

# A Holistic Building Breakthrough

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## ABSTRACT

The holistic building is one where the whole is more than the mere sum of the parts.

Recent advances in window technology allow us to design a building envelope so that it in effect almost eliminates the influence of the outdoor environment and thus existing technology can be more effectively and efficiently utilized.

To do this the building industry status quo will be disrupted. Instead of utilizing machines to beat the building into something approaching comfort conditions, the holistic building uses the building elements as an integral part of the indoor environment control system.

Today's standard buildings provide, at best, a compromise between indoor thermal comfort and hygiene (indoor air quality). HVAC systems are "added" to a building, not integrated into it. They are a progressive outgrowth of past technology rooted in the thinking of the 1920's as the art and science of what became known as "air conditioning" began to take shape.

The holistic building integrates the envelope and structure into the thermal comfort control system and allows the ventilation system to focus on hygiene.

The holistic building discussed in this paper utilizes a high performance envelope, a thermo-active deck (floor structure) and displacement ventilation. These are not pie-in-the-sky concepts but real ideas that have been put into practice in real buildings over the last 3 or 4 years.

## BUILDING DESCRIPTION

### General

The HOLISTIC building is one where all components, envelope, structure, HVAC and electrical are selected and designed so that their interaction results in a better building.

The following describes the characteristics of certain building components. The choice of certain performance characteristics such as window thermal — optical properties, wall insulation levels, etc. can never be generalized, they are site specific. Current computerized analysis programs such as DOE-2, BLAST, Tran TRACE, etc. can not properly analyze a building that utilizes radiant heating and cooling for temperature control and floor level low velocity-low turbulence displacement ventilation. These programs can, however, be used to give a "feel" for the appropriate envelope performance parameters.

Figure 1 shows the exterior, interior and general arrangement of components used in a holistic (BA TISO) building. The term "BA TISO" was coined to describe this building concept. BA TISO is derived from the (French) word BA Timent meaning building or edifice and ISOtherm meaning constant temperature; hence BA TISO — constant temperature building.

### Envelope

The holistic BA TISO building became possible only after wall and window manufacturing and construction technology had advanced to the point where it was economically feasible to build a building with an envelope that almost eliminates the influence of the outdoor environment. The two main components of the envelope are window and opaque wall; both use currently available material and products as described in the following.

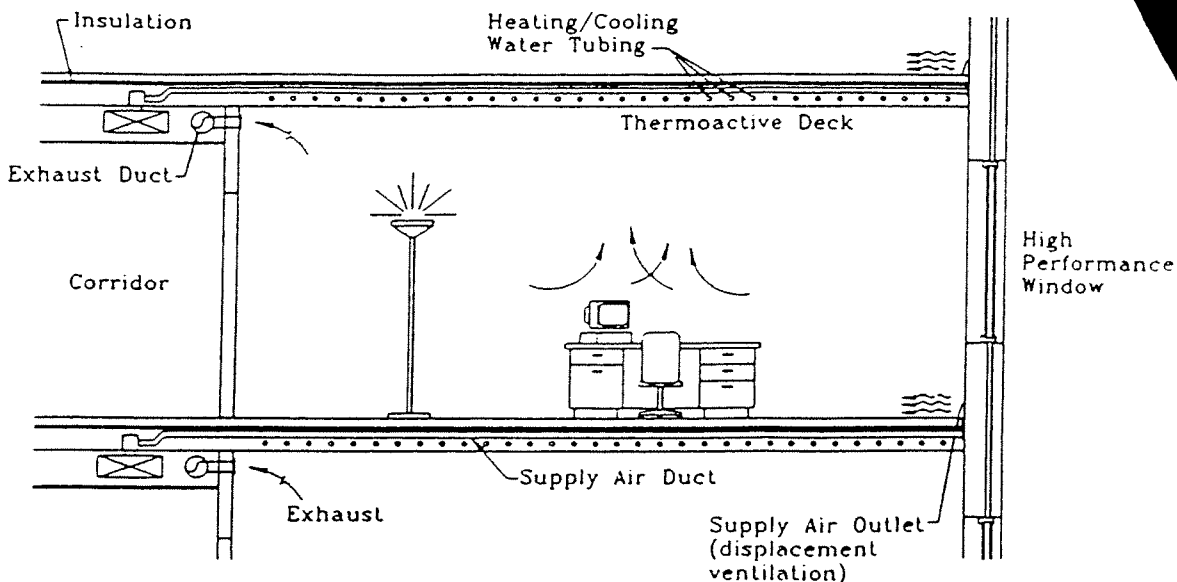
The windows in the BA TISO building, shown in Figure 1, utilize a four element glazing unit set in a low conductivity "aluminum frame as shown in Figure 3.

