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A Lternative Energy Efficiency Design for The Laboratories

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***Abstract*-Research labs HVAC design needs not only to provide the demands of indoor air quality, safe environment for research workers but also needs to offer comfort and protection for other occupants in the laboratory building. As research labs has different types of spaces there is a potential opportunity in energy wastage, if not designed with advanced design strategies.Designer needs to assess the load profile of the labs based on discussion with client on different factors such as hours usage in a day, hours usage in a semester/quarter, class size, occupied hours, unoccupied hours, etc. Research laboratories load profile vary hourly, daily, seasonally, diurnally, annually, and life-cycle bases where occupancy varies during certain periods of time and during extended periods of time.Research labs can represent a relatively high share of total costs, with energy intensities of up to~1000 kWh/sq. ft-year.The importance of minimizing the air volume in research laboratories is well known; as the labs require at least ten times air volume than in an office building. Few ways to minimize the load in the lab facilities includes decrease heating and cooling loads, decrease in dehumidification and humidification loads, decrease in fan and motor energy usage, and decrease in pumps and motors usage.Advance design strategies that help to design energy efficient HVAC design are modular boiler plants, DDC systems, 4- pipe VAV systems, tum-down ratios for chillers, indirect-direct evaporative cooling, heat recovery, and Active Chilled beams.Current paper discusses the pros and cons for active chilled beams and 4-pipe VAV's advanceddesign measures including their first costs and life-cycle costs are discussed.**

***Keywords*-emerging media technologies, emerging information systems, emerging network technologies, emerging technology solutions, emerging technologies and trends comics**

I.INTRODUCTION

As described above the load profile varies throughout the life cycle of HVAC system in labs. Minimum ventilation is required for safety and health reasons for occupants in the building. Minimizing ventilation rates while complying with the codes and standards to provide energy efficient design to reduce the electricity, first cost, and operating cost is the goal. There are three types of dominated labs based on the following.

- Based on the CFM/sf: labs where the airflow needed by the cooling load exceeds the hood exhaust and minimum ventilation rates. This method allows flexibility to not use the ceiling height to determine the ventilation cfm required but it requires based on the square footage of the building for hazard environment. Minimum requirement is 2cfm/sf.
- Based on the Hood density: Labs where the hood exhaust rate exceeds that required by the cooling load or minimum ventilation. A number of fume hoods, size of fume hoods, and VAV hoods needs toe considered to reduce airflow and thereby reducing the hood energy use.
- Based on the Air Changes per Hour (ACH): ACH rates are governed by the thermal loads (i.e. heating and cooling loads). Generally based on the standard 4 ACH (unoccupied) and 6ACH (occupied) are typically used for the design of ventilation using this method. Ventilation rate greater than 6 ACH should be agreed upon by the owner and designer. Based on this design method, hood exhaust rates and cooling load requirements are lower than the minimum air changes per hour (ACH).

The aim of laboratory HVAC design is to reduce the terminal unit reheats energy and also to reduce the energy used to condition outdoor air. Modern labs HVAC design, had replaced the constant volume systems(CAV) with variable air volume(VAV) and VAV fume hoods in order to significantly improve energy efficiency. One of the VAV is two-pipe systems and four-pipe systems, is considered in lab designs based on the advantages it brings to the HVAC industry.

II. CHILLED BEAMS

Chilled Beams provides space only with sensible cooling and heating, as the unit has an coil which is installed as part of the device. They are two types: Active Chilled Beam and Passive Chilled Beam.

1. Passive Chilled Beam:

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An Active Chilled Beam can be recessed in the ceiling or suspended from ceiling as shown in Figure #1
The heat exchanger type is a fin-and-tube heat exchanger in active chilled beam. It has a primary air connection and pipe connections. Most of these are either two-pipe or four-pipe designs that are connected to the units. Induced air passesthrough nozzles, from the space up through the cooling coil.

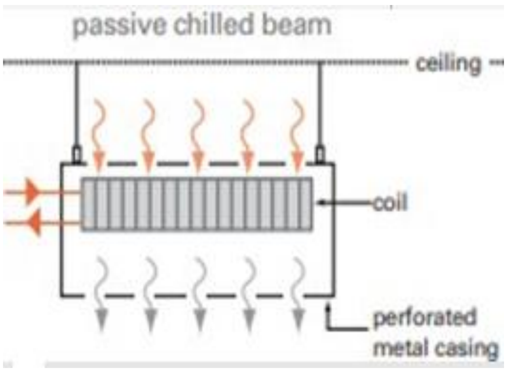

Figure 1 Passive Chilled Beam.

