Designing an energy efficient and comfortable building

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It's not often you get to work on a project with an enthusiastic, knowledgeable client, a renowned architect and a very resourceful contractor.

The building has a gross area of 17 000 m², and contains a basement with 4 levels above grade. The spaces are distributed in the following manor:

- Server room, classrooms, a parking garage and mechanical and electrical rooms in the basement,
- The 1st and 2nd floors contain a mix of classroom studios as well as office and support facilities;
- The 3rd and 4th floor contains the main administrative offices, faculty offices and ancillary support spaces.

Early on, it was decided that occupant comfort and energy conservation would be a priority. The goal was to provide comfort levels at 10% PPD (Percentage of Person Dissatisfied) or less for each space and at the same time consume the least amount of energy against both California's Title 24 requirements and ASHRAE 90.12007 for LEED points.

Engineering the Architecture

The place to start in creating comfortable spaces is with the architectural design and not the conditioning systems. IBE spent considerable time working with the architects, analysing different glazing alternatives and investigating the inside surface temperature for the glass as this drives the mean radiant temperature (MRT) in the occupied spaces. A dynamic comfort simulator was used that could analyse space conditions for a single day, month or year. Having a better understanding of the building shade characteristics and thermal conditions, the overall thermal comfort was improved in addition to reducing energy consumption by implementing some or all of the investigated strategies.

Claremont McKenna College is located in Claremont, California at 34.1 degrees Latitude. Using a software program, a sun path diagram was created to show the total solar radiation on south and west facing surfaces of a 90 degree structure. The sun path diagram reveals the maximum solar radiation potential for September and July are 450 W/m² (144 Btu/h ft²). and 530 W/m² (168 Btu/h ft²) respectively. The design peak days selected for the analysis were July 30th for the western facing windows and September 24th for the southern facing windows.

On the fourth floor of the southern façade of the college there are 0.45 m (1.5 ft.) long fins protruding from both sides of the windows. There is also a 0.45 m overhang above the windows.

The material characteristics of the fins are very important. The material should have a high reflective factor to reflect solar radiation from being absorbed into the shade. In Claremont California the peak solar intensity is 530 W/m² (168 Btu/h ft²). By allowing only minimal radiation to hit the windows, the solar gain to the space is reduced significantly. At the same time, the solar radiation penetrating the fins must be utilized to enhance the natural day lighting of the spaces.

The inside surface of the fins must also be carefully selected., If the surface has a higher reflectance than any radiation reflected from the glass, after being allowed to hit the glass, could be reflected back into the building from the shade. If the inside surface of the fins is not reflective, the solar radiation reflected from the glass will be absorbed by the fins.

The glazed surfaces of the college were carefully selected as the glass had to perform to reduce solar loads, yet permit natural day light to enter the spaces. During the winter the glazing must have a low U value to reduce heat losses. A low U value is most often obtained by having a coating on either the second or third surface of the double glazed construction. The ideal glazing is one with a balance between a high visible light transmittance and low shading coefficient. This is often a difficult compromise to maintain a clear appearance yet achieve the required shading performance.

The glazing type used in the analysis for the College was an insulating glass with a low shading coefficient of 0.32 and high visible transmittance of 62%, a winter night-time U value of 1.65 W/m² K and a summer U value of 1.42 W/m² K.

System choice

The choice of an appropriate conditioning system was based upon the required comfort compliance requirements. But the different characteristics of classrooms and offices would lead to two different conditioning systems.

Classrooms

Based upon previous design for academic buildings such as Cooper Union, we had some excellent operational feedback that would help us select a system for CMC. Each classroom was designed for 30 students, with and without computers. Experience in designing academic buildings over the years requires a flexible solution, taking into consideration the amount of students attending classes and at what time of day will the classes be held. The basis of the design is a variable volume ventilation air supply; we chose to provide 20 CFM of outside air for each person present. By providing 34 m³/h the ventilation rate qualifies for the LEED point for extra ventilation. The cooling provided by supplying 34 m³/h per student and with a maximum of 30 students in the room is nearly sufficient to maintain a space temperature of 23,5°C. But we were looking for comfort compliance so a radiant ceiling was introduced mainly for heating during the brief and relatively mild winters in California. The choice of a radiant ceiling was based upon the system being able to control radiant

