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SYNOPSIS

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Total Environmental Quality: Ensuring Occupant Acceptance

As HVAC systems become more complex, the pressures to meet both the demands of economy and comfort have the potential of creating systems that may overlook one factor in order to meet another. However, to meet the increased expectations of building occupants, it's important to be aware of the conflicts between occupant productivity and system and life cycle costs. Buildings that do not meet the needs of their occupants often result in expensive redesign, or worse, lawsuits. Recent court cases make it imperative that building owners and managers understand the concept of Total Environmental Quality (TEQ).

Total Environmental Quality is the relationship between air distribution, thermal comfort, acoustics and indoor air quality. The inter-relationships of all these factors must be considered both in determining specifications for HVAC design and in maintaining building comfort. In order to understand the relationships between these factors, it is important to be aware of the latest test procedures and requirements for measuring them, as well as standards and guidelines for operating buildings. Recent court decisions illustrate that the acceptable standard of care now extends beyond the building code.

Air Distribution

There are two principal design conditions in HVAC systems. Perimeter zone loads vary over a broad range from heating to cooling and are affected by both exterior and interior factors. In interior zones, the heat generated

Typical 'Executive' Profile

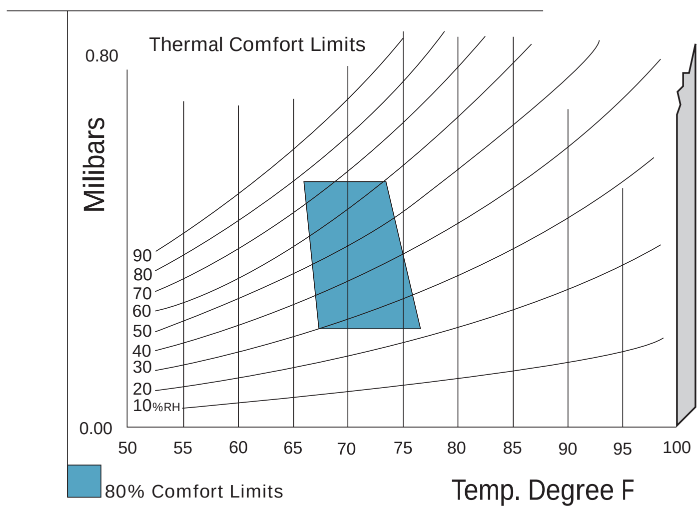


FIGURE 1

by lights, occupants and office machinery provides a continuous year-round cooling demand, regardless of outdoor temperature.

The proper selection of air diffusers is necessary to ensure that both occupant comfort and adequate ventilation are provided. Diffuser selection is critical to avoiding problems with a building's design. Failure to select diffusers with regard to proper design can result in discomfort and concerns over poor indoor air quality.

Diffusers are created with specific performance parameters inherent in each design. These parameters need to be understood and used when selecting the size and type of unit for each situation. The ideal selection is dependent on the type and operation of the air supply to the diffuser, as well as the size of the space. There are many ways of supplying conditioned air to an office space, including displacement ventilation, underfloor vertical air distribution, task cooling, and ceiling supply. The 1997 ASHRAE *Fundamentals Handbook*, Chapter 31, provides recommendations for diffuser selection that have been included in at least one lawsuit as being the "acceptable standard of care."

While diffuser selection is based in part upon a load calculation, it's possible that over time the load will increase and the diffusers will not have the capacity to meet the increased load. This can be caused both by an increase in people and computer equipment in a workspace. If occupants are complaining of either drafts or hot spots, better diffusers may be necessary or your diffusers may need to be adjusted. Adjustable diffusers need to be adjusted! Of course the installing contractor should have performed this initial adjustment, but changes in internal loads and other factors may require a re-adjustment be made periodically. There are very few applications where diffusers should blow air on people. Diffusers are typically designed to blow air along the ceiling. If a diffuser blows air directly down on people, it should be adjusted so that it does not or the air distribution throughout the space will not be as effective. Do not let occupants adjust diffusers to blow on them as a method of comfort control, as this will sabotage air distribution effectiveness. Likewise, occupants have been known to place cardboard and tape over diffusers if cold air is blown directly on them. This results in an imbalance of the air system and may create other problems in adjacent areas. Linear diffusers should only blow down if they are directed at the window glass.

Hot spots and drafts are not caused by the placement of cubicles and other partitions. Given that diffusers have been properly selected, the location of partitions and cubicles is independent of diffuser location.

Don't mistake dirt on the ceiling around your diffusers as a sign that filters need to be changed. Dirt on the ceiling is actually a good thing, a sign that the diffusers are working properly. The dirt is not coming out of the air handler but is actually room dirt that has found its way into the jet of the diffuser as it's emitting air out across the ceiling.

