Design and Development of an Energy Efficient Livable Office Building

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The era of the sick building is coming to an end in the 1990's. Energy efficiency, electronic office technology, building materials, furnishings and finishings were recognized as primary contributing factors to sick building problems in the 1980's. These same factors are now providing the solutions which have been sought by the building design community.

The British Columbia Ministry of Energy Mines and Petroleum Resources has embarked on a pilot project that may signal the end of the sick building era. In coordination with the British Columbia Buildings Corporation, the Ministry has designed and constructed an office building to house their Head Offices in Victoria, British Columbia, which is energy efficient and also provides a superior indoor environment for occupants. The new energy and environmental features of this building include: operable windows, a direct digital control system including window sensors, compartmental fan systems utilizing low pressure design, evaporative cooling plus conventional chiller, low power density lighting and perimeter daylight switching controls.

Introduction

The design of an energy efficient office building attempts to minimize operating costs. A smart office building incorporates state of the art electronic convenience, especially with regard to communications. A livable office building integrates energy efficient and smart building technology with state of the art environmental system technologies to improve productivity in the office workplace by enhancing the quality of the ambient office environment. Oddly enough, it has been the overemphasis of energy efficiency in office buildings that has largely created the poor environmental performance of heating, ventilation and air conditioning (HVAC) systems that now exists in many commercial structures. Uncomfortable conditions have been caused by design and operating efforts that reduce building ventilation to absolute minimum standards and allow temperature an humidity levels to approach the limits of thermal acceptability (Woods 1984, Janssen 1989, U.S. GAO, 1991). Such designed in conditions causing poor environmental performance has resulted in a demand by tenants for a higher standard of control.

Initially, building technology in the 1980's focused attention on minimizing energy usage. Modifications to standards for building ventilation and thermal comfort enabled significant reduction in operating energy requirements (ASHRAE 1981a; 1981b). Industry responded with

sophisticated mechanical and electrical systems that reduced individual control of lighting, ventilation and temperature in favor of centralized control systems. Paralleling these changes to building standards that reduced the tolerance for design and operating errors were the rapid introduction of new building products (such as composite wood products and adhesives) that emit high levels of volatile organic compounds and heat producing office equipment (such as video display terminals, laser printers and photocopiers). These parallel factors combined to create a polluted and often uncomfortable indoor environment, one that has manifested itself in increased employee complaints, reduced productivity and even disease (Woods 1989; Brundage et al. 1988). The resulting lawsuits have placed enormous pressure on designers, builders, building owners, managers and employers to revise their priorities. In addition, government regulatory authorities such as the U.S. Occupational Safety and Health Administration have proposed new standards that would regulate air quality in office and other commercial buildings (U.S. Department of Labor 1994).

Designing a Healthier Workplace

We know how to make buildings efficient to operate and convenient to use. We can now also design user-friendly office buildings that will increase productivity, reduce worker grievances and minimize interpersonal stress among occupants. We can design surroundings that actually provide a more livable workplace, an office that literally contributes to the mental and physical well-being of building users. After all, the key purpose of office buildings is to provide an atmosphere in which people can perform productive work.

An office building that does not achieve adequate environmental conditions can affect not only the health of occupants but also office productivity. If building occupants are satisfied with their indoor environs, the prevalence of complaints about health and comfort is lower, truancy is decreased and the work place is generally more productive. This has been demonstrated in one study of Vancouver office workers before and after their company relocated to a modern-type office building (Sterling and Sterling 1983). Figure 1 demonstrates a dramatic increase in absenteeism related to the prevalence of health and comfort complaints after relocation. Both of these factors reduced office productivity. In a related study, Fireman's Fund Insurance found that improving the environment of two California office buildings by increasing the ventilation, decreased occupant complaints by 40% (Hicks 1984).

Often buildings that are not user-friendly develop a reputation as "Sick Buildings." There are more and more

reported incidents of so-called "sick" office buildings. This problem was first recognized and studied in Scandinavia in the early 1970's and has subsequently been widely studied throughout Western Europe and North America (Stolwijk 1984). The most common symptoms reported by occupants of these buildings include mucous membrane irritation, eye irritation, headaches, lethargy, fatigue, nausea, dizziness and skin rash or itchiness. In addition, the occupants of "sick" buildings often report problems with the environmental control systems such as a lack of fresh air, stuffiness, inadequate temperature control and unpleasant odours.