The induced air has airflow to offset the sensible cooling load (space) and at least draws in outdoor air to each space for ventilation.

2. Active Chilled Beam:

A Passive beam consists of a fin-and-tube heat exchanger that is suspended from the ceiling or contained in housing. Warm air from the space rises towards the ceiling, and the air around the chilled beam is cooled and descends backs to floor. Thespace is cooled by using the mechanism of convection.

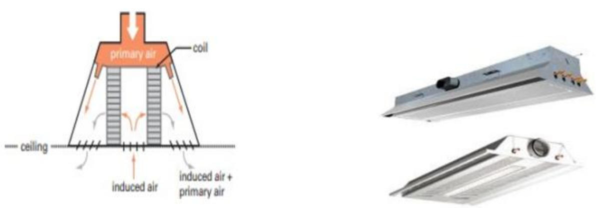

Figure 2 Active Chilled Beam System Configuration and Description of Chilled Beams.

- We have used active chilled beams in spite CHW/HW coil downstream of the supply air valve and 6-way valves.
- Chilled beam water supply is mixture of supply temperature and return water temperature to avoid low loads for the active chilled beams and to avoid any condensation on chilled beam surfaces. Typically, the water is about 58F for chilled beams.
- At a typical design conditions chilled beams have an output of 2 times the sensible load – with primary outdoor air alone. When using Four-pipe VAV systems, it requires 12 air changes per hour (ACH) of supply air vs 6 ACH typical minimum ventilation requirement to satisfy the cooling demand. Designer should not move forward with chilled beam systems based on the reduction in the outdoor air flow rate, because for load-dominated labs the initial cost savings will results based on various parameters such as outdoor air flow rate, space constraints, and size of the lab not solely based on the outdoor airflow rates.

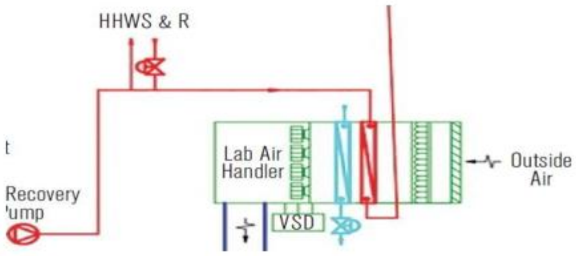

Figure 3 Chilled Beam Systems at the AHU with heat recovery pump.

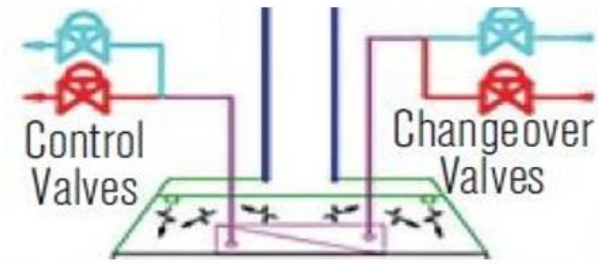

Figure 4 Chilled Beam Systems with Change over valves.

For example, in lab buildings the plenum height is only 1 foot and the active chilled beams depth is more than 1 feet, especially this is a hood-dominated building and therefore there is no ceiling space that accommodates the units. In this case, typically 4-pipe terminal units are used.

- Note that the water is tempered to achieve warmer supply temperature to achieve efficiency and to avoid condensation (terminal for chilled beam systems), it is always recommended to upsize at least one size for few zones.

2.1. To prevent condensation for active chilled beams:

- Temperature of water supplied to chilled beams must be warm (58F thru 60F) above the dew point of the space and they are often selected with lower delta T (5F or 6F).
- The drawback of chilled beam is it does not contain a condensate drainage system. The indoor dew point should be less than the surface temperature of the chilled beam coil, sothat there is no dripping of moisture resulting from condensation on the coil and into the space.
- The key to note is the chilled beams does not process the load for dehumidification purposes.

- Steps must be taken to reduce condensation, dry-bulb temperature of entering air is too cold, there is a high chance for risk of condensation forming on the housing of the active chilled beams.