Thermal Comfort

According to the Building Owners and Managers Association, thermal comfort, or lack of it, is the number one reason tenants do not renew a lease. Workers who are not comfortable are also not productive. Too often, building owners and managers place a priority on the economics of system and life cycle costs, rather than on occupant comfort.

A look at comfort economics helps illustrate why adjusting the thermostat actually can cost you more than

it saves. Buildings cost an average of $2 a square foot per year to heat and cool, while their occupants are paid $200 a square foot per year. The ratio of energy cost to productivity is 100/1! Adjusting the thermostat for the sake of economy can't save you more than 5% in energy. Compared with the losses in productivity that may be incurred, there isn't much gain in tangible savings.

While understanding that occupant comfort is important, calculating the predicted comfort level of occupants of buildings served by modern HVAC systems is a complicated process in system design, requiring analysis of up to seven variables. Equations and tables are provided in Chapter 8 of the ASHRAE *Fundamentals Handbook*, and can be computed with readily available computer programs.

Using the ASHRAE computer program, a design engineer can develop realistic and repeatable design limitations for space temperature set points, and determine the effect of changes in the space variables on the building occupants. ISO Standard 7730, ASHRAE Standard 55-1993, and Chapter 8 of the ASHRAE *Fundamentals Handbook* should also be referred to for a better understanding of the comfort parameters, limits and applications.

A locked thermostat sends a bad message. It tells occupants that the owner doesn't trust them and it doesn't allow occupants to adjust the temperature for comfort. Employees will create their own comfort, if necessary, with fans and space heaters. Fans and space heaters increase costs in two ways, both in electricity and the air conditioning required to eliminate the extra heat. In an ideal situation, the building owner/manager needs to have a dialogue with the people using the building so that they can get feedback on the comfort needs of the occupants and can provide information about the optimal settings for the thermostat for the system to work properly.

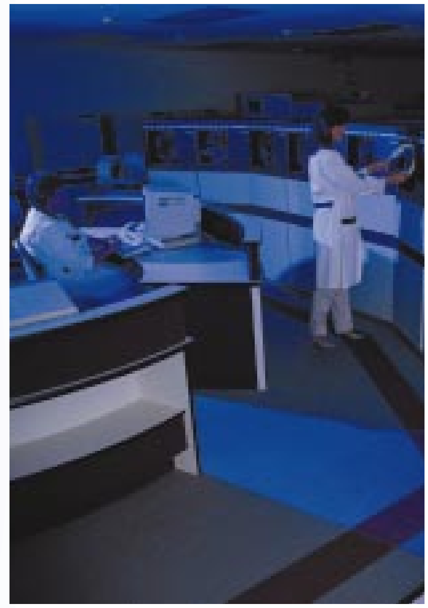
Communication is sometimes the most important ingredient in providing thermal comfort to a group of people, all of whom may have different body temperatures, levels of physical activity in their work, and differences in the way they dress. It may not be possible for the HVAC system to satisfy the comfort of all employees; some employees may have to modify their level of activity or their clothing.

The graph on page 2 shows that a set point greater than 76°F will result in significant discomfort and should be avoided. In fact, under most conditions, a set point of 73°F will satisfy the most people (Figure 1).

Acoustics

According to ASHRAE, acoustical quality is defined as not too quiet, not too loud, not too annoying and not felt. Building owners or engineers often specify the level of sound. When specified at too low a level, unnecessary expense may be incurred. When specified too high, acoustical discomfort may result. Acceptable background sound levels may depend on the occupant. For instance, a CEO in a private office may require a lower sound level than that of an open area with cubicles.

Sound levels inside buildings are measured in terms of Noise Criteria (NC) values. The higher the NC number, the higher the sound level. The most commonly specified sound level is NC=35, which is actually near the threshold of hearing in most offices, as background sound levels often approach or exceed NC=35. This specification is seldom met or required. Unnecessary expense may result from trying to meet this specification with no gain in occupant comfort. As a matter of fact, a little noise is a good thing. When it's too quiet, productivity



decreases because employees are distracted by the sounds of each other.

ASHRAE suggests a level of NC=35 – 40 for offices, a better requirement since NC levels lower than 40 are seldom objectionable. A constant sound level is less objectionable than a varying sound level and a higher noise level may also save energy.

As mentioned previously, background noise levels in many offices are often quite a bit higher than NC=35. Many open offices have background sound masking, where a "white noise" is introduced to mask conversations between cubicles. These systems are often set to an NC=41 – 43. An open office environment is seldom acoustically effective without background masking.