### Opaque Walls

The design and construction of the opaque portion of the envelope (walls and roof) is based on known and used materials and practices. The walls should:

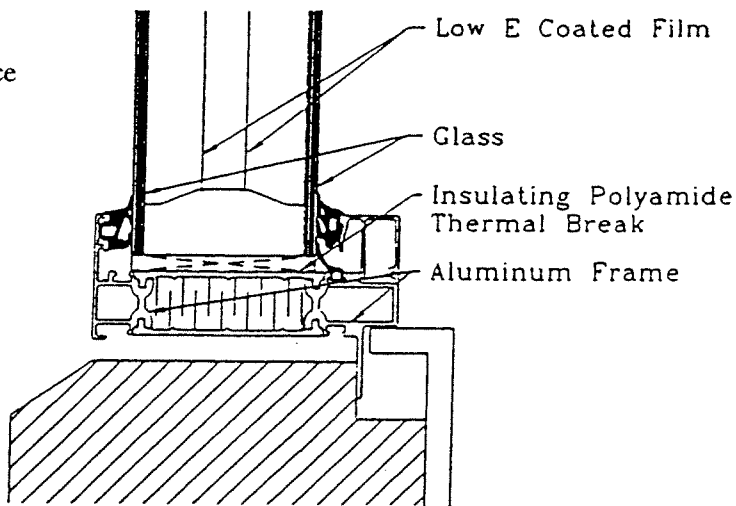
- be designed as a pressure equalized rain screen
- contain an effective air/vapour barrier

Figure 1  
The Holistic  
BA TISO  
Building



General Arrangement of Components

Figure 3  
The High  
Performance  
Window



WINDOW* PERFORMANCE DATA	
U	0.15 BTU/hr-ft <sup>2</sup> -F (0.85 W/m <sup>2</sup> -°C)
SC	0.22
SHGC	0.19
Tvis	24%
STC	40

\* Glazing Unit and Frame

- contain no, or very limited, thermal bridges
- have near zero air and water leakage
- have optimum thermal characteristics for the specific building site and use

The required design principles for good effective walls has been well documented (Building Science) over the past 30 years. Material for effective air/vapour barriers (National Building Code) are in common use and are economically available.

The two problems that still must be overcome to ensure the construction of the envelope needed for a truly holistic building are:

