

ENHANCING PERFORMANCE CONTRACTS: INTEGRATING IAQ SOLUTIONS IN HOT & HUMID CLIMATES

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ABSTRACT

IAQ and performance contracting intersect in several ways. Improper execution of energy-related building projects may have a deleterious effect on IAQ. Careful execution may enhance IAQ. Economic benefits deriving from energy improvements may be forfeited if the improvements are abandoned due to IAQ complaints. While some IAQ requirements may conflict with energy performance goals, reexamining relationships between energy and IAQ demonstrates that there are opportunities to improve building performance with respect to both factors simultaneously.

Topics addressed as these opportunities are explored include: standards, the basic roles of HVAC in IAQ, HVAC-related IAQ improvements, and common energy conservation measures and IAQ. Aspects of IAQ are examined that, when incorporated into energy services companies' performance contracting work, can enhance their value. These enhancements can deliver performance benefits to building owners and operators beyond energy savings. When incorporated into performance contract offerings, these enhancements can add value to an energy service company's qualifications and proposals. This translation of IAQ insight into market advantage is a significant opportunity for energy service companies in an increasingly competitive marketplace.

STANDARDS

Building codes typically establish required minimums for ventilation and some other IAQ-related elements of performance contracts. In addition, widely accepted industry standards are often referenced in building codes, and become part of a building owner or operator's reasonable expectations in a performance contract. As a result, in any energy services project, there is a "standard of care" for IAQ. This standard of care determines the level of performance with respect to IAQ that the energy services company

(ESCO) and the building owner or operator is expecting from the project.

When no standard of care for a project is declared, the owner or the ESCO may be accepting the absence of any minimum performance expectations with respect to IAQ. More often, these expectations exist but are undeclared. Establishing a clearer basis for expectations regarding IAQ performance can clarify project acceptance criteria, and can avoid unanticipated changes in IAQ due to performance contract work. Establishing a clearer basis for expectations regarding IAQ performance can also clarify remedial work that the building owner may seek to be rolled in to a performance contract, and help establish an appropriate financial basis for accomplishing that work.

Often, establishing a clearer basis for performance expectations with respect to IAQ is complicated by the age of a facility or the capacity of its existing heating, ventilating, and air conditioning (HVAC) systems. Buildings of different ages, or even parts of the same building built or renovated at different times, may require substantial modification to HVAC systems to comply with current building codes and ventilation standards.

Ventilation rates have varied in different revisions of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62-1989 "Ventilation for Acceptable Indoor Air Quality." Rates from the 1973 version may still be in use in seventies buildings. The lower rates adopted in the wake of the "energy crisis" in the 1981 version of the standard may still be found in eighties buildings. The current rates are found only in the relatively small percentage of buildings that have been built or upgraded to current codes or standards since 1989. Regardless of the applicable code or the retention of "grandfathered" compliance with an earlier code or standard, the current version of the ventilation standard, ANSI/ASHRAE 62-

1989 has been established as the cornerstone of a standard of care in IAQ-related litigation.

Selecting a standard of care for use in reviewing the performance of an existing HVAC system can be complex. Often, buildings built under earlier standards may be incapable of delivering the rates called for under ANSI/ASHRAE Standard 62-1989 without losing control of temperature and humidity in the building. In such cases, the owner may agree to continue the use of original design ventilation rates, but may seek to comply with the remaining provisions of ANSI/ASHRAE Standard 62-1989, the most current version of the prevalent standard dealing with ventilation for acceptable IAQ. In some buildings, compliance with ANSI/ASHRAE Standard 62-1989 under such circumstances has been established using the IAQ Procedure of the standard, instead of the more commonly applied Ventilation Rate Procedure.

Three common complications with respect to determining appropriate ventilation rates are:

- The need to consider the standard of care and resultant ventilation rate capacity in effect at the time the building was built or substantially renovated
- The existence of different standards of care and resultant ventilation rate capacity, sometimes within the same facility
- The de facto creation of a new standard of care through the implementation of energy conservation measures

Through careful consultation with performance contracting clients, and careful explication of the standards of care that are to be applicable on a specific project, the varying standards of care associated with the age and use of existing buildings can be managed. Declaration of the agreed basis in standards and codes for project work can clarify expectations and help demonstrate acceptable completion of project work.

