Modeling Induction Beams in HAP v4.8

This HAP e-Help provides a high-level overview of induction beams, how they work and how to model them in HAP 4.8 (and later versions). The first half of the article explains how induction beams work. The second half deals with HAP modeling. Please consult specific manufacturers' application and product literature for application and design information. Carrier offers the 36IB series induction beam system. Application information is available for downloading at www.commercial.carrier.com or by contacting your local Carrier sales representative.

Ever since Willis Carrier designed the first modern air-conditioning system in 1902, Carrier has led the world in the discovery of innovative ways to provide occupant comfort using sustainable technologies that emphasize efficiency and environmental integrity. The induction beam of today is based on technology invented by Willis Carrier himself in the 1930s and refined by today's pioneers to meet the needs of the high performance building of the future.

An induction beam (IB) takes a source of primary outdoor air at an inlet static pressure ranging from 0.4 to 0.8 in. wg. Induction beams use conditioned (cooled and dehumidified) primary air in a quantity necessary to ensure good air quality for the occupied area. The system distributes this primary air through a bank of specially designed aerodynamic nozzles and discharges the air at a high velocity into a mixing chamber (see Figure 1). This creates a differential pressure which enables a draw of room air across a coil. This imparts either cooling or heating to the induced air as it passes over the coil. The primary air and induced air are mixed and discharged through a supply air louver in a Coanda effect air distribution pattern at the ceiling.

