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Design and Development of an Energy-Efficient, Livable Office Building

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ABSTRACT

The era of the sick building is coming to an end in the 1990's. Energy efficiency and electronic office technology 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 is embarking on a pilot project the may signal the end of the sick building era. In coordination with the British Columbia Buildings Corporation, the Ministry is designing and constructing an office building to house their Head Offices in Victoria, British Columbia, which will be both energy efficient and will provide a superior indoor environment for occupants. This paper will describe the program of requirements for the design of an energy efficient, livable office building.

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 that now exists in many commercial structures. Uncomfortable conditions caused by poor environmental performance has resulted in a demand by tenants for a higher standard of control.

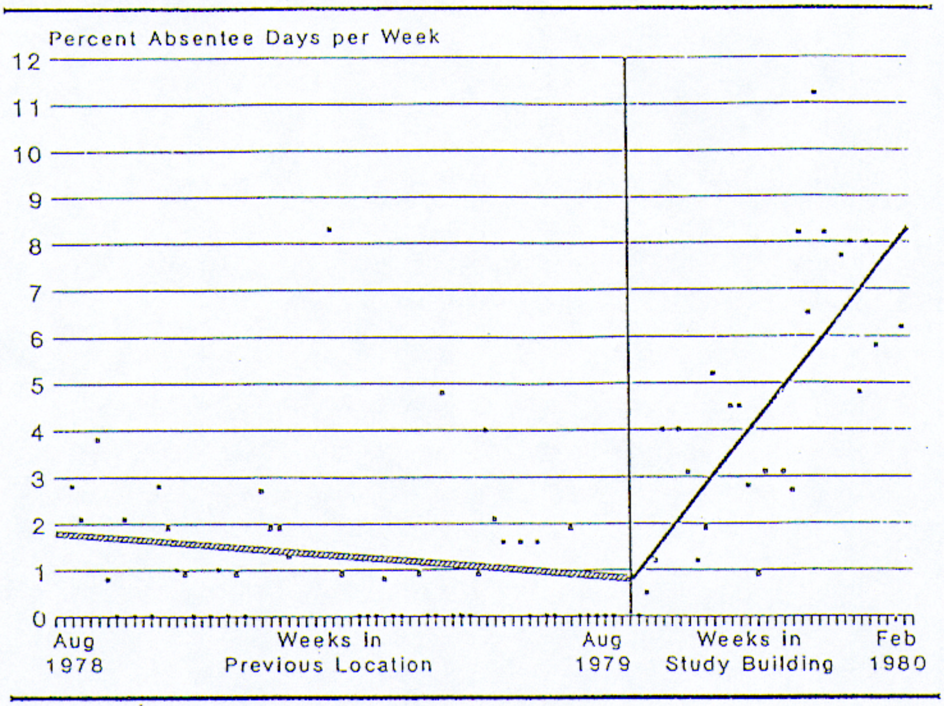
Initially, building technology in the 1980's focussed attention on minimizing energy usage. Sophisticated mechanical and electrical systems evolved and new building products were utilized in office construction. These same factors, however, combined to create a polluted and often uncomfortable indoor environment, one that has manifested itself in increased employee complaints, reduced productivity and even disease. The resulting lawsuits have placed enormous pressure on designers, builders, building owners, managers and employers to revise their priorities.

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 is not energy efficient and 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). The graph (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).

Absentee Rate of Office Workers Before and After Relocation



Theodor D. Sterling & Assoc. Ltd., Vancouver, B.C.
Published in: Sterling & Sterling (1983) Canadian Journal of Public Health, Vol. 74.

Figure 1.

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 1970s and has subsequently been widely studied throughout Western Europe and North America. 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 odors.

There have now been several hundred investigations of sick buildings carried out in North America and Western Europe. 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 that had contributed 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. These findings suggested nearly 80% of sick buildings could be cured and the buildings made user friendly by improvements to environmental systems or renovations with environmentally safe materials.

Table 1
Investigator's Conclusions From Reports Contained in the Building Performance Database

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 been estimated that up to ninety per cent of the currently available office building stock has a potential for becoming a "sick" building. 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 generating components of buildings, microbiological contamination of air conditioning (HVAC) systems and exposure to toxic construction materials during remodeling.

Fortunately, such problems can be eliminated. To create livable buildings, architects and engineers need to understand the health and comfort problems that can be created by poor building design.

CASE STUDY: DESIGNING A LIVABLE OFFICE BUILDING

Our case study is the Jack Davis Building now under construction in Victoria, British Columbia. The building will be the 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 provide 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. 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 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 have been reached.

3. Inspect the building after construction and test building performance relative to the environmental objectives.

Although the environmental consultant's input will encompass all phases of the design and development process from program through acceptance, this discussion is limited to the Program and Design Phases of the project since the building is now under construction.

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 were developed to exceed criteria specified in ASHRAE Standard 62-1989 "Ventilation for Acceptable Air Quality." 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 slightly exceeds the rate recommended by ASHRAE Standard 62-1989. The quality of outside air was considered, alongside 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 were developed to maintain target ranges for temperature, based on ASHRAE Standard 55. In addition to temperature, humidity has a significant effect on how livable an environment is perceived by the occupants (Sterling, 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 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 is based on B.C. Workers Compensation Board recommendations. The goal for formaldehyde of .05 ppm is based on Health and Welfare Canada recommendations.

Filtration Goals were established for filters to achieve a minimum 60% dust spot efficiency based on ASHRAE Standards.

Energy Management Goals were developed for a target of 45,000 BTU square foot per year. In the resulting design, this goal was achieved without compromising the ventilation goals, by incorporating an economizer cycle.

Illumination

Goals for illumination were established based on the Illuminating Engineers Society and the Canadian Standards Association recommendations. These goals are 50 - 70 foot-candles for general office areas and 30 - 50 foot-candles 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:

As a revolutionary or evolutionary concept, the building envelope was not sealed.

For ventilation, all windows above the ground floor were operable.

For illumination, the glazing and building configuration 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.
- Daylight penetration to all areas.
- Fluorescent fixtures equipped with parabolic diffusers.
- Free cooling through HVAC economizes 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.
- Outside air intake locations which avoid sources of contamination.
- Use of high efficiency filtration systems.
- Separate HVAC systems on each floor to improve occupant off hour control.
- Careful selection of finishing materials.

Although energy simulations indicate that building energy demand will be on target, until the building is constructed and commissioned there is no way of confirming that both livability and energy goals will be met.

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 will be undertaken upon completion and prior to final acceptance. Further livability parameters such as ventilation, indoor air quality, temperature, humidity and illumination will be seasonably monitored during the first year of operation along with all energy utilization. The occupants will have the opportunity to respond to a questionnaire to determine their perception of the acceptability of conditions.

Scheduled for completion in January 1993, we will have the opportunity to determine if the Jack Davis Building is truly a flagship for livability and energy performance and has lead us out of the sick building era.

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