2.2. System Configuration And Description Of Four-Pipe Vav Systems

- Heat recovery piping concept is used as part of the four-pipe VAV systems is contained with a hot water coil and there will be no need to have a separate hot water coil in the air handling unit.
- Expansion tank and makeup water is connected to the loop, first costs had decreased.
- Hot water coil is used for preheating purposes and it supplies only warm air during winter season. Emergency heating is provided with the hot water connection- when heat recovery does not work. In this building located in SanFrancisco, the design outdoor temperatures are more than 40F.
- To avoid any dehumidification at the space level when the humidity at the outdoor design re conditions are high, the supply air temperature has been programmed as high as 70F.
- For the load dominated lab, chilled water supply temperature for the VAV systems is somewhere between 42F to 45F to satisfy cooling peak loads. Because of the lower chilled water temperatures, this will require condensate drain at the coil. This concludes that it has lower risk of condensation damage.
- A mixed air plenum with hybrid air handling units can be used to office areas and labs.
- These types of systems can be relocated easilyChangeover of coils: When compared with two-way valves, this type requires less space, lower fan energy due to the decreased fan energy, results in small hot water piping and there is no need for hot water coil.

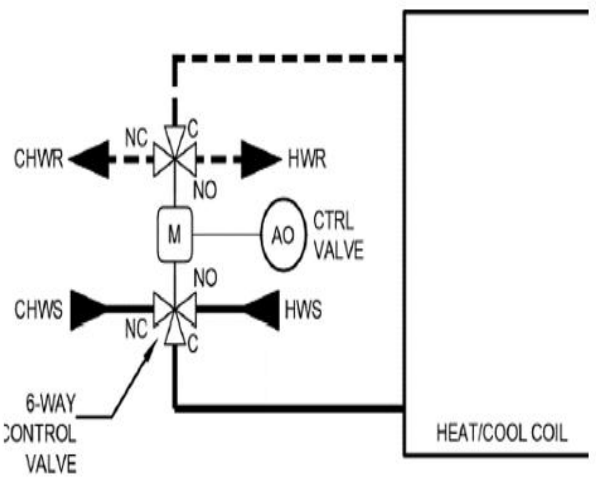

Figure 5 Change over valves.

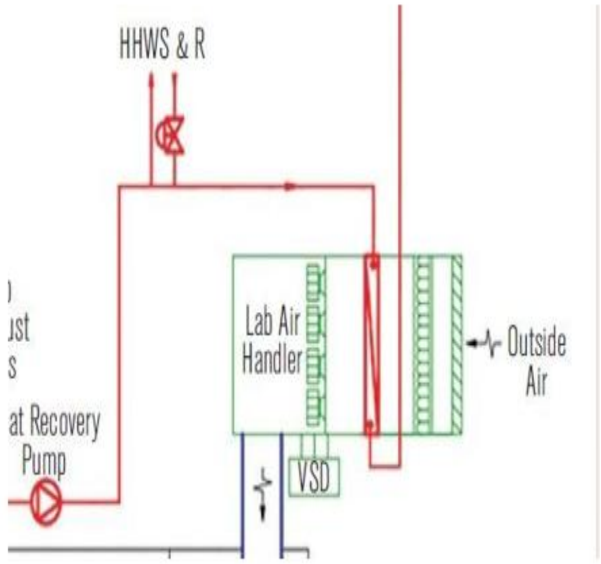

Figure 6 Four-pipe VAV Systems at AHU.

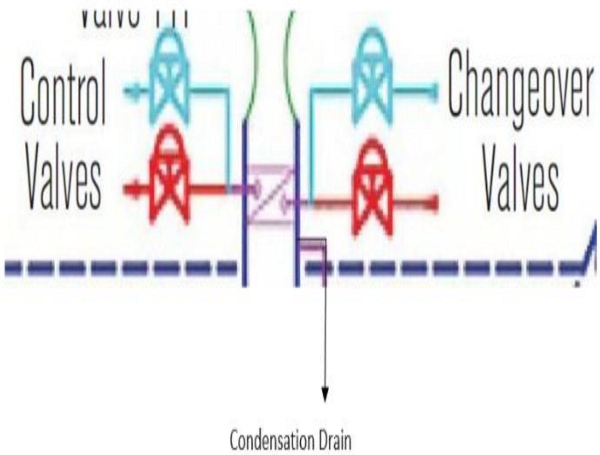

Figure 7 Change over valves for Four-pipe VAV Systems
Load and Energy Analysis:

Energy efficiency of Active chilled beams is better when dehumidification is necessary in humid weather conditions as well as when the cooling loads is high than minimum ventilation rates and hood exhaust. For mild and dry climates, ventilation requirements are high i.e. Air changes per hour required is greater than exhaust rates of hood and cooling load rates – the energy efficiency is low for the active chilled beams.