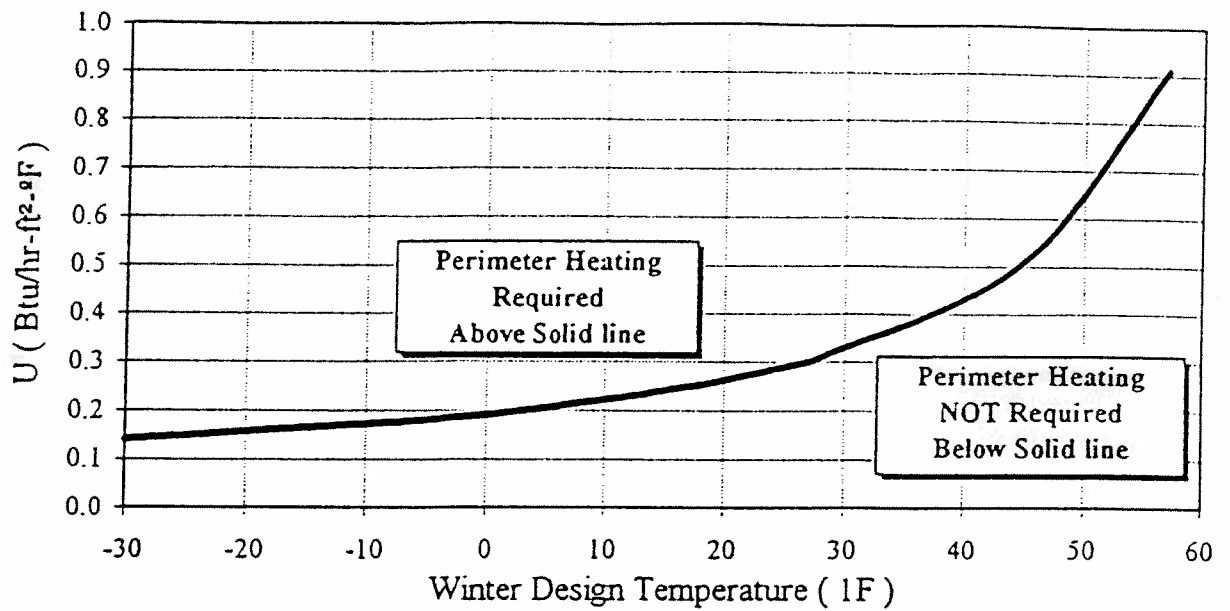
1. design technology: which appears to be almost completely lacking in most North American building design, and
2. construction expertise to properly execute the design.

## Windows

The selection of the windows, be they punched, strip or curtain wall, is the most critical decision to be made in the design of the building envelope. The two most important characteristics are the overall heat transfer (U) value and solar heat gain coefficient (SHGC).

The U value must be such that the surface temperature of the interior pane of glass does not fall below about 60°F (16°C) at the 1% ASHRAE winter design temperature. Figure 2 shows the required U value as a function of winter design temperature.

Figure 2  
Window  
Selector



Experience in over 150 buildings using high performance windows in climates where winter design temperatures are as low as  $-40^{\circ}\text{F}$  ( $-40^{\circ}\text{C}$ ) has shown that perimeter heating is not required if the indoor glass surface temperature does not go below about  $60^{\circ}\text{F}$  ( $16^{\circ}\text{C}$ ).

The SHGC of the window must be such that internal solar heat gain is kept to a minimum while at the same time visible light transmission (TVIS) is not reduced too far or the "colour" of the light changed too greatly. The ratio of TVIS/SHGC should always be greater than one.

Modern windows achieve the desired performance characteristics through the use of low emissivity or multifunctional coatings and high performance thermally broken frames. The impact of the window frame on overall window performance has been examined and evaluated by many organizations (Window Innovations '95; ASHRAE Handbook — Fundamentals) over the last 5 to 10 years.

The envelope of a BA TISO building uses windows built with both high performance glazing and high performance frames.

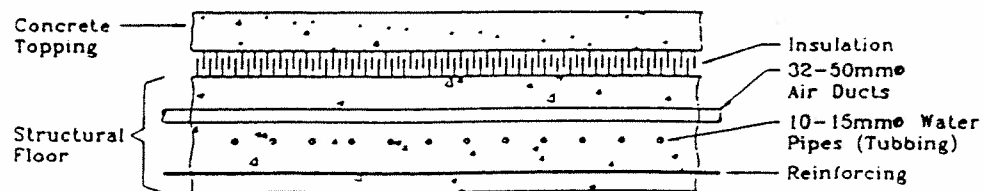
## Structure

The building structure, in particular the building floor (deck), plays a key role in the BA TISO building. The deck provides the heat transfer that is used to control the space temperature. Figure 4 below shows the deck construction.

The fluid (water) used to add or extract heat from the occupied space is circulated through the small 12mm round pipes (tubes) imbedded in the concrete deck into which is also imbedded the small (32-50mm round) plastic ducts supplying air to the displacement ventilation system baseboard air outlets. The insulation on top of the structural deck has two functions, namely thermally separating the floor above from the conditioned space below and reducing impact noise transmission.

This arrangement results in a building with a radiant heating and cooling ceiling. The underside of the concrete floor is exposed and finished as required. There is no suspended ceiling system as it would impede the heat transfer process.