THE BASIC ROLES OF HVAC

HVAC systems primary roles in serving occupants include:

- Thermal comfort and control
- Dilution ventilation

- Filtration and air cleaning
- Control of directional airflow and local exhaust

HVAC system control affects all of these roles. ESCO projects often include HVAC control work. The primary purpose of HVAC design has traditionally been providing heating and cooling for comfort. The “V” part, ventilation, has traditionally been included for dilution of odors and protection against airborne disease. Figure 1 highlights some of the ways that HVAC systems can influence IAQ.

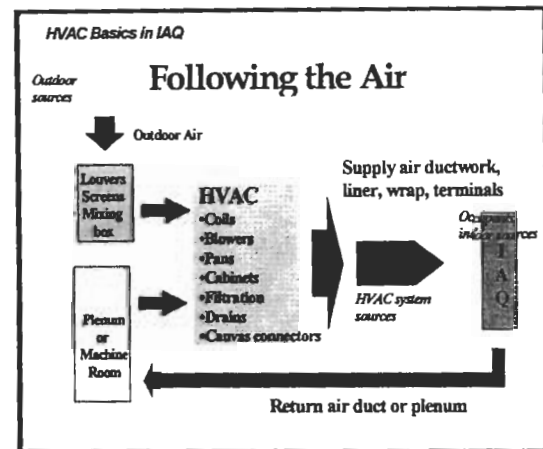


Figure 1. HVAC Basics in IAQ (From ENVIRONMENT®, Fundamentals of IAQ)

THE BASIC ROLES OF HVAC (Cont'd)

When outdoor air and return air both contain problematic concentrations of constituents, the HVAC system is the last line of defense. But the HVAC system itself can become a source of problematic constituents. Dirty cooling coils and dirty, wet drain pans are significant potential sources of bioaerosols. They offer a source of food and moisture for the growth of bacteria and fungus. Their location in the air stream makes them effective distributors of viable organisms and spore.

Local exhaust or “plug flow” ventilation provide for control of indoor sources of many airborne constituents. Effective exhaust ventilation requires sufficient make-up air to prevent effects such as “puffing” and “pooling” of the materials to be exhausted. These conditions occur frequently in poorly ventilated restaurants.

Thermal Comfort

ANSI/ASHRAE Standard 55-1992 establishes indoor thermal conditions for occupant comfort. It is not incorporated by reference in most building codes, in the way that ANSI/ASHRAE Standard 62-1989 is. In some projects, it may *not* be chosen as the standard of care by other guidance as agreed between the ESCO and the building owner or operator. In most projects, however, ASHRAE Standard 55-1992 will serve as the basis for conditions in occupied spaces. The standard stipulates that, in summer, the optimum operative temperature is from 73 to 79 degrees F. In winter, the stipulated optimum operative temperature range is from 68 to 75 degrees F.

Operative temperature is the average of the air temperature and the mean radiant temperature. Operative temperature does NOT factor in relative humidity. Humidity and local air velocity are also factors in thermal comfort, as are clothing levels and occupant activity parameters including metabolic rate. Dry bulb temperature, humidity, air movement, occupant activity levels, and clothing all profoundly affect comfort. Temperature ramping speeds – the speed with which temperatures change, even though they may remain within the optimum range – also affect occupant comfort. Careful attention to capacity and control with respect to these parameters can improve occupants' thermal comfort, and may improve occupants' overall perception of indoor environmental quality.

Outdoor Air Intake

The basics of outdoor air intake include:

- Providing adequate outdoor air intake on a per person basis
- Never resetting outdoor air below the exhaust air flow rate
- Preventing infiltration during unoccupied periods
- Meeting the lead or lag time provisions of ANSI/ASHRAE Standard 62-1989, where applicable
- Avoiding poor control from non-linear air flow response from dampers
- Addressing failure or improper adjustment of damper actuators, linkages, and blades

Outdoor air dampers sometimes fail, but more often they are disabled during extreme weather and never repaired. Linkages must be in place, blades must move smoothly through their pattern, and damper actuators must function properly. Minimum settings, control range, and control parameters should not be taken for granted when performing HVAC related work in a building.