When ventilation requirements are reduced from high occupied rates e.g., 6 to 8 . Outdoor airflow rates are decreased as the cooling capacity of the active chilled beams because of induced air into the unit. Loads require the peak airflow is less than 4 ACH. Results shows that during all operating hours of the lab, it shows it is ventilation – based on the air changes per hour – see Table A.

Table 1 Ventilation based on the ACH

ACH	Loads (W/sq.ft)
2	1.75
4	3.78
6	5.64
8	7.56
10	9.62
12	11.48
14	13.12

Table 2 Measured (W/sq.ft).

Lab Name	Upper End	Low End
A	1.2	6.3
B	0.1	3.5
C	1.2	4.35
D	0.22	2.5
E	0.2	2.67
F	6.8	8.4
G	0.3	2.2
H	6.2	17.3
I	1.87	9.2
J	0.2	2.2
K	1.67	10.3

Per the occupied rates ASHRAE standards, the minimum requirement is 6 ACH for ventilation, Table B and Figure #8, shows that at least 4 labs are load-dominated.

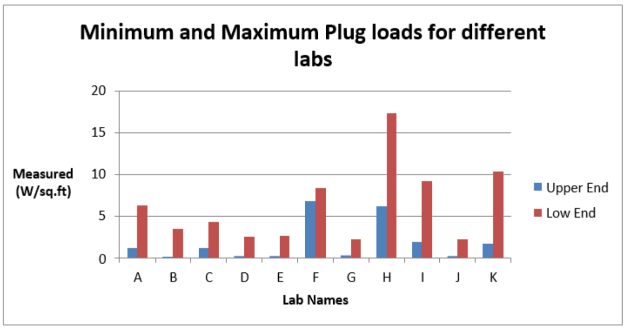

Figure 8 Minimum and Maximum Plug loads for different Labs.

We have assumed 4 ACH when the lab building is unoccupied and assumed 6 ACH when the lab building is occupied. Energy analysis for a lab in SanFrancisco, California. Chilled water and hot water for the VAV's(four-pipe) and Chilled beams(active) has air-to-water heat pumps.

For active chilled beams, it is air-cooled and as such there is no waterside economizer required. A careful analysis must be done to control the chilled beam, as the reheat energy increases if the dew point of supply air is too cold.

2.2.1. Control logic: Condensation sensors can be mounted on pipe which helps to detect condensate deposit, so that the input to the control systems can be tweaked. Set point of Air handling unit supply air temperature is reset. The simple method is resetting the required supply air temperature so that condensation if it occurs, will barely happens on chilled water supply piping to each zone. A damper can be installed at the zone with controls for an air handling system per zone demand. Zone controller measures the demand based on damper position. Reset supply air temperature set point based on zone cooling or heating control loop output, reset hot water supply temperature set point based on valve position.

Energy analysis is performed using few supply air temperatures from 55F, 58F, 60F and 65F for clarity. Air handling unit has heating coil, as the cooling is done at the zone level for the VAV systems (four-pipe). In this case, design cooling supply air temperature is same as the AHU supply air temperature. Reheat and overcooling is not required because cooling happens at the zone level for this type of systems. See Table C for the equipment loads using EnergyPro. For the active chilled beams, for few instances the zone requires reheat due to the higher supply flow rate (over cooling) and higher cooling loads.

III. EQUIPMENT LOADS

Table 3 Equipment Loads

Item #	Equipment Type	Specific Details	Chillers/Heat Pumps(tons)	AHU (cfm)
1	VAV	4-Pipe	102	59,355
2	Active Chilled Beams (ACB)	Supply Air Temp (55 F)	193	38,251
3	Active Chilled Beams (ACB)	Supply Air Temp (58 F)	182	38,251
4	Active Chilled Beams (ACB)	Supply Air Temp (60 F)	174	38,251
5	Active Chilled Beams (ACB)	Supply Air Temp (65 F)	160	38,251

