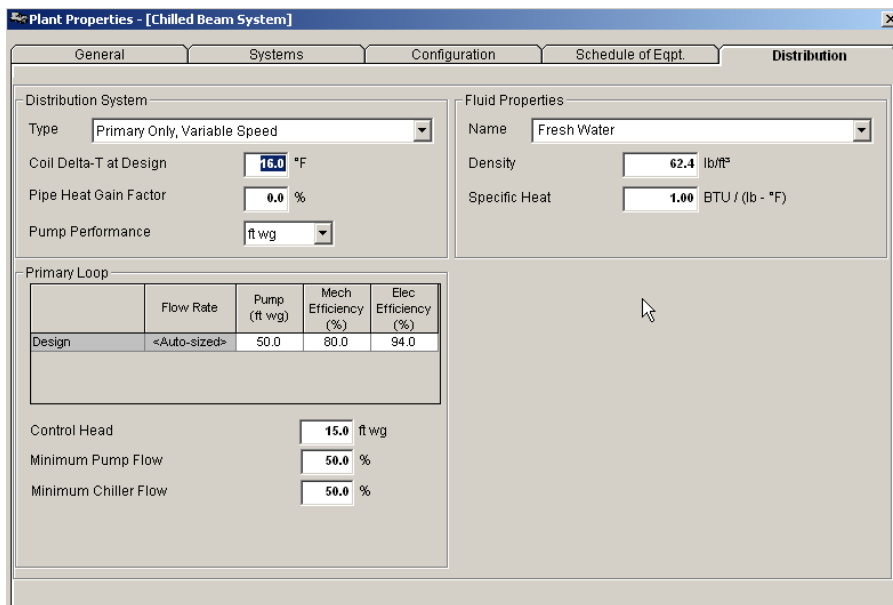


Figure 12 – Chilled Water Plant Modeling For Chilled Beam

In conclusion, chilled beams are becoming more popular. They provide many operational and design advantages, as discussed. By decoupling the ventilation loads from the zone sensible and latent loads, the terminals are designed to handle lower total airflow quantities, thereby using smaller equipment while resulting in uniform air distribution, high air-change rates and uniform temperatures in the zone with fewer drafts. It is important to account for the zone latent loads in your design considerations and to ensure proper sizing of the DOAS including the ventilation air loads plus the zone latent loads, while the chilled beams are sized to handle the zone sensible loads only.

As mentioned previously, you should consult manufacturer’s specific design application literature when attempting to design a chilled beam system.

References:

- 1) *Design Considerations For Active Chilled Beams*; Alexander, Darren, P.E. & O'Rourke, Mike; ASHRAE Journal, Sept. 2008; pp. 50-58
- 2) *DOAS & Humidity Control*; Larranaga, Michael D., Beruvides, Mario G., Ph.D., P.E., Holder, H.W., Karunasena, Enusha, Ph.D. & Straus, David C, Ph.D.; ASHRAE Journal, May 2008; pp. 34-39.
- 3) *36CB Active & Passive Chilled Beams Product Literature*; Form 36CB-1PD; August 2008; Carrier Corporation, Syracuse, NY.
- 4) *36CBA, CBP Active & Passive Chilled Beams Application Data*; Form 36CB-1XA, August 2008; Carrier Corporation, Syracuse, NY.