A Framework for Design to Prevent Indoor Environmental Problems in Buildings

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INTRODUCTION

The design of energy efficient office buildings 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 efficiency 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 focused attention on minimizing energy usage. Sophisticated mechanical and electrical systems evolved and new building products were utilized in 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 Quality Environment

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. In these buildings 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 conditions of environmental quality 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[1]. The graph 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, lead to a decreased prevalence of occupant complaints by 40%[2].

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. 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 thousand investigations of sick buildings carried out in North America and Western Europe. The results of nearly 400 of these investigations comprising over 100,000,00x square feet of buildings have been synthesized into a computer database, the Building Performance Database[3]. Table I 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.

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[4]. Examples of such litigation to date include materials such as asbestos and formaldehyde products. Other examples are radon generating components of buildings, micro biological 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, construction and operation.

A Framework for Design

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.

The environmental consultant should be 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 is 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.

A Design Brief should be prepared by the design team which includes detailed criteria for the building requirements. An integral part of these criteria should be 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 goals should be established for ventilation, thermal control, indoor air quality, filtration and energy management.

Ventilation Goals should meet or exceed criteria specified in ASHRAE Standard 621989 "Ventilation for Acceptable Air Quality"[5]. For example, the standard recommends an outside air ventilation rate of 20 cfm/occupant for office space. In a recent project, the target was set to achieve a design ventilation rate of 40 cubic feet per minute (cfm) per occupant[6]. 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 should also be considered, alongside the quantity of air- If the outside air is determined not to be of acceptable quality for ventilation purposes, designers should employ appropriate filtration technologies.

Thermal Goals should be developed to maintain target ranges for temperature, based on ASHRAE Standard 55-1992 "Thermal Environmental Conditions for Human Occupancy"[7]. In addition to temperature, humidity has a significant effect on how livable an environment is perceived by the occupants[8]. The humidity target for buildings should be established at 30 - 60% relative humidity. This target is based on recommendations contained in ASHRAE Standard 62-1989.

Indoor Air Quality Goals should be established for carbon dioxide and formaldehyde. Carbon dioxide is an index of occupant generated contaminants and formaldehyde is 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. Appropriate goals for carbon dioxide are 600 ppm and for formaldehyde are 0.05 ppm.

Filtration Goals should be established for filters to achieve a minimum 60% dust spot efficiency based an ASHRAE Standard 52-76 "Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter"[9].

Energy Management Goals should be developed. A recent project set a target of 45,000 BTU\square foot\year[6]. It is possible to achieve this goal without compromising the ventilation goals by incorporating economizer technologies.

Illumination. Goals far illuminance should be established based an the Illuminating Engineers Society[10]. These goals are 50 - 70 footcandles for general office areas and 30 - 50 footcandles for Video Display Terminal workstations.

Targets for spectral quality, daylighting, and task lighting should also be set based on tenant use requirements.

Architecture. The overall architectural goal should be to meet or exceed the 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. In buildings, appropriate architectural design is critical to avoid problems of the stack effect. Special attention must be given to the design of all vertical components.

Commissioning. To ensure that environmental quality targets have been met, a complete

commissioning process of the building environmental and energy system should also be undertaken upon completion and prior to final acceptance. Ongoing building commissioning should include seasonal monitoring of livability parameters such as ventilation, indoor air quality, temperature humidity and illumination during the first year of operation along with all energy utilization. The commissioning process should be based on ASHRAE Guideline 1 1989 "Guideline for Commissioning of HVAC Systems"[11].

New buildings can be designed and constructed in which occupants will not experience sick building problems by following a design framework that includes and environmental consultant. In one recent case study, the design team followed this framework and incorporated the following characteristics into the final design[6].

- Opening windows above the ground floor.
- Separate HVAC systems on each floor to improve occupant off hour control.
- 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.
- Daylight penetration to all areas.
- Fluorescent fixtures equipped with parabolic diffusers.
- Careful selection of finishing materials.

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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

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Source: Sterling & Sterling, Cdn J Pub Health, Vol. 74, 1983

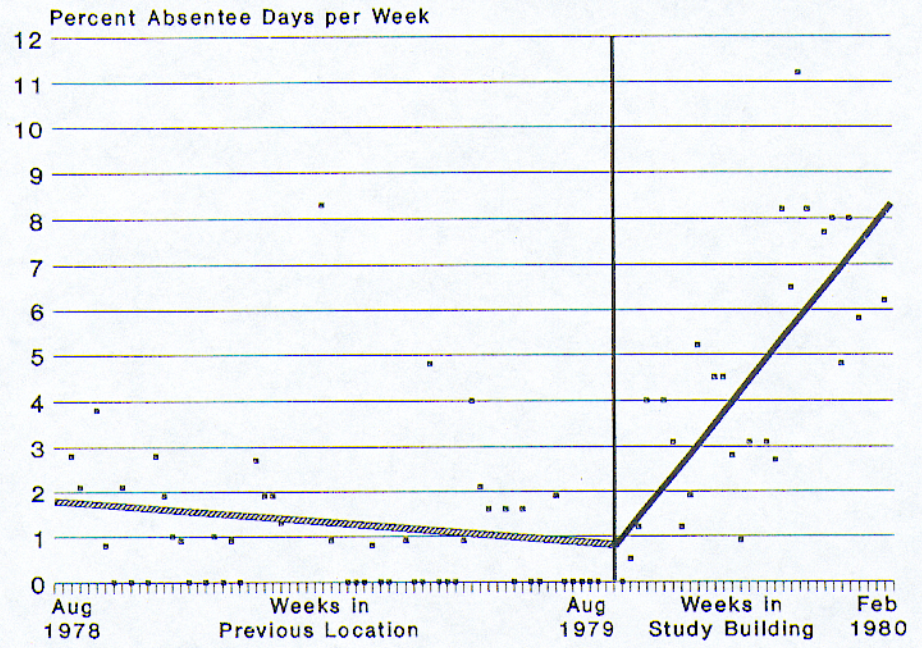

Figure 1. Absentee rate of office workers before and after relocation.