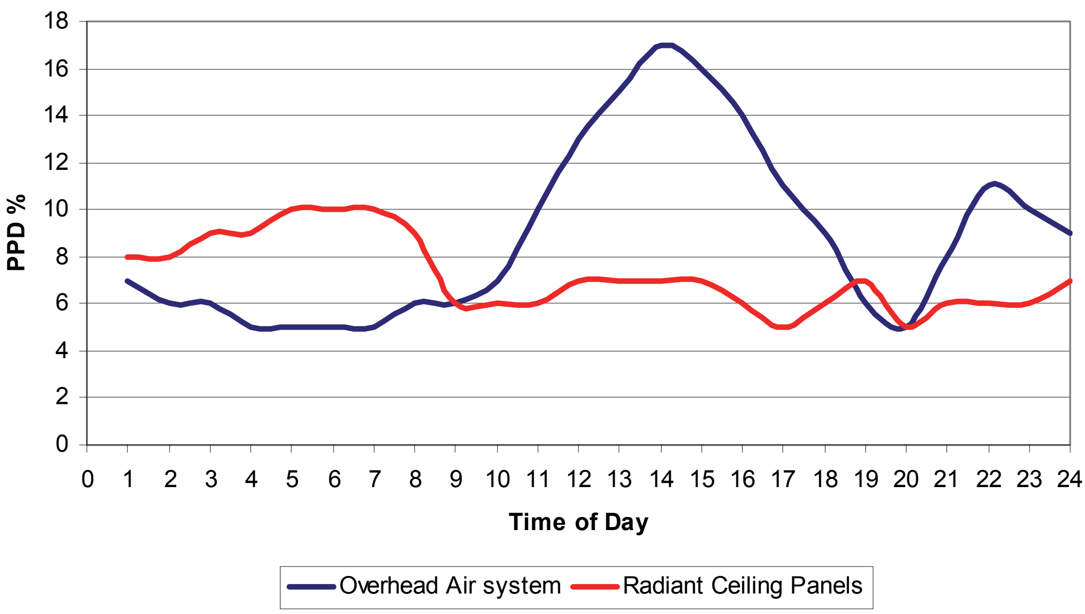


Figure 1. Percentage of people dissatisfied for different air conditioning methods for the classroom.

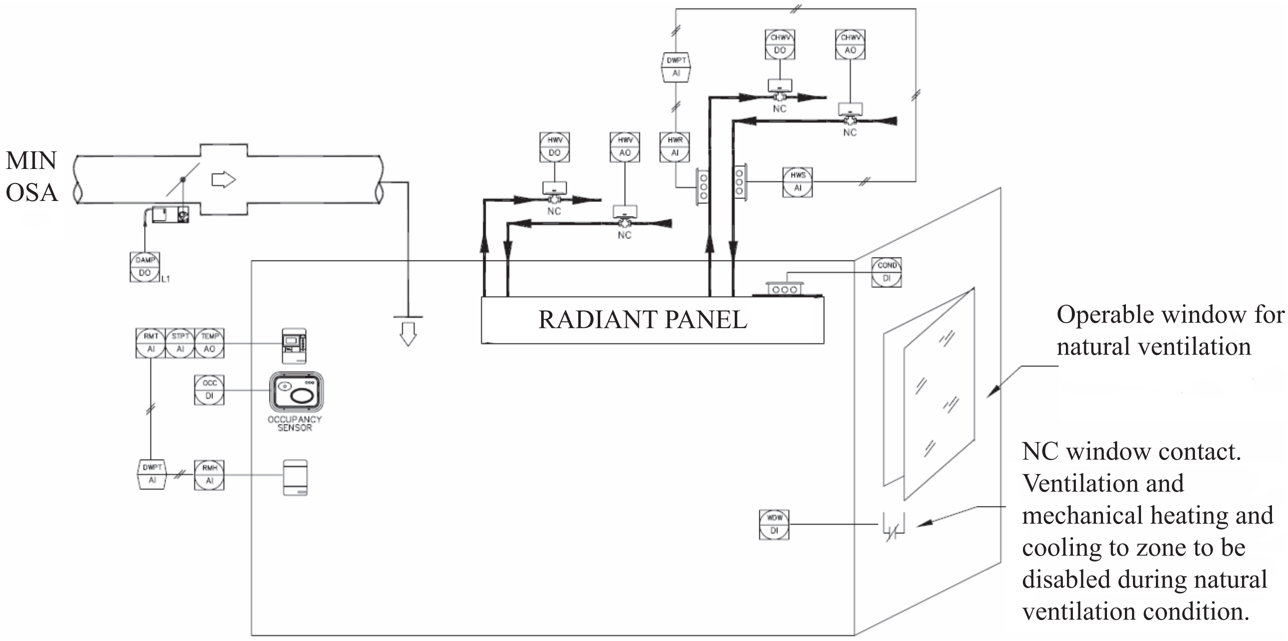


Figure 2. Controls for the classrooms and meeting rooms at CMC.

temperatures in the space, especially for the first lesson of the day and with only a minimum of students present. The radiant ceiling would provide heat to the space and control space radiant temperatures and the ventilation air would be supplied in amounts determined by individual space CO_2sensors. Another spin off from this methodology is the reduction in fan power for the ASHRAE 90.1 energy performance. Once the choice for a radiant ceiling was made, investigations then took place to look at the utilization of cooling from the radiant ceiling. It was basically the same scenario as heating, if the class was partially occupied the ventilation air would be reduced and the cooling and radiant temperature control would be performed by the radiant ceiling.

