



Design and Analysis of the Air Conditioning System using Chilled Beam Technology

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Abstract- The movement toward sustainable building designs is being driven largely by environmentally sensitive building owners and/or their prospective tenants. There are also heightened concerns about assuring a proper indoor environment at all times and conditions for the building occupants. In addition to providing temperature control, a fully effective HVAC system must also address many other indoor environmental issues that affect occupant comfort, productivity and health such as ventilation air, air distribution, humidity control, noise levels, etc .As these owners and their consultants weigh their HVAC system alternatives, they often find that chilled beam systems are the ideal "green" solution for many buildings. There is also a persuasive overall comfort and economic argument for the use of active chilled beam systems over other of the more conventional systems choices. While relatively new in India, chilled beam systems are proven and are successfully being used in Europe since a decade. The chilled beam system promotes excellent thermal comfort, energy conservation and efficient use of space due to the high heat capacity of water used as heat transfer medium. It is an energy efficient HVAC technology which works on dry cooling principle. The goal of this project is to design a Chilled Beam Air-Conditioning System for a hotel building which is followed by a complete examination of its energy conservation potential in comparison with a conventional Chilled Water Air-Conditioning System for the same building.

I. INTRODUCTION:

Chilled beam are defined as A cooled element or cooling coil situated in, above or under a ceiling which cools convectively using natural or induced air flows. The cooling medium is usually water.”

Chilled beams feature finned chilled water heat exchanger cooling coils, capable of providing up to 1100 BTUH of sensible cooling per foot of length and are designed to take advantage of the significantly higher cooling efficiencies of water. Figure 4.1 illustrates that a one inch diameter water pipe can transport the same cooling energy as an 18 inch square air duct. The use of chilled beams can thus

dramatically reduce air handler and ductwork sizes enabling more efficient use of both horizontal and vertical building space.

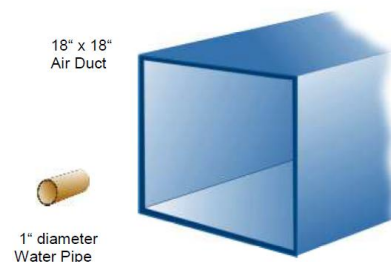


fig.1 Cooling Energy Transport Economies of Air and Water

An Active Chilled Beam uses a pre-cooled (and dehumidified) primary air using chilled water in a quantity needed 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; ensuring the chilled beam coil operating without condensation. The chilled beam then cools or heats the induced air to meet the room sensible load and react to the room thermostat requirements.

A Passive Chilled Beam works 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. This downward flow induces air from the room upward to the ceiling level and then through the beam coil.

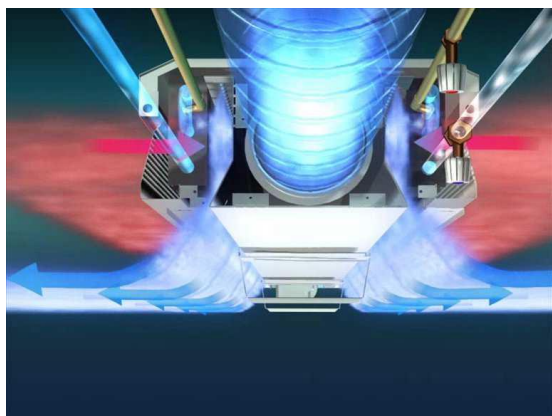


fig.2 Active Chilled Beam Air Flow Simulation

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. 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.