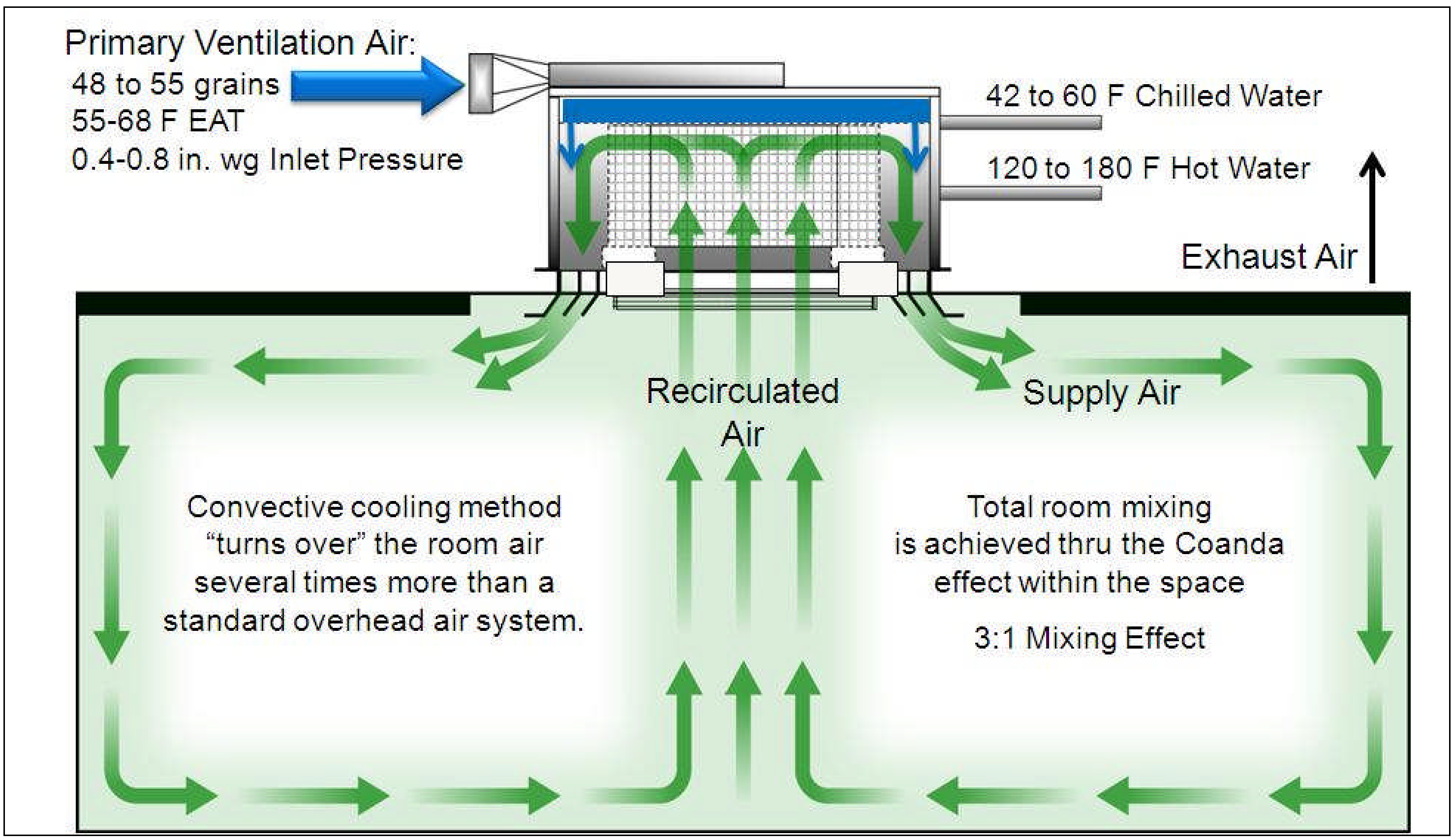

Figure 1. Induction Beam Operating Diagram

Modeling Induction Beams in HAP v4.8

Buildings are dynamic, with latent cooling loads that change over time. A large group of people enter a conference room, a door is left open, or air infiltrates the building envelope. These types of load fluctuations can cause condensation to occur at the beam. A drain pan provides peace of mind and eliminates risk of condensation leaking into the space when latent loads fluctuate. As an added benefit, the integrated drain pan on the Carrier ActivAIR™ induction beam allows the specifying professional to design the system for use with chilled water that is below the dew point of the room. The ability to use colder water means a greater capacity of cooling can be produced by each induction beam unit while reducing chilled water distribution piping size and pump size.

With the ability to provide both sensible and latent cooling, the ActivAIR induction beam delivers more capacity per unit than
sensible-only active chilled beams, so spaces can be conditioned using fewer units. The unit's unique air distribution design creates a uniform temperature within the space, thus providing a comfortable environment with no stratification. In addition, ActivAIR requires only a simple thermostat connected to the coil valves, with no additional controls needed.

What are the advantages of induction beam systems over conventional designs? Induction beam systems provide a cost-saving alternative to traditional commercial zoning systems for new construction or retrofit. They are suitable for use in a variety of single- to multi-floor facilities, from schools and universities to healthcare, office spaces and all applications in between. Compared with a system where the cooling duty is supplied entirely by air (all-air systems), an induction beam system reduces the fan power requirements and space needed for air-handling plant equipment and ducting. Induction beam systems have the following advantages:

- High sensible load capacity
- Decouples ventilation load from room sensible and latent loads resulting in better temperature control.
- Typical supply air temperature is 64-66 °F exiting the induction beam, maximizing occupant comfort. Conventional systems deliver cold air at 55 °F with the potential of creating drafts if poor mixing occurs
- Constant volume airflow eliminates potential air dumping as compared to varying airflows in VAV systems.
- 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
- Easily integrates with T-bar dropped ceiling grids
- Some units offer directional air flow pattern control, optimizing comfort and preventing drafts
- Minimal maintenance required in the occupied zone due to no moving parts in the induction beam
- Low sound levels in the occupied zone
- Induction beams include drain pans that offer the additional benefit of latent cooling at the terminal

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

Induction beams can be used with chilled water entering temperatures ranging from 42° to 60° F due to inclusion of a full drain pan to handle condensation.

The induction beam inlet primary air temperatures are typically between 55° and 70° F. 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. Unlike active chilled beams, where the latent cooling in the space needs to be handled solely by the primary air, the induction beam coil with a drain pan provides additional latent cooling capacity in the space. This allows for primary air supply temperatures closer to neutral space air temperature, reducing the risk of overcooling the space.