Figure 4  
BA TISO  
Building  
Floor (Deck)  
Construction



## HVAC

The holistic BA TISO building HVAC system is very different than the systems commonly used in today's office buildings. Space temperature control and ventilation are separate. The building floor (deck) acts as a radiant ceiling heating and cooling system. Ventilation is provided by a low velocity, low turbulence displacement ventilation system supplying air through perimeter baseboard outlets. This separation of temperature control and ventilation allows the ventilation system design to focus on space hygiene which is what it was intended when we first designed building ventilation systems.

Using the building floor slab (deck) as an integral part of the heating and cooling system is a significant first step in making active use of the building mass to assist in the task of space temperature control. By doing this it was found that the temperature of the water being circulated through the tubes in the floor slab need only be at the maximum, a few degrees above or below the required space temperature. A temperature range of 64°F (18°C) to 77°F (25°C) was found satisfactory in most cases.

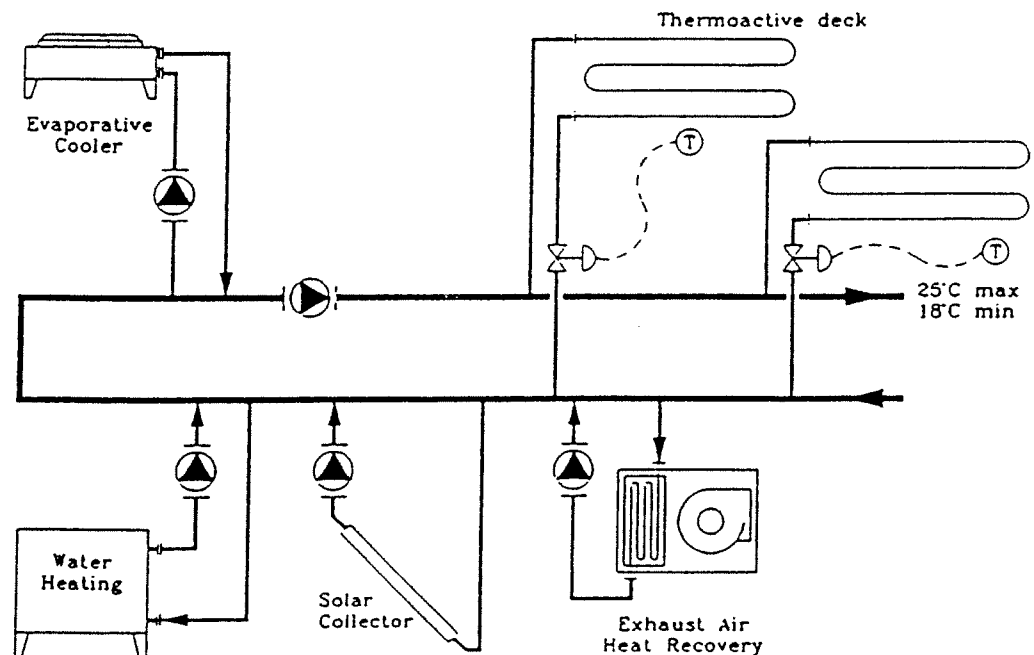
With building heating and cooling being done using water at a temperature of 64°F (18°C) to 77°F (25°C) many changes could be made to the conventional heating and cooling plant, such as:

- the use of evaporative coolers instead of mechanical refrigeration in dry climate areas
- improved refrigeration equipment efficiencies due to the use of "warmer" chilled water
- effective use of solar heat collectors to heat water
- effective use of low grade heat from exhaust air heat recovery

In addition to the ability to provide heating and cooling using water near space temperature the highly efficient envelope and the optimum use of internal heat results in greatly reduced equipment sizes and of course energy demand and consumption.

Figure 6: shows schematically the heating-cooling system.

Figure 6  
Heating and  
Cooling  
System  
Schematic



# BUILDING PERFORMANCE

## Comfort

The holistic BA TISO building provides very good comfort. The space enclosure (walls, windows, floor, ceiling) are very nearly thermally symmetrical all year. There are no "cold drafts" or hot or cold radiant surface to cause unequal occupant heating or cooling. Figures 7 and 8 below show data from recorded temperature taken from the building shown in Figure 1.