Passive Chilled Beam

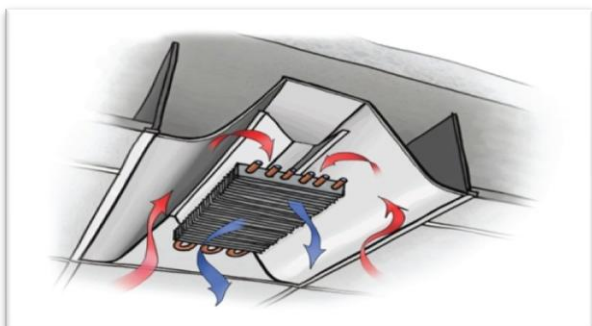
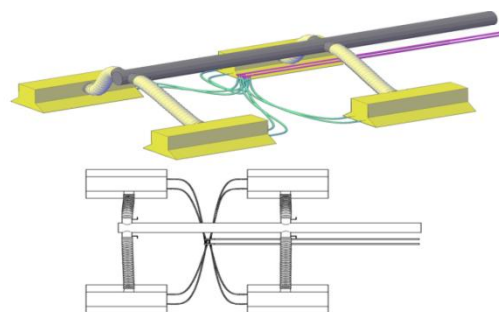


fig.3 Suspended Passive Chilled Beam

Advantages of chilled beams over conventional air conditioning systems: In general the design intent is for the central system to circulate only the amount of air needed for ventilation and latent load purposes, with the active chilled beams providing the additional

air movement and sensible cooling and/or heating required through the induced room air and secondary water coil. In this manner the amount of primary air circulated by the central system is dramatically reduced (often 60-70% less than conventional "all air" systems). The net result of this shift in loads with active chilled beam systems is lower energy consumption and operating costs. Fans are the largest consumer of energy in most commercial buildings. With active chilled beam systems the fan energy is dramatically reduced due to the relatively small amount and low pressure of the primary air being circulated by the central system. Chilled beams design considerations: Selection of thermal environment load: Room air temperature (summer/winter). Selection of the indoor air quality level and air flow rate: Fresh airflow temperature, Infiltration through walls—pressure, temperature, Relative humidity in the space, Primary air cooling coil temperature, Humidity balance. Calculation of required cooling and heating capacity: Heat loads, Heat losses, Comfort conditions, cooling effect of primary air. Adjustment of building design parameters: Decrease electrical load losses by better solar shading and improved window type. Selection of chilled beam type: Active beam (exposed/integrated), Passive beam. Selection of inlet water temperature: Temperature climate, Location of the building. Selection of water temperature and air water flow rate: Temperature difference, Water flow rate Selection of water temperature and air water flow rate: Specific cooling capacity of beam, Specific primary air flow rate. Noise level and system pressure loss calculation: Selection of room controls, Room air temperature is controlled by modeling water flow rate, two port valves, and Air flow rate. Air and water distribution system: Dehumidification of AHU, 3 port mixing valves in cooling pipe to keep the inlet water temperature in design value, Free cooling equipment's in chiller.

fig. 5 Mixing vane



Chilled beams are mounted in a suspended ceiling and then anchored to the overhead structure, because T-bar ceilings cannot support the typical operating weight of a chilled beam. Operating weight is approximately 15lb/ft (6.8 kg/m) for 2ft (600 mm) wide, double deflection units. Hanging a beam from the structure is through four adjustable hanging brackets that can be

fastened to the concrete under floor via threaded rod or aircraft cable

These systems are used mostly in the nonresidential buildings. These are commercial buildings, offices, hotels, banks, universities, schools and hospitals. Typical applications are cellular and open plans offices, hotel rooms, hospital wards, and retail shops, bank halls etc Chilled beam systems are primarily used for cooling, heating and ventilating spaces, where good indoor environmental quality and individual space control are appreciated. These systems are dedicated outdoor air systems meant to be applied primarily in spaces where internal humidity loads are moderate. “A cooled element or cooling coil situated in, above or under a ceiling which cools convectively using natural or induced air flows. The cooling medium is usually water.” Chilled beams feature finned chilled water heat exchanger cooling coils, capable of providing up to 1100 BTUH of sensible cooling per foot of length and are designed to take advantage of the significantly higher cooling efficiencies of water. Figure 4.1 illustrates that a one inch diameter water pipe can transport the same cooling energy as an 18 inch square air duct. The use of chilled beams can thus dramatically reduce air handler and ductwork sizes enabling more efficient use of both horizontal and vertical building space.