Requiring too low a level of sound from variable air volume (VAV) components may be unnecessarily expensive. To reduce sound levels, discharge attenuators and oversized units may be employed at the expense of both first costs and operating expenses.

Indoor Air Quality

Indoor air quality (IAQ) is of great concern in modern airtight buildings. VAV systems, when properly designed, provide ventilation proportional to occupancy in interior zones. Different strategies are employed to provide perimeter zone ventilation, including the use of fan terminals or under-window air induction units.

The ASHRAE IAQ Standard on Ventilation for Acceptable Indoor Air Quality, which is part of the building code in most areas, is continuously being updated. The current standard is 62-1999. Acceptable indoor air quality is the result of careful attention to contaminant source control, proper ventilation, humidity management, and adequate filtration in design, construction and maintenance of the HVAC system. Commonly, IAQ complaints are the result of poor maintenance of a building's systems rather than due to poor design.

What occurs in many cases is that a higher than acceptable temperature set point will result in complaints of building "stuffiness." The human body cannot always differentiate between slight thermal discomfort and actual air quality problems. In fact, people cannot actually detect most poor air quality conditions. Space temperatures above 75°F should be expected to result in some complaints of stuffiness.

Complaints by tenants of poor IAQ should always be taken seriously. Litigation cases have set a precedent whereby owners/operators of buildings may be held liable for negligence if IAQ problems are not corrected. When complaints of poor air quality are received, the space temperature should be the first measurement taken. On the other hand, true air quality problems come from one of three sources:

1. Outside air dampers have failed, or been closed to save energy. Either can result in poor indoor air quality.
2. Indoor air pollutants overcome ventilation rates. New carpeting, new construction or retrofit, new furniture and office equipment can outgas pollutants at a greater rate than the ventilation system mixing can remove them.
3. Outside air may be polluted or contaminated. Wind can blow exhaust air into fresh air intakes and ambient air quality may be poor due to smog, inversion layers, etc. Poor building filter maintenance can also contribute to air quality problems and have a detrimental effect on HVAC system operation. A proposal in front of the ASHRAE Standard 62-1999 committee will require that outside air must meet federal standards or it will have to be filtered or scrubbed to meet requirements.

There are several ventilation control strategies for maintaining optimum indoor air quality, including ventilation reset, scheduled ventilation, outdoor airflow measurement and control, and building pressure control. A recent development is the use of carbon-dioxide (CO_2)-based demand-controlled ventilation (DCV). The use of CO_2 sensors can reduce outside air based on actual sensed occupancy. Don't confuse CO_2 with CO (carbon-monoxide). CO_2 is not a pollutant. People create CO_2 when they breathe, so by placing CO_2 sensors inside various areas of the building we can accurately measure how many people are in each area, and most importantly we can measure when people enter or leave an area because the CO_2 levels will change accordingly. This allows us to reduce the amount of outdoor air that we have to introduce into the building, thereby saving energy. CO_2 is measured as a surrogate for occupancy odor control. Indoor CO_2 levels above 2,000 parts-per-million (ppm) are not harmful. The average level of CO_2 in outdoor air is about 350 ppm. Therefore, when indoor CO_2 levels are at or below 700 ppm above outside levels, this indicates compliance to ASHRAE 62-1999.

Demand controlled ventilation (DCV) offers a significant advantage over constant ventilation. Using CO_2 sensors, a zone's occupancy can be precisely monitored and adequate ventilation provided for each changing condition. This dynamic, flexible response eliminates over-ventilation and its accompanying problems, and results in significant cost savings.

Conclusion

Air distribution, thermal comfort, acoustics, and indoor air quality are all closely inter-related. An understanding of all these factors is required in providing an acceptable environment to building occupants. It's a challenge for building owners and managers to listen to occupant complaints and translate what's being described to what's really happening in the facility.

It's important to fix the right thing. Recent litigation on IAQ issues has shown that building HVAC systems may fall under Federal and local product liability statutes, requiring building owners to meet the guidelines of good practice in addition to specific building codes. ASHRAE and ARI specifications are a part of the expected professional background used by designers and operators, and should be followed even if not in the actual building codes.

It's in the best interests of all building owners to provide Total Environmental Quality for the occupants or those who want to ensure the greatest productivity from employees, and from rental owners, who want to avoid litigation and maintain tenancy in their buildings.

Total Environmental Quality doesn't negate economy. A system with proper air distribution, comfort, acoustics and good IAQ can be enhanced with a demand controlled ventilation system, a strategy that can significantly reduce energy costs.