Modeling Induction Beams in HAP v4.8

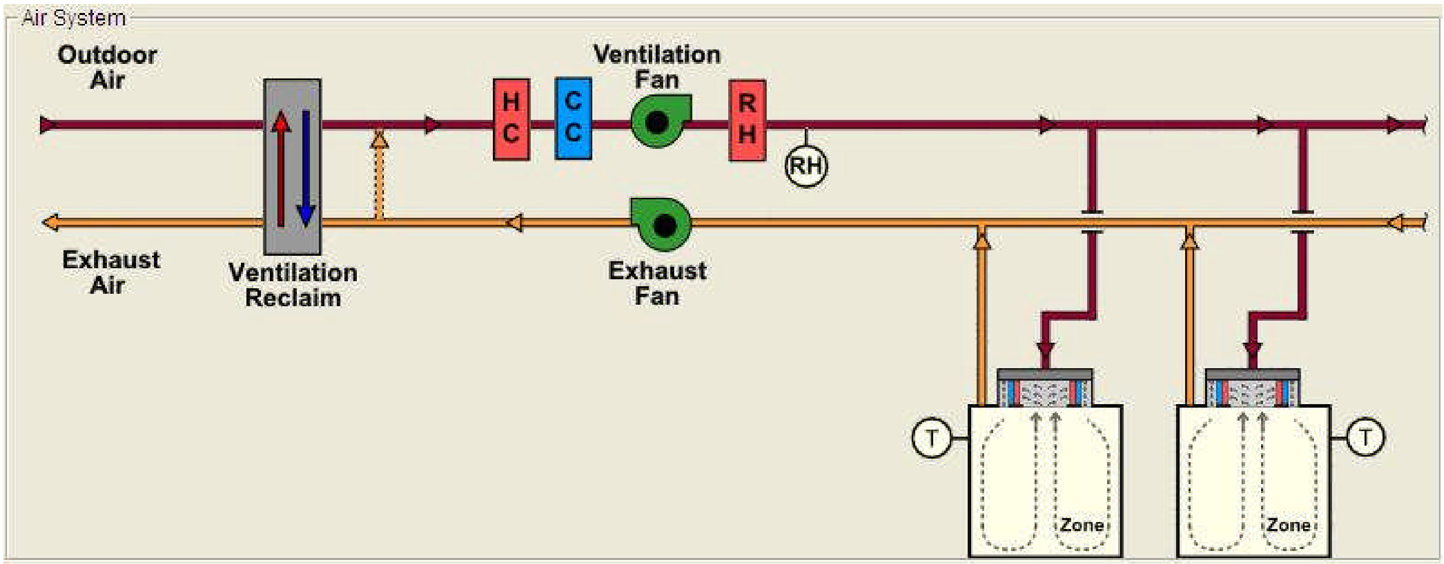

Figure 2. Simplified Induction Beam System Diagram

How do you model an induction beam system in HAP v4.8 (and later versions)?

HAP v4.8 (and later versions) have the ability to directly model induction beam (IB) systems. Construction of a model for an example IB system in HAP will be described in the following paragraphs to explain the basic modeling procedure.

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

To begin construction of the system model specify the following on the ***General*** tab of the HAP air system properties window (Figure 3):

- Equipment Type = Terminal Units
- System Type = Induction Beam
- Ventilation = Common Ventilation System

"Common ventilation system" is HAP's term for the DOAS unit. Note that the selection of a common ventilation system is defaulted and locked because it is mandatory. It is what drives the operation of the induction beam terminals.