Possible sources of contamination nearby may require special response. A walk around the exterior of the building, starting from the roof, can help in identifying potential outdoor air quality problems that may impact IAQ, such as dumpsters, water towers, and loading docks. Wind direction is important, as is the distance of potential problems from the nearest outdoor air intake. Information on prevailing wind conditions may be available from a nearby airport. Where transient outdoor air problems exist with constituents that are not readily filtered, such as carbon monoxide, ANSI/ASHRAE Standard 62-1989 allows temporary reduction in outdoor air intake.

Atmospheric conditions may lead to increased ambient conditions of industrial emissions at night, adding another concern. Lower wind speeds lead to lower outdoor dilution rates and "pools" of contaminants which may drift into a building's outdoor air intake.

Filtration

It is important to optimize air cleaning for every job. Particulate filters should be specified using average ASHRAE Standard 52.1 dust spot ratings for media filters (or MERV ratings under ASHRAE Standard 52.2 when it is finalized). When specifying filtration, pressure drop and racks must be suited to needs. In maintaining energy improvements or handing over completed performance contract projects to building owners and operators, it is important to promote awareness of proper change-out, and educate customers on how better filtration saves energy and improves IAQ.

Table 1. Average ASHRAE Dust Spot Efficiency Ratings

Filter Type	Rating
1" panel or trimmable	< 20%
2" extended surface	up to 40%
High performance 2"	up to 60%
Mini-pleat	up to 80%
Bag and cartridge filters	up to 95%
HEPA & ULPA	up to 99.997%

Filtration is an often overlooked element of an IAQ management program. Filtration levels in many areas are often minimal, with 10% to 30% efficient filters the norm. Filtration at these levels does not effectively protect coils and ducts from dirt buildup, and has no significant benefit for occupants.

Optimal filtration for protection of equipment is greater than 60% dust-spot efficiency. Benefits of higher filtration levels continue to increase up to 90% or better efficiency. Reduced coil and duct cleaning and lower facility housekeeping costs add together with the energy benefits of clean coils and fan blades to achieve a significant payback on high levels of filtration.

A new filtration rating standard is under preparation by ASHRAE that will assign Minimum Efficiency Reporting Values (MERV) from 1 to 16 for conventional filters, and from 17 to 20 for very high efficiency filters. The higher the rating, the better the filter.

Air Pressure Concepts

In order to maintain proper building pressurization, a reasonable tight building envelope with effective air barriers or retarders is a prerequisite. Oversupply creates positive pressure; under-supply creates negative pressure. Within building zones or spaces, directional airflow should be maintained from areas with lower concentrations of constituents of concern or fewer sources, to direct airflow towards areas with higher concentrations of constituents of concern or more sources. Building dynamics can affect directional airflow, including such mechanisms as wind direction and strength, stack effect, relative temperatures from zone to zone, VAV operation, opening of doors, and movement of occupants.

Test, adjust, and balance (TAB) is a very specialized business. TAB practitioners use flow

hoods, velometers, and other measurement means to determine airflow, direction, and balance. TAB procedures rarely call for careful evaluation of pressure relationships.

Air balance often is set when a system is built and started up for the first time, then left alone. Many factors contribute to air balance problems, including changes in use, aging of equipment, poor maintenance, seasonal changes, and even major weather changes. Because air balance is critical to moisture control and IAQ management, it should be verified upon completion of HVAC related performance contract work.

HVAC-RELATED IAQ IMPROVEMENTS

Common HVAC energy conservation measures (ECMs) include reduced air flow or ventilation rate, economizers, energy recovery ventilation (ERV), variable air volume (VAV) retrofit, and CO₂-based demand controlled ventilation. Proper design of any type of HVAC system, including constant volume reheat, dual duct, variable air volume, or induction, can provide both energy efficiency and good IAQ. Poor design or operation, or careless modification can lead to a sacrifice of one or both.

Air Test, Adjust, and Balance

Reduced air supply or re-balancing air supply systems represents an opportunity to optimize both energy use and IAQ. A complete Test, Adjust, and Balance (TAB) project can result in improved comfort and correction of outdoor air supply and ventilation effectiveness problems. Projects including TAB work must be managed carefully. Flexibility for future increases in occupant density, or additional process equipment, should be retained. Frequently, air supply reduction is done without a complete TAB project as an energy saving measure. This practice can lead to many problems. For example, diffuser throw patterns may be affected by lower air velocities, resulting in poor ventilation effectiveness. Outdoor air minimum settings may also require adjustment if fans are slowed to reduce airflows. Planning for TAB projects for energy conservation purposes must also take into account the variations in occupancy levels and activities in each space. Major changes require updating of airflow requirements based on occupant and thermal considerations.