Figure 7  
Warm Weather Temperature Profiles

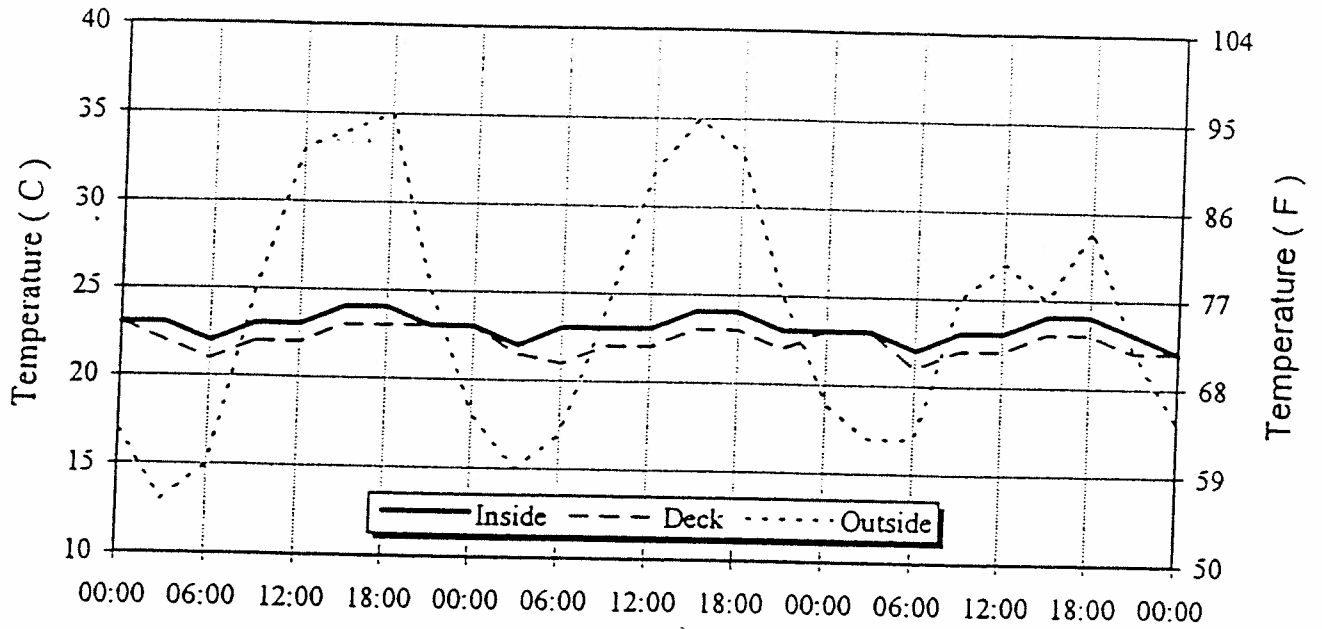
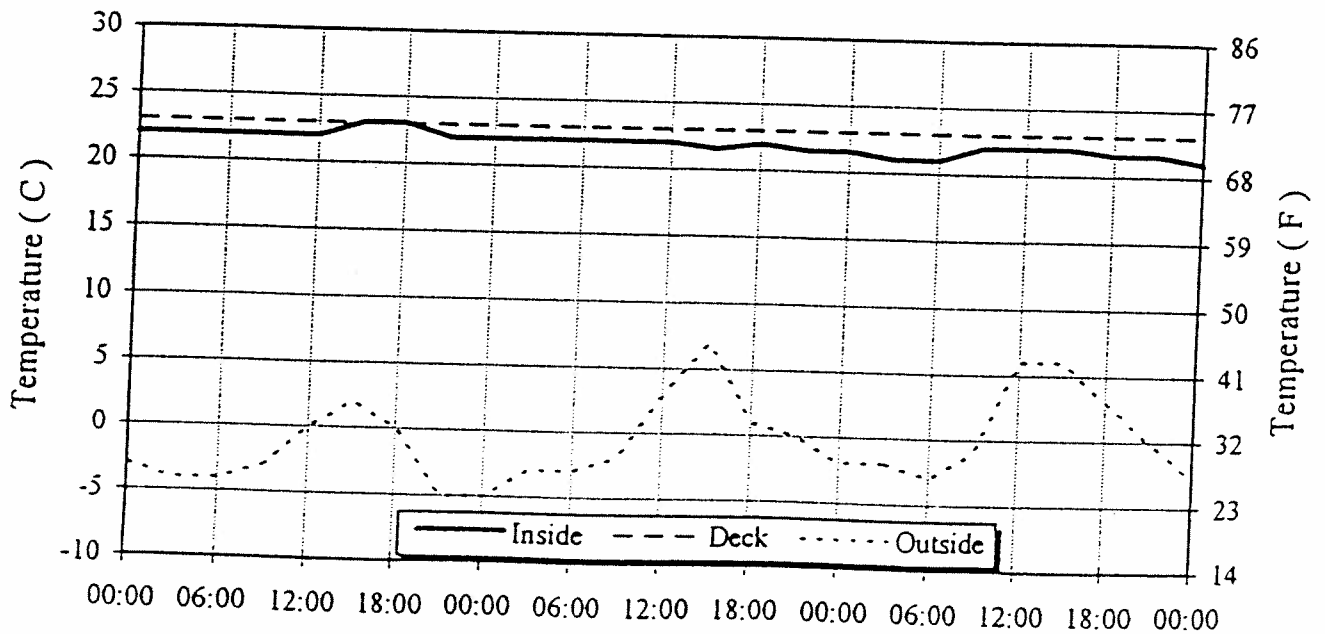