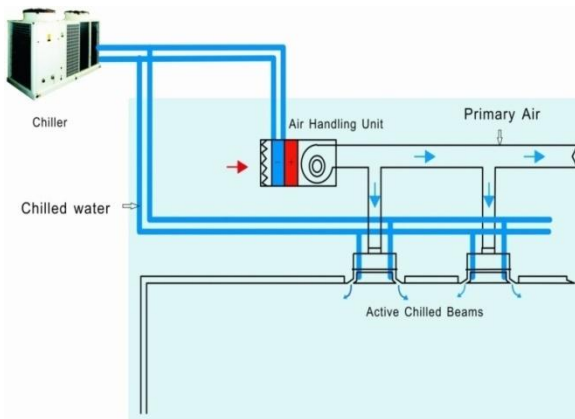


fig.6 Working of Active Chilled Beam

Modelling Of Chilled Beam System in HAP: HAP v4.8 (and later versions) has the ability to directly model active chilled beam (ACB) systems. Construction of the ACB model for our hotel building in HAP is described in the following paragraphs to explain the basic modeling procedure.

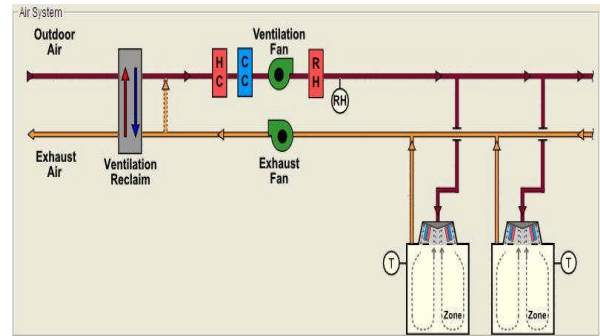


fig.7 Air system sizing for office

Air System Information		Number of zones	
Air System Name	OFFICE		1
Equipment Class	CW AHU	Floor Area	377.0 ft²
Air System Type	SZCAV	Location	Hyderabad, India

Sizing Calculation Information		Calculation Months	
Zone and Space Sizing Method:			
Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data			
Total coil load	1.9 Tons	Load occurs at	Jul 15/00
Total coil load	22.5 MBH	OA DB / WB	106.0 / 78.0 °F
Sensible coil load	20.3 MBH	Entering DB / WB	75.0 / 64.5 °F
Coil CFM at Std 1500	1226 CFM	Leaving DB / WB	59.4 / 58.3 °F
Max block CFM	1226 CFM	Coil ADP	57.6 °F
Sum of peak zone CFM	1226 CFM	Bypass Factor	0.100
Sensible heat ratio	0.905	Resulting RH	53 %
#/Ton	201.4	Design supply temp.	58.0 °F
BTU/(hr·ft²)	59.6	Zone T-stat Check	0 of 1 OK
Water flow @ 10.0 °F rise	4.49 gpm	Min. zone temperature deviation	0.1 °F

Central Heating Coil Sizing Data			
Max coil load	0.6 MBH	Load occurs at	Dec 15/00
Coil CFM at Des 15/00	1226 CFM	BTU/(hr·ft²)	1.5
Max coil CFM	1226 CFM	Enr. DB / Lvg DB	69.5 / 70.0 °F
Water flow @ 20.0 °F drop	0.66 gpm		

Supply Fan Sizing Data			
Actual max CFM	1226 CFM	Fan motor BHP	0.00 BHP
Standard CFM	1148 CFM	Fan motor kW	0.00 kW
Actual max CFM @ 0.1	3.25 CFM/ft²	Fan static	0.00 in wg

Outdoor Ventilation Air Data		CFM/person	
Design airflow CFM	37 CFM		12.80 CFM/person
CFM/ft²	0.10 CFM/ft²		

HAP v4.8 (and later versions) has the ability to directly model active chilled beam (ACB) systems. Construction of the ACB model for our hotel building in HAP is described in the following paragraphs to explain the basic modeling procedure.

New for HAP v4.61: a Weather Wizard for quickly selecting weather data either by (1) clicking on map images to select region, country/state/province and city, or (2) selecting from drop-down lists. A Building Wizard for creating a building thermal model. Define the building footprint and zoning, the number of floors, the envelope assemblies and the space usage type, and the program then automatically generates a set of detailed space definitions for the entire building. An Equipment Wizard for configuring HVAC equipment scenarios. Specify the equipment type, key features and components and its configuration, and the program then automatically generates a set of air system, plant, chiller, cooling tower and boiler definitions for the building.

