Chilled Beams 101

A Designer's Guide to Understanding and Applying Active Chilled Beams

Presented by TROX USA

INTRODUCTION

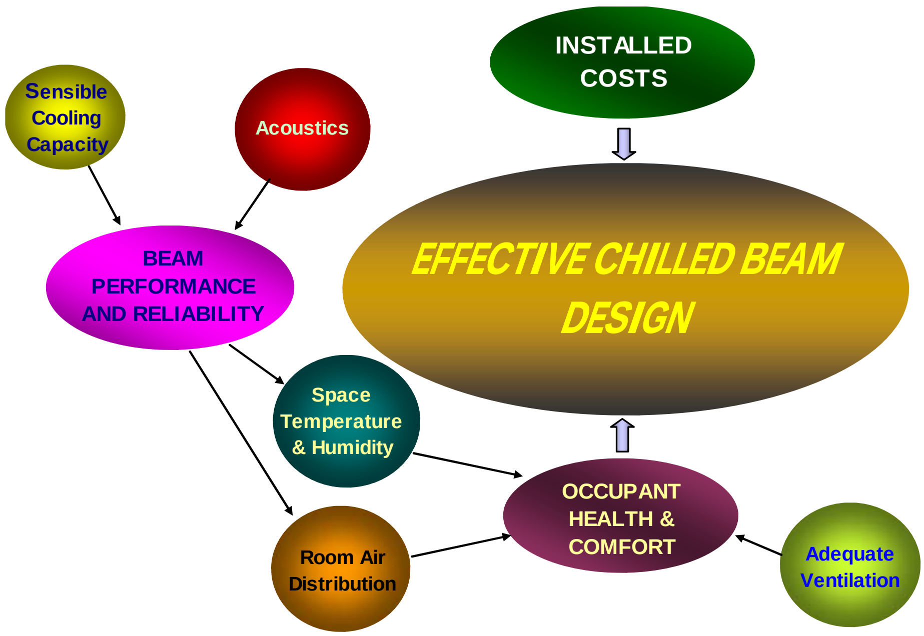
Chilled beams have been widely used in Europe for some time but have only burst onto the North American HVAC scene in the past couple of years. Active chilled beams incorporate a convective heat transfer coil that is used to cool (and often heat) induced room air to supplement the cooling of its pretreated primary air source. Up to 60 to 70% of the sensible cooling provided by the beams is often associated with the sensible heat removed by the integral heat transfer coil.

The primary reason for the sudden interest in chilled beams relates to their ability to considerably reduce system operating and maintenance costs and to effectively integrate into high performance HVAC operational schemes that are often used to accumulate points toward LEED™ certification. Active chilled beams have been particularly embraced for use in heat driven laboratories as a measure to significantly reduce primary air capacities (and consequently reduce the cost of conditioning the ventilation air).

Despite their noteworthy benefits, active chilled beams are still "mortal". They consist of a series of induction nozzles, a (sensible) heat transfer coil and linear slots for distributing the conditioned air to the space. As such, **each component will exhibit performance consistent with its application in conventional systems and do not possess some supernatural ability to perform better within the chilled beam.**

Chilled beams a) provide space sensible cooling, b) deliver a sufficient supply of dehumidified air to counter space latent heat gains, and c) deliver primary air at a supply airflow rate sufficient to maintain adequate space ventilation. However, the active chilled beam is also an air distribution device that tasked with delivering such cooling in a manner that conforms to ASHRAE Standard 55-2004 guidelines for maintaining occupant thermal comfort. As with all room air distribution devices, there are practical limitations to the discharge velocities and throw values of the beams that should be observed.

Effectively selecting and specifying chilled beam systems involves consideration of a number of tradeoffs. The diagram below identifies some of these tradeoffs regarding chilled beam selection and design.



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Over the past couple of years several manufacturers have entered the USA chilled beam market. The diversity in these manufacturers' offerings is not always obvious to the designer who has not designed such systems in the past. The following paragraphs discuss identify some measures of good practice and identify some rules of thumb that intended to help the designer arrive at an effective chilled beam solution.

GOOD PRACTICE TIP #1: Remember that the primary goal is good occupant comfort!