There have now been several hundred investigations of sick buildings carried out in North America (NIOSH 1989; Kirkbride 1990). The results of nearly 400 of these investigations comprising over 100,000,000 square feet of buildings have been synthesized into a computer database, the Building Performance Database (Collett et al. 1989). Table 1 summarizes the factors identified by the investigators as contributing to sick building problems. 49% of problems were a result of inadequate ventilation and air conditioning systems and a further 28% were a result of indoor pollutants. Table 1 also shows that 10% of the problems were caused by infiltration of unfiltered outdoor air. In addition to inadequate ventilation, many of the ventilation and air conditioning system problems were caused by poor filter maintenance, improper balancing, poor air distribution from diffusers and temperature



Figure 1. Absentee Rate of Office Workers Before and After Relocation

control problems. These findings suggested nearly 80% of sick buildings could be cured and the buildings made healthier and more comfortable by improvements to environmental systems or renovations with environment-ally safe materials.

Suspected Cause	# of	
	Reports	%
Ventilation Control Problem	159	39.0
Ventilation Infiltration Problem	40	10.0
Indoor Sources	115	28.1
Stress	12	2.9
Ergonomic/Workstation Design	5	1.2
Undetermined Cause	42	10.2
No Problem	35	8.6
Total	408	100.0

It has recently been estimated that up to 30% of the current U.S. office buildings have indoor air quality problems (U.S. Department of Labor 1994). An article in the American Institute of Architecture Journal warns that the single most important area of liability litigation facing architects and engineers is that of public health hazards associated with the environmental performance of buildings (LePatner 1987). Examples of such litigation to date include materials such as asbestos and formaldehyde products. Other examples are radon and other soil contaminants, microbiological contamination of air conditioning (HVAC) systems and exposure to toxic construction materials during remodeling.

Fortunately, such problems can be eliminated. The following case study shows how working as a team, architects, engineers, energy and environmental consultants can create healthy buildings.

Case Study: Designing a Livable Office Building

Our case study is the Jack Davis Building located in Victoria, British Columbia. The building is the new headquarters of the British Columbia Ministry of Energy, Mines and Petroleum Resources. In addition to energy resource development, the Ministry is responsible for programs managing energy demand and utilization within the Province. The building is therefore intended not only to be a flagship of energy efficiency but also to demonstrate that livability and comfort need not be sacrificed.

The ideal strategy for achieving an energy-efficient livable building is for environmental and energy consultants to begin working with the design team at the program and conceptual stages of a project. Though far less than architects, energy consultants are often included at this stage. However, environmental consultants are rarely called upon until well into the design process, or more often until the building is constructed and problems are occurring.

In the case of the Jack Davis Building, the environmental consultant was brought into the project early enough to assist in development of the building program and to review design decisions that could influence the ultimate livability of the building. Specifically, the environmental consultants role was to:

- 1. Formulate a program of environmental goals and objectives for the design.
- 2. Review the design schematics to evaluate whether the environmental objectives were reached.
- 3. Inspect the building after construction and test building performance relative to the environmental objectives.

Initially, a Design Brief was prepared by the design team which included detailed criteria for the building requirements. An integral part of these criteria were environmental and performance goals.

These goals encompass:

- Heating, Ventilation and Air Conditioning (HVAC)
- Illumination
- Architecture
- Commissioning and operation

Heating, Ventilation and Air Conditioning

Inadequacies of HVAC systems have been identified as the primary cause of livability problems in the majority of so called sick buildings. Because these systems play an integral role in creating a livable environment, the Design Team focused most attention on establishing acceptable performance goals.

Goals were established for:

- Ventilation
- Thermal control
- Indoor Air Quality
- Filtration
- · Energy management

Ventilation Goals. These goals were developed to exceed criteria specified in ASHRAE Standard 62-1989 "Ventilation for Acceptable Air Quality" (ASHRAE 1989a). The target was to achieve a design ventilation rate of 40 cubic feet per minute (cfm) per occupant. This target assumed that the configuration of the mechanical system results in a ventilation effectiveness of 70%. Ventilation effectiveness is the measure of the actual amount of outside air that reaches building occupants. Assuming a ventilation effectiveness of 70% at 40 cfm/ occupant, the net result would be an actual ventilation rate of 28 cfm/occupant. This rate of outdoor air ventilation slightly exceeds the rate recommended by ASHRAE Standard 62-1989 of 20 cfm/occupant that assumes 100% ventilation effectiveness. The quality of outside air was considered, as well as the quantity of air. The outside air was determined to be of acceptable quality for ventilation purposes. However, the designers were cautioned to avoid placing intakes on the east facade which fronts on a busy thoroughfare. In the resulting design, outside air is to be introduced separately on each floor and the windows are to be operable, providing a high degree of localized occupant control.

Thermal Goals. Thermal goals were developed to maintain target ranges for temperature, based on ASHRAE Standard 55-1992 "Thermal Environmental Conditions for Human Occupancy" (ASHRAE 1992). In addition to temperature, humidity has a significant effect on how livable an environment is perceived by the occupants (Sterling et al. 1985). The humidity target for the building was established at 30- 60% relative humidity. This target is based on recommendations contained in ASHRAE Standard 62-1989.