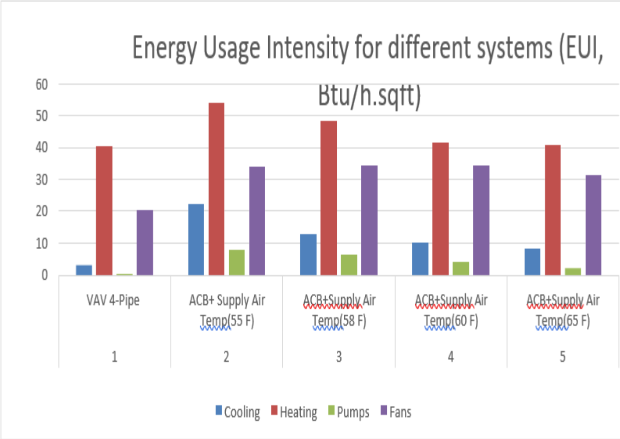

Figure 9 Energy Usage Intensity for different systems based on the source energy.

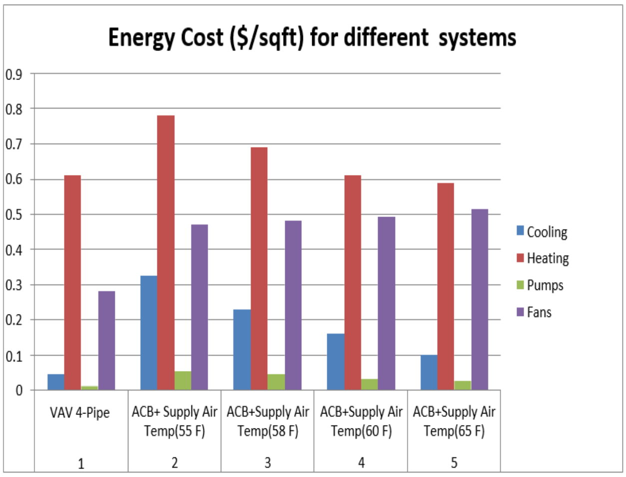

Figure 10 Cost $/sq. ftfor different systems.

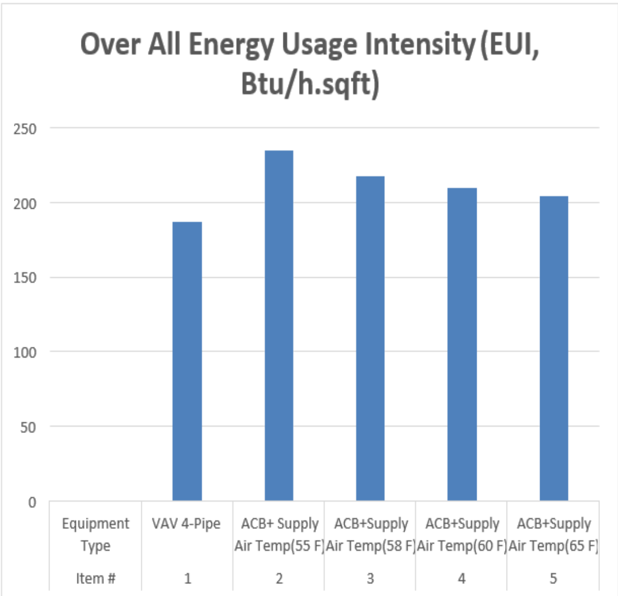

Figure 11 Over All Energy Usage Intensity (EUI, Btu/h.sqft).

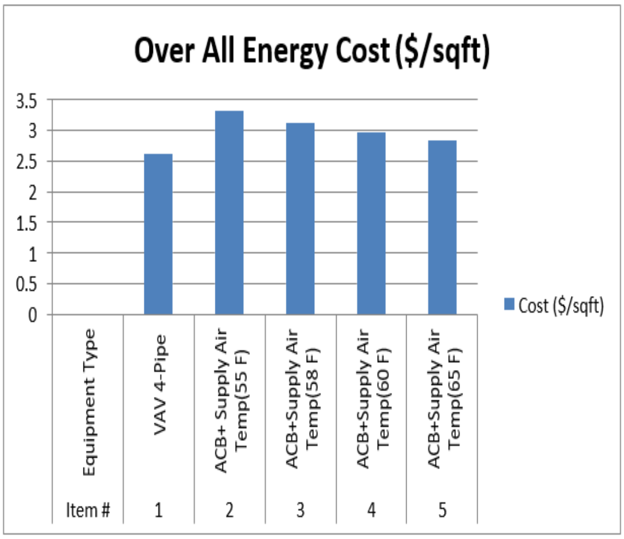

Figure 12 Over All Energy Cost ($/sqft) .