Figure 8  
Cold Weather Temperature Profiles



## Ventilation

The holistic BA TISO building uses a low velocity, low turbulence displacement ventilation system. Much work has been done over the past 10 years on the design, operation and evaluation of displacement ventilation systems (ASHRAE Database). The basic concept of this system is the floor level introduction of a supply of fresh clean air, at or just below, space temperature and the exhaust of the contaminated air near the ceiling — as shown in Figure 1. When properly designed and installed, the system provides superior indoor air quality primarily due to the upward flow of clean air and the displacement of contaminated air from the breathing zone. As nearly all objects in a room (people, computers, lights, etc.) are above normal space temperature, the natural air flow pattern in a room is vertically up. The displacement ventilation system makes optimum use of this natural air flow pattern.

In contrast, the conventional ventilation systems using ceiling supply diffusers and return air grills (openings), is a dilution system which relies on the mixing and dilution of space contaminants to some unknown and hopefully acceptable concentration level. When a dilution ventilation system has to also provide temperature control and the volume of the supply air is varied to regulate temperature, then the ability of the ventilation system to maintain acceptable space hygiene is questionable.

One of the problems associated with the application of displacement ventilation system, particularly in colder climates, is the disruption of the air flow pattern by (down) drafts from cold window surfaces. This problem is eliminated in the BA TISO building by the use of high performance windows that basically eliminate cold weather down drafts. Another problem that is sometimes encountered with displacement ventilation systems is occupant complaints of cold feet and legs. This is caused by a supply air temperature that is too much below room (space) temperature which in turn is usually a result of using the ventilation supply air to provide some, or all, of the space cooling. This problem is eliminated in the BA TISO building as nearly all space sensible cooling is done by the thermoactive deck.

The BA TISO building displacement ventilation system characteristics are:

- 1 to 1.5 air changes per hour
- 100% outside air supply
- low sidewall (baseboard) air supply outlets
- high side wall exhaust
- exhaust air heat recovery
- supply air conditioned to a dry bulb temperature just below space temperature and a wet bulb temperature as required to handle space latent loads.

Considering an average office of 150 ft<sup>2</sup> (13.9m<sup>2</sup>) floor area and a 9 ft (2.7m) ceiling height, then for 1 air change per hour; Q<sub>supply air</sub> = 22.5 cfm (10.6 l/s) and for 1.5 air changes per hour; Q<sub>supply air</sub> = 33.8 cfm (16 l/s).