Modeling Induction Beams in HAP v4.8

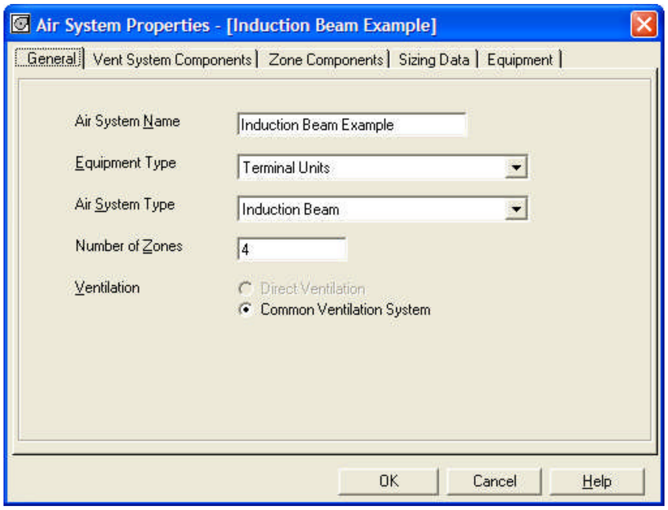

Figure 3. Air System Properties, General Tab

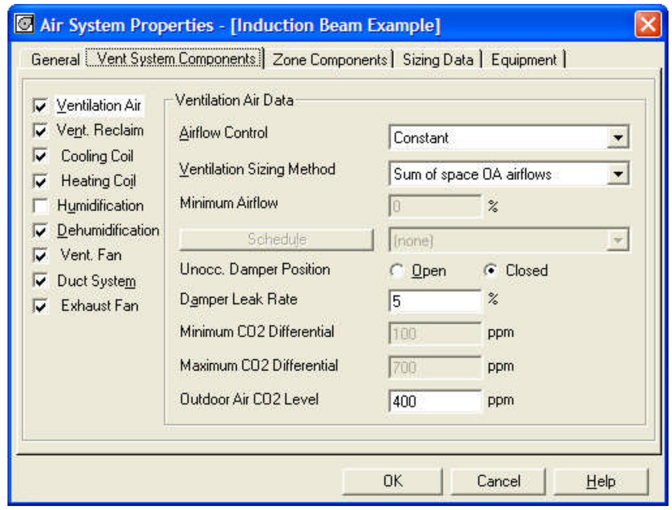

Figure 4. Vent System Components Tab, Ventilation Air Data

Next, on the ***Vent System Components*** tab select the components in the left-hand panel as shown in Figure 4. Then, working from top to bottom, review and revise data for each of the components:

1. **Ventilation Air Data** – Sample inputs are shown in Figure 4. Note that outdoor air dampers are marked as closed for the unoccupied period. Because the ventilation fan needs to run to power the induction beam terminals, there can be value in closing the outdoor air dampers during the unoccupied period to reduce the loads on the DOAS cooling and heating coils. In cold climates this can result in substantial savings for heating energy.

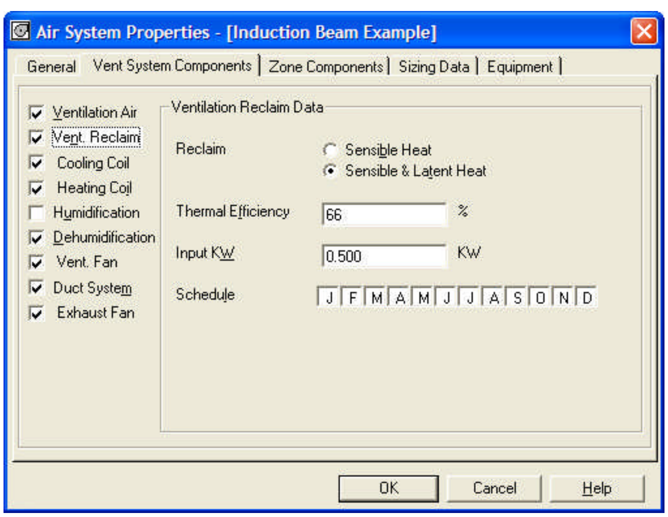

Figure 5. Vent System Components Tab, Ventilation Reclaim Data

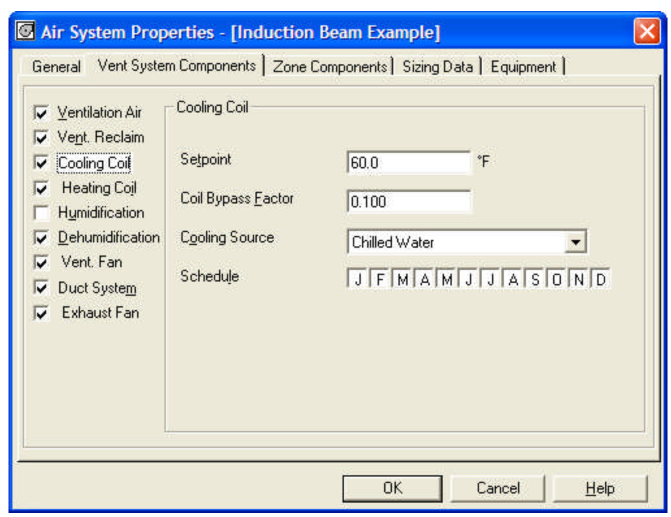

Figure 6. Vent System Components Tab Ventilation Cooling Coil Data

Modeling Induction Beams in HAP v4.8

2. **Ventilation Reclaim** – In this example our system includes an Energy Recovery Ventilator (ERV) wheel. As shown in Figure 5, this device has the ability for both sensible and latent heat reclaim. The thermal efficiency and motor input power are sample values. Be sure to obtain this data from manufacturer's product data if you are modeling specific equipment in your system.