Economizers

The upside of economizers, in addition to energy savings, is added outdoor air capability, which can permit occasional "flushing" of a building. Economizers have significant downside in hot and humid climates, and have limited applicability along the Gulf Coast. Humidity control problems are abundant, since cool air at dawn or dusk may be near saturated, and sensible loads may be so low that system sensible heat ratio is inadequate to remove moisture from outdoor air intake. High relative humidity in economizer air can lead to humidity build-up in the occupied space and HVAC system, and may lead to condensation. Active moisture control, such as energy recovery ventilation, heat pipes, or face and bypass, can help. Economizers also have the potential to introduce outdoor constituents of concern other than moisture. Outdoor air quality is a critical factor in the success of economizer operations. These conditions often lead to biological contamination. Some economizer cycles are designed with low or zero minimum outdoor air intake settings. Outdoor air intakes should always be set to acceptable minimums.

Energy Recovery Ventilation

ERV has tremendous potential, both for energy savings and for improving IAQ. The upside of ERV includes adequate outdoor air, and improved humidity control when the ERV selected provides enthalpy exchange. The downsides include cross-contamination potential, and loss of humidity control with sensible only exchange. Cost effectiveness is a big issue for selecting appropriate ERV applications. Hours of operation need to be sufficient to generate value. The greatest value typically occurs at temperature extremes. Recovery and outdoor air intake ducts must be close enough to make installation practical. Large air flows require large wheels, and wheel geometry dictates limited equipment configurations. Aggressive maintenance is required to sustain performance.

Variable Air Volume

The upside of VAV retrofits is the potential for energy savings, and the capability to match ventilation to load. The downside of traditional applications are that airflows follow sensible thermal load. This can make it hard to maintain humidity control, ventilation rates, and ventilation effectiveness. Variable Air Volume (VAV) HVAC systems use either inlet damper

control or variable frequency drives (VFD) to match the amount of supply air to the temperature demands of the space. These systems can be highly effective in achieving improved energy efficiency and IAQ. But great care is required on the IAQ side of the equation. For VAV systems, ANSI/ASHRAE Standard 62-1989 requires critical zone calculations to ensure that each zone receives adequate ventilation air despite variations in zone airflow rates. Zone minimum air flows in VAV systems are critical to maintaining design ventilation rates with varying thermal loads. VAV systems use terminal boxes of varying designs. Poor diffuser design or selection can cause "dumping" of cool air at low velocities. Boxes with "zero-flow" minimum settings cannot provide acceptable outdoor air ventilation in occupied space when the thermostat or zone is "satisfied." With these designs, even a properly operating box is no guarantee of acceptable IAQ.

Demand Controlled Ventilation

Outdoor air intake can be adjusted in response to occupancy using CO₂-based demand controlled ventilation (DCV), as provided in ANSI/ASHRAE Standard 62-1989 and a recent interpretation of the standard that clarifies the role of CO₂-based DCV. Many HVAC systems, including VAV systems and constant volume systems capable of economizer operations, are potential candidates for DCV applications. The best applications for this technology are ones with variable occupancy levels, such as auditoriums. In these settings, ventilation is supplied as occupancy increases, optimizing the balance between energy efficiency and IAQ. Setting the correct value for control of the system based on a carbon dioxide sensor requires thorough study of comparative levels of CO₂ in the occupied space, at the sensor location, and outdoors to achieve the desired balance between energy savings and IAQ.

VENTILATION COMPARISON

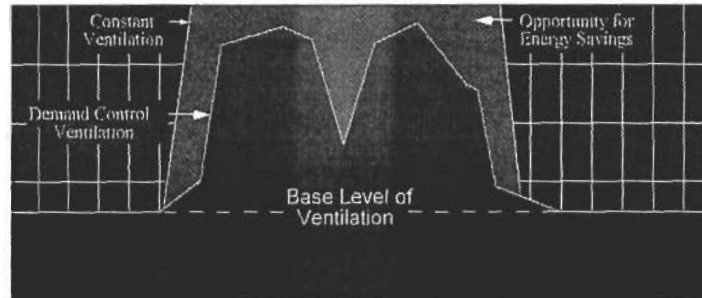


Figure 2. CO₂ Based DCV Savings

Air-side Controls

Temperature control is essential to maintaining projected energy savings, as well as providing occupant comfort. System setpoints often rely solely on dry bulb temperature, meaning that humidity control is assumed to be achieved indirectly. When system sensible heat ratio does not correspond to load sensible heat ratio, humidity control may be lost.