Indoor Air Quality Goals. Indoor air quality goals were established for carbon dioxide and formaldehyde. Carbon dioxide was selected as an index of occupant-generated contaminants and formaldehyde as an index of contaminants off-gassed from furniture, fixtures and building materials. Increased outside air ventilation should provide adequate dilution for most other indoor source contaminants. The goal for carbon dioxide of 600 ppm, 400 ppm less than the ASHRAE goal of 1000 ppm, is based on guidelines developed by the B.C. Workers Compensation Board. The goal for formaldehyde of .05 ppm is based on Health and Welfare Canada recommendations (Health and Welfare 1987). Recently the State of California Air Resources Board has also adopted this goal (Levin 1993).

Fiitration Goals. Filtration goals were established for filters to achieve a minimum 60% dust spot efficiency based on ASHRAE Standard 52-76 "Method of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter" (ASHRAE 1976).

Energy Management Goals. Energy management goals were developed for a target of 45,000 BTU per square foot per year. In the resulting design, this goal was achieved without compromising the ventilation goals, by incorporating an economizer cycle. In addition the building was to meet or exceed ASHRAE Standard 90.1-1989 "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings" (ASHRAE 1989b).

Illumination

Goals for illuminance were established based on the Illuminating Engineers Society and the Canadian Standards Association recommendations (IESNA 1984, CSA 1989). The goals selected are 50 - 70 footcandles for general office areas and 30 - 50 footcandles for Video Display Terminal workstations.

No specific targets were set for spectral quality, daylighting, and task lighting. However, the design team was determined to address these issues qualitatively and within the building budget. For example, high quality parabolic lenses have been included and daylighting is to be achieved throughout the interior.

Architecture

The overall architectural goal was to meet or exceed the previously described environmental goals wherever possible in the architectural design of the building, through careful consideration of: envelope and glazing, configuration and massing, interior planning, materials and acoustics.

Within this framework, the resultant design included the following:

- The building envelope was not sealed. For ventilation, all windows above the ground floor were operable.
- For illumination, the glazing and building configuration with the aid of a light shelf allows daylight to penetrate far into the core office space.
- For Indoor Air Quality, construction and furnishing materials will be low off-gassing and non-toxic. To achieve this, manufacturers and suppliers have been required to provide materials and content information.

Conclusions

The Jack Davis Building has been designed to meet the livability and energy goals included in the Design Brief. As a result of the integration of environmental

considerations into the design process, the following characteristics have been incorporated into the final design:

- Opening windows above the ground floor to provide occupant access to free cooling. To avoid misuse, window position has been integrated into direct digital controls. Each window is equipped with a sensor. When a window is open in any zone of the building the control system locks the ventilation at minimum and no longer relays information from that zone back to the central air handling unit..
- Daylight penetration to all areas is provided by light shelves. Daylighting is coupled with photocells that monitor illumination levels and automatically shut off lighting near windows when sufficient daylight is available.
- Fluorescent fixtures equipped with parabolic diffusers.
- Free cooling through HVAC economizer operation, allowing outside air ventilation rates in excess of 40 cfm/person, with minimal energy consequences.
- Minimization of potential for contamination of workspace by laboratories or parking garages by separation and air pressurization.
- Outside air intake locations which avoid sources of contamination.
- Use of high efficiency filtration systems.
- Independent mechanical services for each floor monitored and managed by a direct digital control system to reduce problems associated with building wide air recirculation and provide improved occupant control.
- Careful selection of finishing materials to reduce offgassing potential. Low emission products were used where feasible. Finishing materials containing formaldehyde were avoided. Interior partitions were aged for nine months prior to installation.

The building is part of the B.C. Hydro sponsored Power Smart Program. This program requires follow up monitoring of energy performance. A complete commissioning process of the building environmental and energy system has been undertaken. Livability parameters such as ventilation, indoor air quality, temperature and humidity are being seasonally monitored during the first year of operation along with energy utilization. Early indications are that building design features that focused on considerations of the indoor environment have had a positive effect both subjectively and objectively. The tenant has indicated that the building features such as opening windows have contributed to staff moral and a positive working environment. Measurements have shown that ventilation and thermal control targets have been met and indoor contaminants are at very low levels.

As for energy-efficiency, the building uses 1.6 million fewer kilowatt - hours of electricity than a conventional structure and meets or exceeds design targets.

The cost for increased comfort and energy efficiency was less than 5% more than for conventional construction.

The building received a 1993 B.C. Hydro Power Smart Design Excellence Award and may provide guidance for solutions that will end of the sick building era.

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