3. **Ventilation Cooling Coil** – Sample inputs are shown in Figure 6. Induction beam terminals that include a drain pan can operate as total cooling devices, handling both sensible and latent loads in the zone. For this reason control of DOAS supply air temperature and humidity is not as critical as it is for an active chilled beam terminal, which is a sensible-only device. The DOAS generally is designed to handle the outdoor ventilation air sensible and latent loads, and often part of the zone sensible and latent. A DOAS primary air leaving air temperature (LAT) setpoint of 60 F will be used in this example. Because 60 F is below zone-neutral conditions it will meet the ventilation sensible load and part of the zone sensible loads.

4. **Ventilation Heating Coil** – We will use the same DOAS supply air discharge setpoint for heating as for cooling (see Figure 7). Therefore when discharge air from the ERV is below 60 F it will be heated to maintain a 60 F discharge temperature from the DOAS unit. When it is above 60 F it will be cooled to maintain a 60 F discharge temperature.

5. **Dehumidification Control** – Our sample system will use a humidistat at the DOAS unit discharge to control the humidity of the primary supply air. A maximum relative humidity (RH) setpoint of 75% will be used (Figure 8). When the discharge RH rises above 75% the ventilation cooling coil will sub-cool the air to condense additional moisture and bring the humidity down to 75%. If necessary, the heating coil will provide dehumidification reheat to bring the DOAS discharge temperature back up to the 60 F setpoint temperature.

   If the zone cooling thermostat setpoint is 75 F, primary air at 60 F and 75% is slightly below zone neutral. As a result, the DOAS cooling coil will not only handle the ventilation sensible and latent load, but will contribute to meeting part of the zone sensible and latent loads.

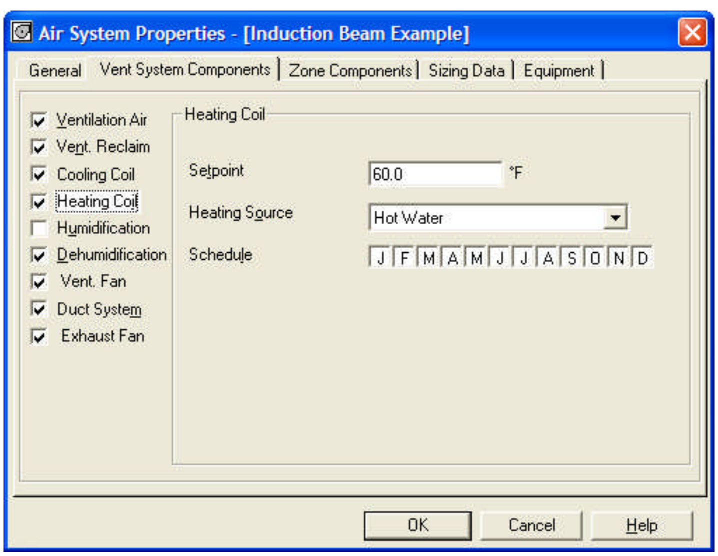

Figure 7. Vent System Components Tab, Ventilation Heating Coil Data

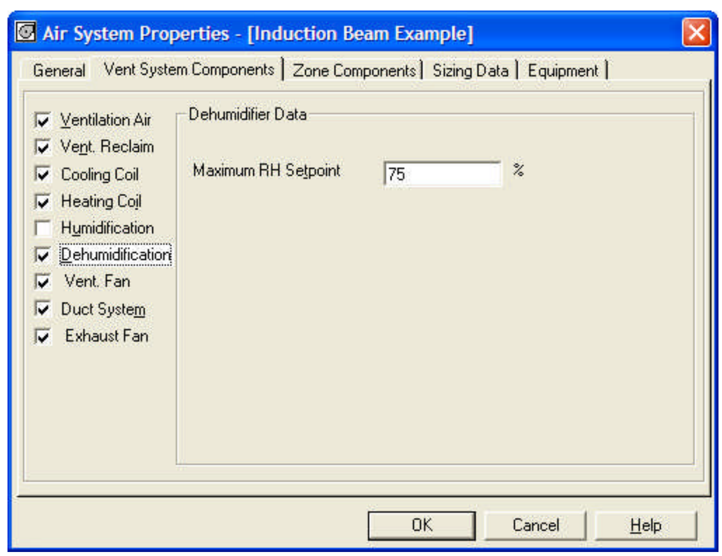

Figure 8. Vent System Components Tab Dehumidification Control Data

Modeling Induction Beams in HAP v4.8

6. **Ventilation Fan** – Sample fan inputs are shown in Figure 9. A forward curved fan with variable frequency drive will be used. The total static pressure of 5 in wg represents static needed to overcome the pressure drops of the ERV, filters, coils, and ductwork, and to supply the required static pressure at the induction beam terminal nozzles. The efficiency is representative for this type of fan.