Active chilled beams are seen by the room as simply linear slot diffusers. As such, active beam discharge velocities should be kept in the same range as those employed with linear slot diffusers if similar occupant comfort is to be expected. While maximizing the primary airflow of the beam will reduce the number of beams (and their subsequent installation cost), this must be weighed against the beams' air distribution performance. Active beams discharge their primary air through a series of nozzles that create induction of room air through their heat transfer coil(s). Nozzle types and sizes with induction ratios (total air supply to the room divided by the primary airflow rate) varying between 3.0 and 6.0 are available. This means the primary air represents only 15 to 33% of the discharge airflow rate of the beam. Linear slot diffusers (of similar discharge area) are seldom selected for more than 40 to 45 CFM per linear foot of slot, there is no reason why active chilled beams should be selected differently if similar thermal comfort is to be maintained.

ASHRAE Standard 55-2004 recommends that velocities generally exceeding 50 FPM should not be resident in the "occupied" area (zone) of the space. The occupied zone is considered bounded by the floor and the head height of the predominant occupants but excludes the volume of the space within 3 feet of an outside wall or 1 foot of an internal wall. For two beams with opposing discharges the throw to a terminal velocity of 50 FPM should not exceed half the distance between the beams plus the distance from the ceiling to the top of the occupied zone. For example, if beams are mounted twelve (12) feet on center and the distance from the ceiling to the top of the occupied zone is five (5) feet, the beams' 50 FPM throw value should not exceed eleven (11) feet.

Under no circumstances should occupants be subjected to local velocities of 70 FPM or more.

GOOD PRACTICE TIP #2: When heating, minimize the beam discharge air temperature.

Active chilled beams can be used effectively for overhead heating in mild climates. When designing for such, remember that the beam's discharge airflow rate during heating is usually the same as it is during cooling operation. This gives the designer an opportunity to employ lower discharge temperatures to more efficiently deliver warm air down the perimeter wall. Beams used for heating should be located very near (within a couple of feet from) the outside wall and selected for an isothermal throw value (to 100 FPM) which is approximately equal to the distance between the beam and the wall/window plus 40 to 60% of the ceiling height. The discharge air should never be more than 15°F warmer than the room air temperature.

GOOD PRACTICE TIP #3: Limit water side flow rates pressure drops.

Chilled water flow rates should never exceed that which will results in a water side head loss exceeding ten (10) feet. Water side head losses exceeding six (6) feet are not generally associated with cooling or reheat coils located away from the central system water pumps, thus it is recommended that the water side head loss for chilled beams not exceed such a value. In any case, the sensible cooling increase derived by employing water flow rates resulting in head losses above six (6) feet of water is quite minimal.

GOOD PRACTICE TIP #4: Chilled water supply temperatures should be at or above the design dew point temperature of the room

Although it has been proven that condensation will not form on the beams until the chilled water temperature is several degrees above the space dew point, TROX USA strongly recommends that chilled water temperatures be maintained at or below the design room dew point temperature. Chilled water supply temperatures of 58 to 59°F are commonly employed for chilled beams as they allow the space relative humidity to range between 53 and 57%. This also provides a margin of safety in case indoor humidity levels increase beyond design levels temporarily.

CHILLED BEAM RULES OF THUMB

The following equations and "rules of thumb" are intended to help designers determining whether performance claims of chilled beam manufacturers appear valid:

- The sensible cooling capacity of the coil can be approximated as 500 x GPM x ΔT between the entering and leaving chilled water.
- The sum of the ΔT between the induced room air entering and leaving the coil plus the ΔT between the entering and leaving chilled water temperatures should not exceed the ΔT between the room and the entering chilled water. The following equations in which q_{COIL} sensible cooling performed by the integral chilled water coil and $Q_{PRIMARY}$ and $Q_{INDUCED}$ are the primary and induced airflow rates, respectively, will allow a quick check of this relationship:

$$Q_{INDUCED} = Q_{PRIMARY} \times (\text{Induction ratio} - 1)$$

$$q_{COIL} / (1.1 \times Q_{INDUCED}) + q_{COIL} / (500 \times GPM) \leq T_{ROOM} - T_{ENTERING\ CHW}$$

This equation can be rearranged as such to estimate the cooling capacity of the coil:

$$q_{COIL} \leq (T_{ROOM} - T_{ENTERING\ CHW}) / [1 / (1.1 \times Q_{INDUCED}) + 1 / (500 \times GPM)]$$

For example, a chilled beam which produces an induced airflow rate of 300 CFM operating with a chilled water supply temperature 18°F below the room temperature and a chilled water flow rate of 2.5 GPM should not produce more than about 4,650 BTUH of secondary sensible cooling.

Coil sensible cooling claims that exceed this "rule of thumb" should be verified thoroughly. Of course the total sensible cooling provided by the beam is the sum of that provided by the coil and the primary air cooling contribution.