New for HAP v4.61: a Utility Rate Wizard for rapidly inputting electricity and fuel prices. Simple pricing data for electricity and fuels can be entered on a single input screen. For defining more detailed electric pricing structures, the wizard guides you

through the process, eliminating much of the uncertainty normally facing users when entering this data. A Full Wizard Session feature ties all four wizards together so you can create 100% of the data needed for an energy analysis all at one time. that the use of chilled beams although a little heavy on the pocket initially, results in a significantly lesser consumption in terms of power and cost in the long run. Apart from the savings factor, the use of Chilled Beams also results in better air quality, virtually no noise and prevent of cold drafts thereby increasing the overall human comfort significantly. Also, Chilled Beams afford the designer an opportunity to replace large supply and return air ductwork with small chilled water pipes. This results in significant savings in terms of plenum space and increases usable floor space. The sole purpose of the project was to come up with a HVAC system which is more efficient, more energy saving and eco-friendly in nature than the conventional air conditioning systems. By using Chilled Beams, we could save approximately 35% of tonnage which is a huge difference.

Air System Sizing Summary for BASE CASE AHU			
Project Name: chilled beams 01		05-01-2010 07:36PM	
Prepared by: tec			
Air System Information			
Air System Name	BASE CASE AHU	Number of zones	1
Equipment Class	CW AHU	Floor Area	4674.3 ft ²
Air System Type	SZCAV	Location	HYDERABAD, India
Sizing Calculation Information			
Calculation Months	Jan to Dec	Zone CFM Sizing	Sum of space airflow rates
Sizing Data	Calculated	Space CFM Sizing	Individual peak space loads
Central Cooling Coil Sizing Data			
Total coil load	28.1 Tons	Load occurs at	Jul 1600
Total coil load	349.3 MBH	OA DB / WB	105.6 / 77.9 °F
Sensible coil load	227.6 MBH	Entering DB / WB	83.1 / 70.2 °F
Coil CFM at Jul 1600	9832 CFM	Leaving DB / WB	60.3 / 59.1 °F
Max block CFM	9832 CFM	Coil ADP	57.7 °F
Sum of peak zone CFM	9832 CFM	Bypass Factor	0.100
Sensible heat ratio	0.652	Resulting RH	65 %
WYTon	160.6	Design supply temp.	58.0 °F
BTU/hr (°F)	74.7	Zone T-stat Check	1 of 1 OK
Water flow @ 10.0 °F rise	69.89 gpm	Max zone temperature deviation	0.0 °F
Supply Fan Sizing Data			
Actual max CFM	9832 CFM	Fan motor BHP	0.00 BHP
Standard CFM	9214 CFM	Fan motor kW	0.00 kW
Actual max CFM/Ft ²	2.10 CFM/Ft ²	Fan static	0.00 in wg
Outdoor Ventilation Air Data			
Design airflow CFM	2249 CFM	CFM/person	10.45 CFM/person
CFM/Ft ²	0.48 CFM/Ft ²		

In conclusion, it was found that the use of chilled beams although a little heavy on the pocket initially, results in a significantly lesser consumption in terms of power and cost in the long run. Apart from the savings factor, the use of Chilled Beams also results in better air quality, virtually no noise and prevent of cold drafts thereby increasing the overall human comfort significantly. Also, Chilled Beams afford the designer an opportunity to replace large supply and return air ductwork with small chilled water pipes. This results in significant savings in terms of plenum space and increases usable floor space. The sole purpose of the project was to come up with a HVAC

system which is more efficient, more energy saving and eco-friendly in nature than the conventional air conditioning systems. By using Chilled Beams, we could save approximately 35% of tonnage which is a huge difference. Although they are not the solution for every space within commercial and institutional buildings, the strengths of the Chilled Beam Air Conditioning System are becoming a more useful tool to handle challenging spaces in today's high performance and low energy consumption buildings.

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