The results show that comfort conditions comply with ASHRAE standard 55 when a radiant ceiling is introduced as part of the conditioning system for the classrooms.

Offices

We decided to use active beams to condition the offices and administrative spaces at CMC. The choice was based upon our quest for occupant comfort and individual control in each space. Constant volume primary air is supplied to each beam; the sensible cooling from the primary supply air is only about 15–20% of the space sensible cooling load. The larger portion of the cooling load is provided by the control of cooled water flowing through the beam. By putting the control emphasis on the water side control of the system, the response time is improved and this increases the efficiency of the system.

Figure 3. One of the meeting rooms at CMC which is conditioned in the same manner as the classrooms.

Figure 4. Typical office space with floor to ceiling glass.

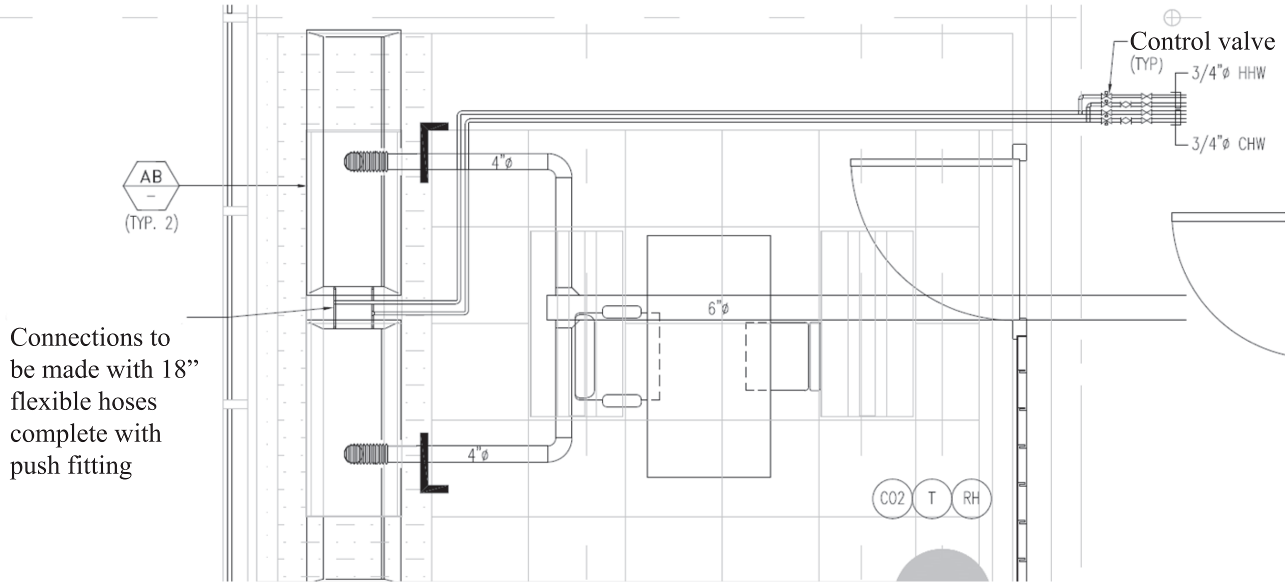


Figure 5. A plan view of the active beams and primary air connections for each space. The temperature, humidity and CO_2 sensors are also shown for each space.