   Note that an unoccupied airflow rate of 50% of design is also specified. In many applications, primary airflow for the induction beam system can be turned down during unoccupied times when thermostat setpoints are set up or set back and zone load levels are low. The DOAS can still provide sufficient dehumidification with the reduced airflow to keep room humidities under control. When airflow turndown is used, airflow can be reduced to between 50% and 95% of design flow. HAP will not allow airflow to be turned down more than 50%. The reduced airflow combined with the ventilation fan VFD will yield significant fan energy savings versus active chilled beam systems which cannot turn down unoccupied airflow rates.

7. **Duct System** – The example system will use a ducted return. For the sake of simplicity we did not specify duct leakage or duct heat gain. (Screen image of duct system inputs not shown).

8. **Exhaust Fan** – Finally, the exhaust fan will be the same type as the ventilation fan (forward curved, variable frequency drive). The total static pressure of 1.5 in wg represents the pressure drops of the ERV and the ductwork. (Screen image of exhaust fan inputs not shown).

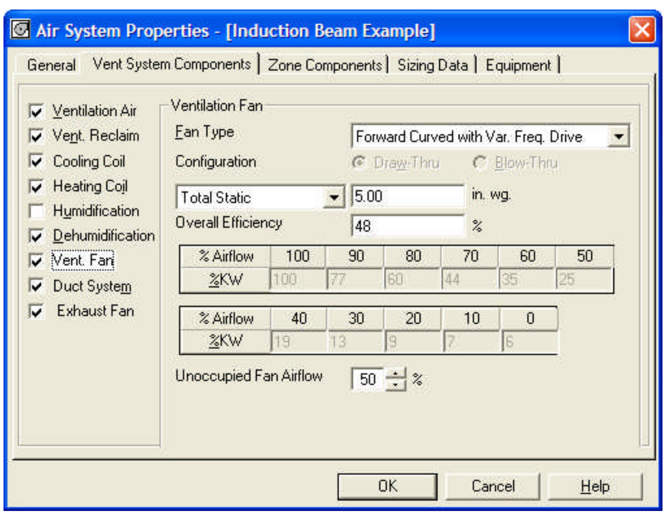

Figure 9. Vent System Components Tab, Ventilation Fan Data

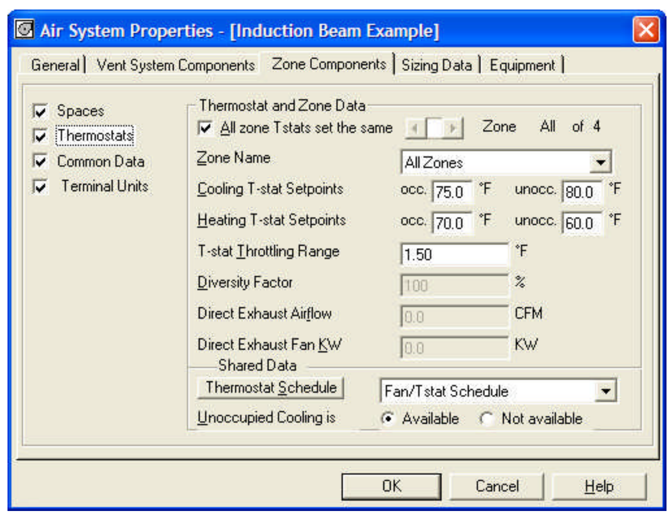

Figure 10. Zone Components Tab Thermostats Data

Next we move to the ***Zone Components*** tab shown in Figure 10. Working from top to bottom through the categories of data shown in the left panel of this tab, review and revise the following data:

1. **Spaces** – Assign spaces to the zones in the system. Our example system has four zones, each with one space. (Screen image of this data not shown).

Modeling Induction Beams in HAP v4.8

2. **Thermostats** – Assign the thermostat setpoints and thermostat schedule. Sample values are shown in Figure 10. Note that unoccupied cooling is specified as "available". This is important because the system needs the ability to continue to dehumidify primary air during the unoccupied hours to keep room humidity under control.

3. **Common Data** – This data category is used to specify the capability of the induction beam terminals. As shown in Figure 11, the terminals in our example have both cooling and heating capability.