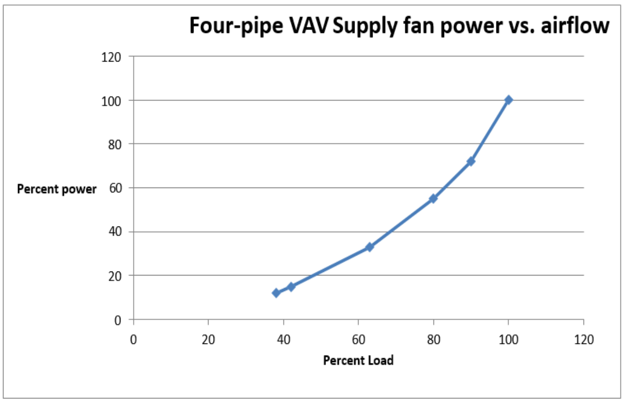

Figure 13 Four-pipe VAV Supply fan power vs. airflow.

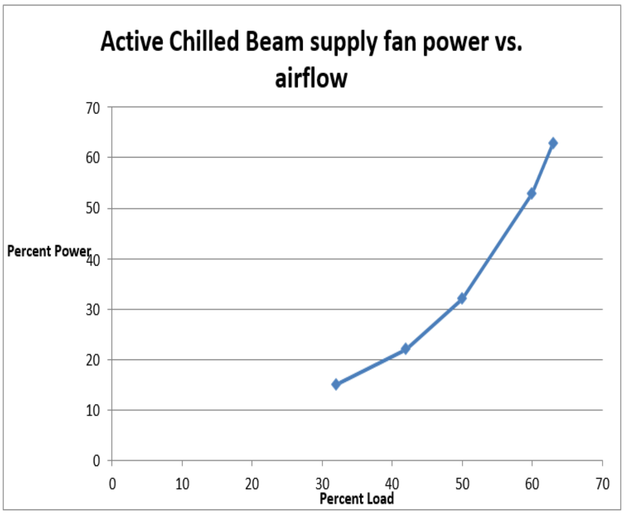

Figure 14 Active Chilled Beam supply fan power vs. Air flow.

1. Evaluation of two systems energy analysis:

1.1. Outdoor airflow rate is higher because of the economizer has the capability to draw the only required amount if outdoor air into the unit and therefore four-pipe VAV systems benefits from the lower cooling energy.

- Mechanical cooling for chilled beams systems needs to operate at much low outdoor air temperatures as the chilled beam systems does not have the any economizers installed as part of their systems. This often results in inefficiency of the systems due to low loads. To offset these inefficiencies due to low load, designer can improve chiller efficiency. Instead of the 46F supply water temperature, a chiller can reject heat at 58F. This will also solve any dehumidification issues. Designer should note that the active chilled beams can produce chilled water temperature of only 46F. Better way to handle this issue is to mix the water i.e. mix return and supply water so that the 58F warm water is produced to avoid any energy inefficiency.
- The chiller plant connected to the air handling unit should deliver up to 46F water and chiller connecting to the active chilled beams should deliver up to 58F. Chiller plant energy is small, see Figure #11 and Figure #12.
- As the project consists of air-cooled chiller, a water side economizer is considered. However, it had increased first-costs and such as it is not utilized in the design analysis.

1.2. There is no reheat with this design as it is not dominated via ventilation and therefore no need for dehumidification and no increase in reheat energy.

1.3. Variable Air Volume (VAV) systems has always large coils, ducts, filters, air handling units and terminal condensate piping. Fans as part of the AHU's operate at part load based on the fan affinity laws – cube performance. Variable speed drives operate based on these laws, as such there is reduction in the energy. Air handling unit for the active chilled beams is smaller in size, however operates the outdoor air rates close to the design fan power. See Figure #13, and Figure #14 for comparison of energy between two systems.

1.4. Pump energy for both of systems are compared and is negligible because of low delta T's for chilled beams and higher delta T's for VAV systems.

IV.CONCLUSIONS

Four-pipe VAV systems are more affordable in mild and dry climates and alternative to chilled beams. Chilled beams can result in turbulence because air is supplied near hoods and control systems to prevent condensation on chilled water surfaces and coils is extremely challenging. The advantage of chilled beams, there is a high potential to decrease floor-to-floor height based on small duct sizes, quantity of shafts, and less space for air handling units. Additionally, chilled beams have no condensate drains and piping's which makes attractive if the load calculations prove that building is load-dominated.

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