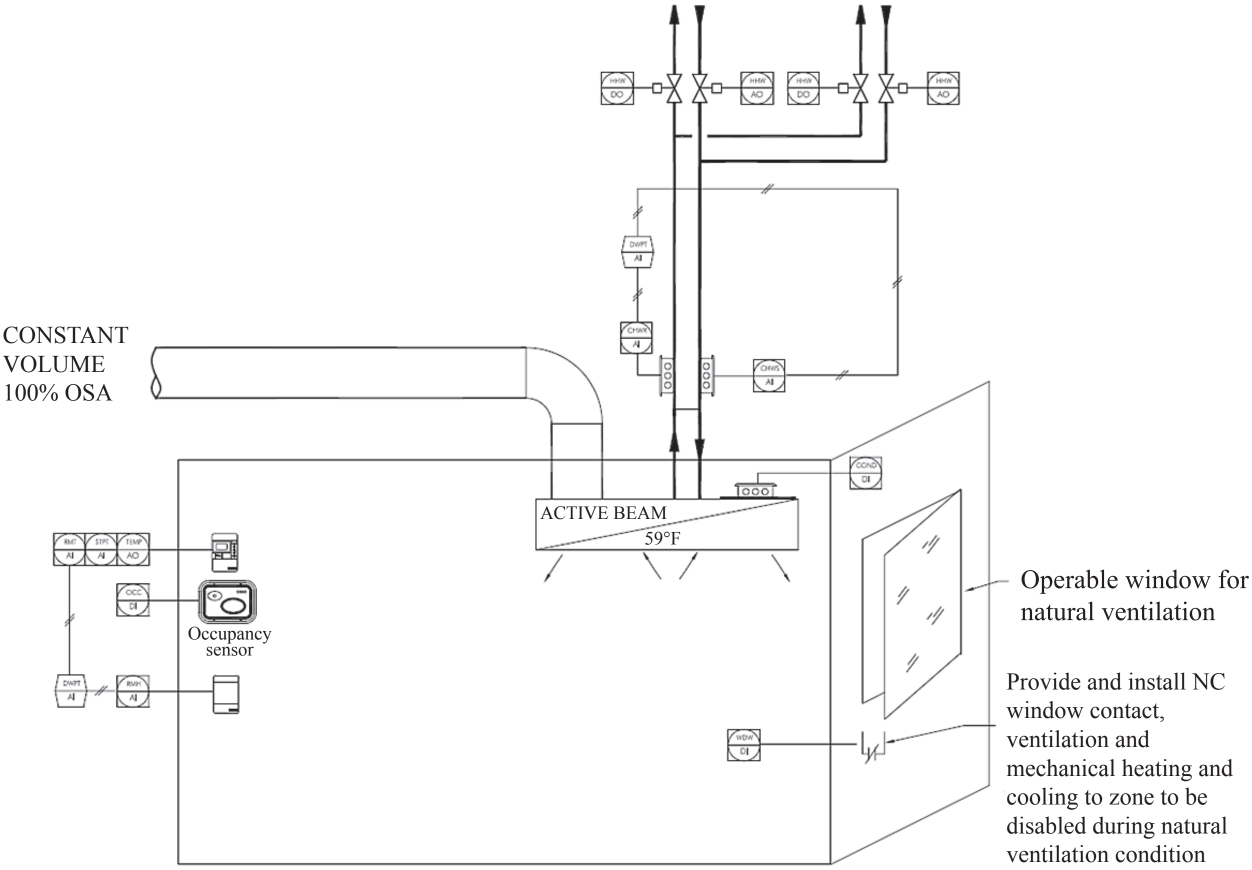


Figure 6. Control systems for offices conditioned by active beams.

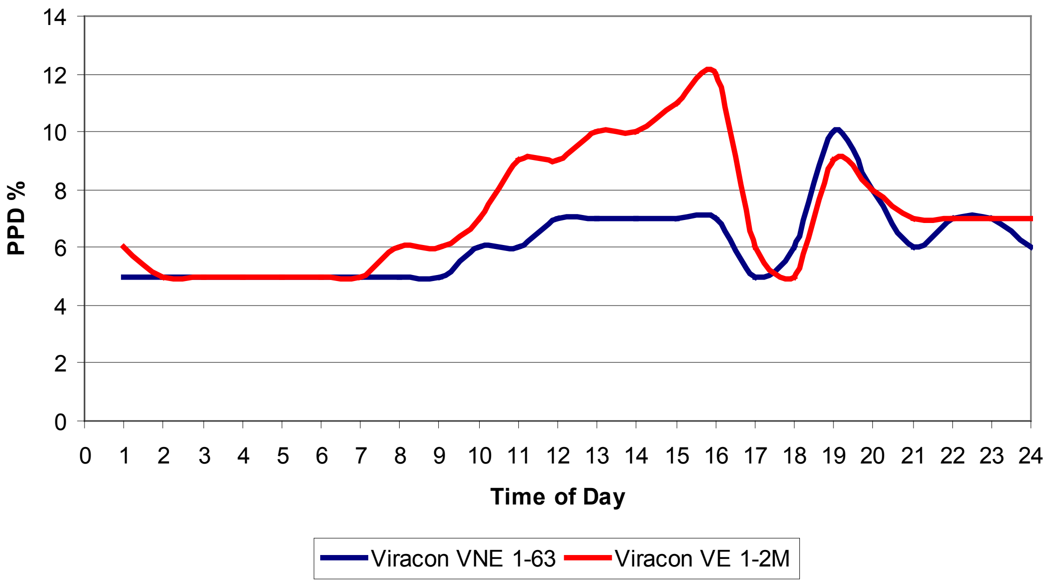


Figure 7. Percentage of people dissatisfied for two different glass types for the corner office.