With one occupant in the space, the required supply air wet bulb temperature to handle the space latent load is about 58°F (14°C) for 1 air change per hour and about 60°F (16°C) for 1.5 air changes per hour. These supply air wet bulbs assume zero wall infiltration which can be very nearly achieved with today's construction. High performance curtain walls with an air infiltration rate of 0.01 cfm/ft<sup>2</sup> @ 030 H<sub>2</sub>O (0.06 m<sup>3</sup>/hr - m<sup>2</sup> @ 75Pa) are a reality today.

## Electrical Systems

The elimination of the conventional (USA and Canada) suspended 'T'-bar ceiling results in changes to both lighting systems and electric power and communication wiring systems.

Lighting systems in the holistic BA TISO building tend to be either direct task lighting or indirect area lighting, or a combination of both. The use of highly efficient windows with good visible light transmission results in improved natural light utilization. To add to the effective utilization of natural outdoor light devices such as external and internal light shelves, are starting to be used on many buildings.

The wiring for electric convenience power and communications is run either in the floor slab (as we used to do many years ago with systems like the "Walker" floor duct), or along the perimeter wall, either separately or integrated with the perimeter baseboard air supply outlet.

## Hygiene

The displacement ventilation system greatly improves space hygiene by effectively removing space contaminants. A continuous supply of 100% outside air purges space generated contaminants. The design of the low-velocity, low-turbulence displacement ventilation system is focused on space hygiene and not temperature control and consequently one function is not compromised to accommodate the other.