4. **Terminal Units Data** – In this final category of data you can define one set of values applying to all induction beam terminals, or can specify individual data for each zone's terminal equipment. This is done via the "All zones the same" check box in the upper left (Figure 12). In our example, we'll specify one set of data applying to all zones.

   The terminal type will always be "induction beam". The "induction ratio" is the ratio of total supply airflow produced by the terminal to primary airflow entering the terminal. Typical values range from 2.7 to 4.0. If you have specific induction beam equipment in mind, consult manufacturer's data to determine the appropriate value. A representative value of 3.0 is used in our example. Finally, specify the bypass factor that is representative for the terminal cooling coil. A value of 0.090 is used in our example.

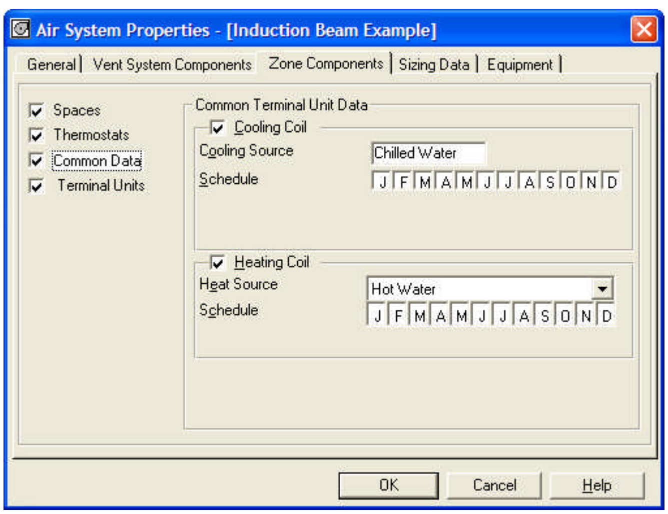

Figure 11. Zone Components Tab, Common Data

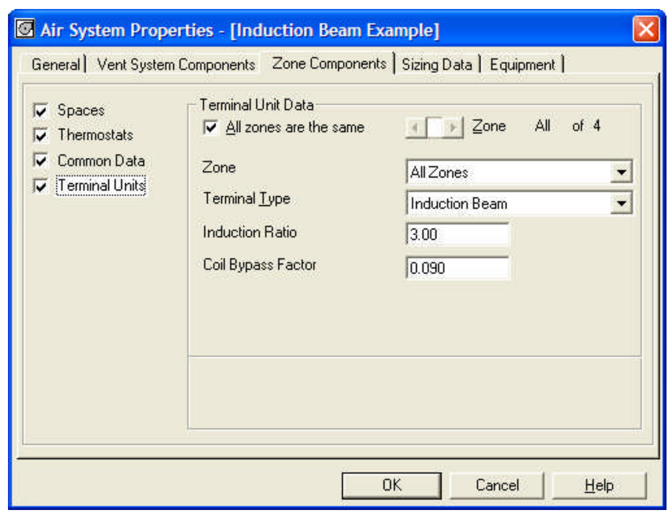

Figure 12. Zone Components Tab Terminal Unit Data

At this point the induction beam air-side system is fully defined and can be saved and then used in system design and energy analysis calculations.

What about the Chilled Water Plant?

A chilled water plant serving induction beam air systems uses a single supply water temperature, typically in the 42 F to 45 F range. There are no special modeling requirements. The plant would be modeled using the same principles as a plant serving conventional systems such as VAV air handlers.

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Conclusion

Induction beams are extremely flexible and enhance the savings and effectiveness of primary air systems such as those using dedicated outdoor air. When using induction beams, the primary air system, which includes the dedicated outdoor air handling unit, and the primary air and exhaust air ductwork, can be sized to handle only the required ventilation outdoor air. This reduces the size of the equipment and ductwork compared to conventional systems, making it easier to fit into a building space. This also reduces the energy required to supply the ventilation air to the building. The total room air circulation is created solely by the induction process within the terminal; therefore, there is no motor requiring an electric power source or maintenance for a fan and motor. As a result, the induction beam is a very quiet and efficient way to provide comfort in a space.

The manufacturer's design application literature should always be consulted when designing an induction beam system.

Resources

1) *Induction Beams, Engineered Comfort for Today's Buildings*, Form 04-581068-01, Carrier Corporation, Syracuse, NY
2) *36IB Induction Beams Product Literature*; Form 36IB-1PD; May 2012; Carrier Corporation, Syracuse, NY.
3) *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.