Energy efficiency

A central cooling and heating plant was provided to serve this building. The central plant is located at the basement level to the north of the building.

The chiller plant consists of two 560 kW frictionless chillers. Each chiller has a variable speed primary pump. The chillers also have the capability of having their speed varied to improve efficiency. Condenser water for the chillers is cooled by a single cooling tower having variable speed fans. The condenser water loop is constant volume.

There are two variable volume chilled water loops:

1. There is a 5.5°C loop that transports water to the air handling units, CRAC units and fan coils in the IDF rooms.
2. The second loop has a variable supply temperature from 12.8°C to 14.4°C for the active beams and the radiant ceiling panels.

Two boilers each with a 580 kW capacity provide water at a constant volume to a common header.

There are two variable volume heating hot water loops:

1. There is an 80°C loop that transports water to the air handling units.
2. The second loop has a variable supply temperature for the active beams and the radiant ceiling panels.

Energy Analysis

An energy model was constructed to explore the building's performance against the California Energy Code (Title 24). This code provides a measuring stick based upon the size and use of a building.

The Reference Baseline building shell is comprised of metal frame wall with R13 batt insulation, insulated glazing with a T24 maximum shading coefficient and roofing with a R19 insulation.

Lighting systems were specified to meet Title 24 allowances of 15,5 W/m².

The Reference Baseline mechanical system was an overhead VAV system and a central heating and cooling plant as allowed by Title 24 standards.

Figure 8 shows the EnergyPro output for the energy analysis. The reference Standard Design is a building of the same size and usage built in accordance with the prescriptive requirements of Title 24. By taking the performance approach, we do not need to follow the prescriptive requirements as long as our proposed building out performs the standard building.

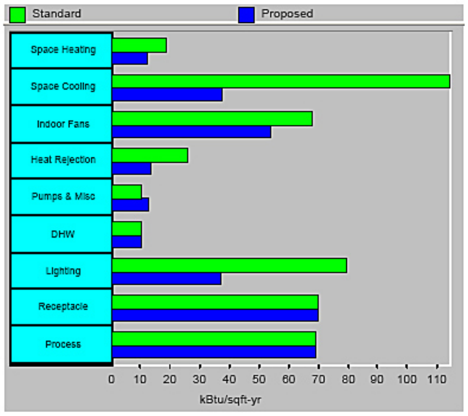
Based on the preliminary model, the proposed building is performing 32.3% better than the standard model, although the value of 37.9% better than Title 24 is used for Savings by Design as this excludes process loads.

PERFORMANCE CERTIFICATE OF COMPLIANCE Part 2 of 3 **PERF-1**

PROJECT NAME: Kravis Hall ECM 3 | DATE: 5/29/2009

ANNUAL TDV ENERGY USE SUMMARY (kBtu/sqft-yr)

ENERGY COMPONENT	Standard Design	Proposed Design	Compliance Margin
Space Heating	18.45	11.78	6.67
Space Cooling	113.98	37.22	76.76
Indoor Fans	67.55	53.54	14.01
Heat Rejection	25.75	13.28	12.47
Pumps & Misc.	9.92	12.36	-2.44
Domestic Hot Water	9.94	9.94	0.00
Lighting	79.07	36.90	42.17
Receptacle	69.76	69.76	0.00
Process	68.70	68.70	0.00
TOTALS:	463.13	313.49	149.64



Percent better than Standard: 32.3% (37.9% excluding process)

BUILDING COMPLIES

Figure 8. Annual TDV Energy Use Summary (kBtu/sqft.yr) compare with kWh/m² per year.

The building includes the following features to increase the performance of the building to exceed Title 24 minimum standards by 37.9 percent:

- High performance lighting systems in classrooms, seminar rooms, meeting room and offices, with occupancy sensors and daylight harvesting sensors.
- High performance glazing
- High efficiency frictionless chillers
- Wall insulation increased to R19 and roof insulation increased to R30.
- Daylight harvesting sensors.

For the LEED submittal the percentage of Energy savings was 63.5% and the cost savings were 46.7%, which was good for 10 LEED points. ■