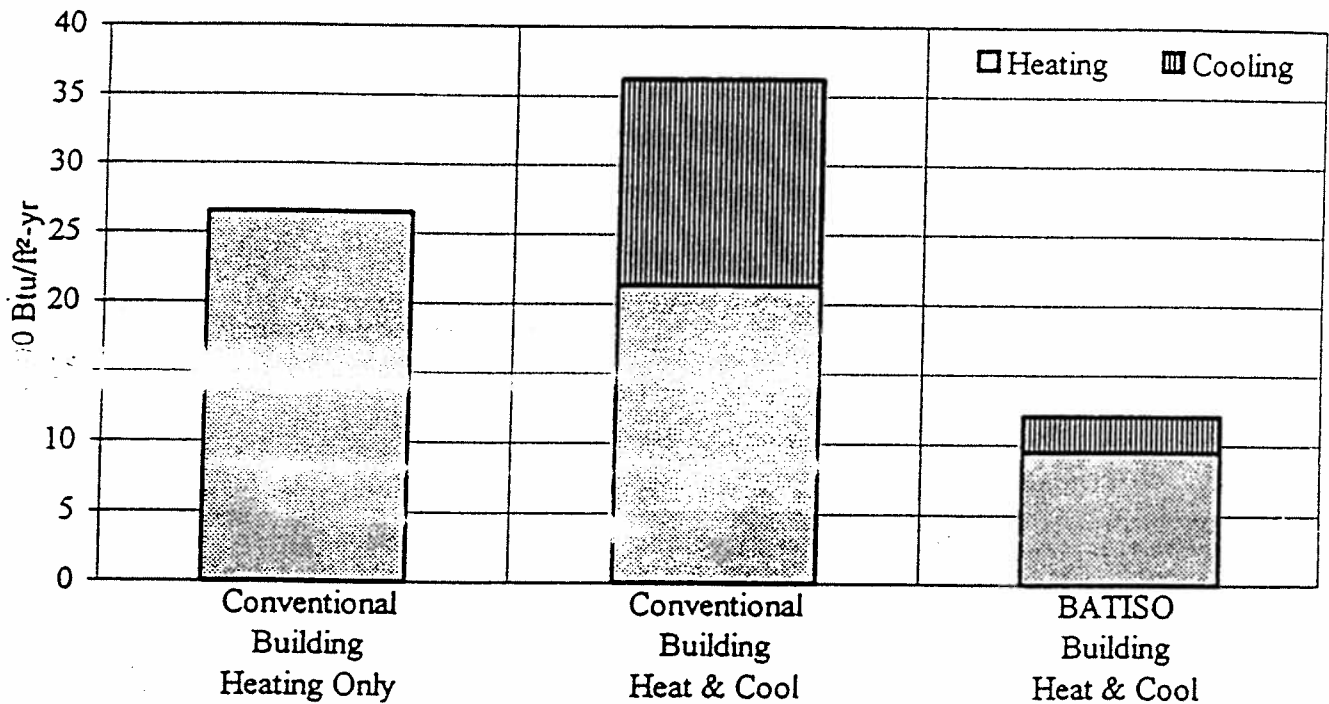
## Energy Use

The holistic BA TISO building is very energy efficient. Figure 9 below shows the estimated energy consumption of the building shown in Figure 1 with three different HVAC systems.

The reduction in energy consumption (and demand) of the BA TISO building is attributable to 3 main systems, namely:

- 1) **Ventilation:** Fan power is greatly reduced. Conventional HVAC system using overhead diffusers supplying cool air for space temperature control usually average 6 to 9 air changes per hour. The displacement ventilation system in the holistic BA TISO building uses only 1/6 of this air quantity. As fan power is a function of air quantity cubed, an 80%(+) reduction in air flow will result in around a 75% to 80% reduction in actual fan (motor) power demand and consumption.
- 2) **Cooling:** the use of evaporative cooling and the ability to "pre charge" the thermoactive deck greatly reduces the energy needed to cool the building.
- 3) **Envelope:** the high performance envelope reduces the building heat gain and loss resulting in smaller heating-cooling systems and reduced operating hours.

Figure 9  
Building Energy Consumption



## Costs

The two main costs associated with any building are first cost and operating cost. In most buildings first cost is paramount. There is always a limited budget for any project. To be "financially" acceptable the holistic BA TISO building cannot cost any more than a conventional building. Limited experience to date indicates that the BA TISO building may actually cost less than a conventional building.

There are three main areas of first cost difference in the BA TISO building namely: structure, envelope and HVAC systems.

**Structure:** the floor structure in the BA TISO building costs more than in a conventional building. It contains more concrete, requires more labour to install and contains an internal insulation layer. It is a 2-pour floor slab.

**Envelope:** the envelope in a BA TISO building may, or may not cost more than in a conventional building. The envelope components, particularly the windows may cost more, however the amount of wall area is about 10% to 12% less due to the fact that the conventional ceiling space is eliminated and thus the floor-to-floor height is reduced.

**HVAC systems:** the HVAC systems in a BA TISO building definitely cost less than those in a conventional building of the same quality. All systems are very much smaller, there are way fewer controls and far less on-site installation work is required.

## Operating Costs

Operating costs are divided into two main categories, maintenance and energy.

In the BA TISO building energy consumption, as shown in Figure 9 is greatly reduced and hence energy costs are greatly reduced.

Maintenance costs in a BA TISO building are also much less than in a conventional building. All components are smaller, thus less costly to service and repair. There are no terminal boxes to maintain, ceiling grilles and diffusers to clean, far fewer controls to maintain and in many cases no refrigeration equipment to service. In addition, the high performance windows eliminate window condensation problems which affect window cleaning and adjacent wall surface staining.

## REFERENCES

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1993 *ASHRAE Handbook of Fundamentals*, Chapter 27, Fenestration

Hutcheon, Neil B. and Handegord, Gustav O.P., *Building Science for a Cold Climate*, Fredericton, New Brunswick, Canada: Construction Technology Centre Atlantic Inc. ISBN 0-9694366-0-2

Part 5, 1995 *National Building Code* of Canada

There are numerous technical papers on Displacement Ventilation, many of which can be accessed via *ASHRAE's Database* of Publications.

## 1. Concept

.1 The term BATISO® is derived from:

BATiment: building or edifice  
ISOtherm: constant temperature

and means constant temperature building.

- .2 Temperature control and ventilation (for hygiene purposes) are separated.
- .3 A highly efficient building envelope almost eliminates the influence of the outdoor environment.
- .4 The building structure, particularly the concrete floor/ceiling, is an integral part of the temperature control system. Maximum advantage is taken of the thermal storage capacity of the building mass.
- .5 Ventilation is provided by a displacement ventilation system to ensure good indoor air quality.