Blower fan cycling controls on simpler systems may also affect humidity control. If Fan switching sub-bases are set to "On," blowers will run continuously, re-evaporating condensate before it drains from coils and pans. If Fan switching sub-bases are set to "Auto," intermittent outdoor air will be provided. In such cases, outdoor air intake controls may have to be adjusted to provide more outdoor air intake so that average design ventilation rates are provided over time.

Alarms/Datalogging Capabilities

With building automation systems, alarms and levels can be defined to assist in maintaining IAQ, including temperature, humidity, CO₂, VOCs, outdoor airflow, and filter pressure drop. Datalogging and trend logs can provide historical information for baseline values, and can reveal time-dependent patterns of decreased control.

Special DDC Strategies for IAQ Control

DCV systems can be controlled to other parameters separately or in conjunction with CO₂-based demand controlled ventilation. Volatile Organic Compound sensors, while not

permitted as the sole basis for demand controlled ventilation strategies under ANSI/ASHRAE Standard 62-1989, can be used in some specific applications to help match outdoor air intake to ventilation requirements. Humidity control can be implemented utilizing DDC capabilities, where appropriate sensors and active dehumidification capability exists. Pre-occupancy purge cycles are readily implemented with DDC, and can help optimize start-up not only with respect to temperature, but with respect to ventilation requirements. Outdoor air intake verification and control, as well as coordinated exhaust control, can help match outdoor air intake to needs while maintaining building pressurization. Occupancy sensors can be used to control local exhaust systems or to automatically switch individual zones into unoccupied mode based on actual conditions, rather than predictions of occupied times.

SOME COMMON ENERGY CONSERVATION MEASURES AND IAQ

Lighting and IAQ

The upside of lighting retrofits is reduced electric and thermal load. When properly implemented, they may increase occupant satisfaction. Most lighting management programs provide equivalent light levels, and sometimes improve the quality of light.

If lighting levels are decreased, or color rendition is ignored, lighting changes can lead to a decrease in perceived indoor environmental quality. The downside of lighting retrofits with

respect to IAQ, particularly in hot and humid climates, is that they may result in a mismatch between the thermal load and the HVAC system's sensible heat ratio, and loss of humidity control. VAV systems which are not set with proper minimum supply damper settings, or do not include other specific provisions for minimum outdoor air flows, may see increased periods when, as a result of lower thermal load from lighting, they deliver less than the minimum required outdoor air to the space. Lowered thermal loads may, with VAV systems, increase low flow operation and associated "dumping" problems. Dumping occurs at low flow rates, when supply air is not delivered with adequate velocity to throw properly into the space.

Reduction of electrical energy consumption, and the resulting cost savings provide the motivation for the effort. These tend to reduce the overall thermal load of the building, which further reduces cooling demands. This may yield comfort improvements in some buildings, which helps improve perception of good indoor environmental quality.

Tight Buildings and IAQ

Tight buildings control the leakage of air and thermal energy through the building skin and other points of interaction with the environment. In a tight building, the supply and exhaust of air to the space defines the entirety of available ventilation. Provision of adequate minimum outdoor air must be maintained for tight designs, since infiltration can't compensate for HVAC system problems. For VAV systems this may require specialized controls or a fixed volume outdoor air intake fan.

Improvement of building envelope can make a significant contribution to a performance contract, particularly if resulting load reductions can be incorporated into HVAC retrofits. Proper caulking and weather-stripping combine with good design, selection of good materials, and proper construction practices to achieve "tight" construction. The elimination of uncontrolled airflow can yield substantial energy savings, and can improve IAQ and control of humidity or condensation substantially.

CONCLUSIONS

IAQ and performance contracting are related in many ways. While some IAQ requirements may conflict with energy performance goals,

reexamining relationships between energy and IAQ has demonstrated that there are opportunities to improve building performance with respect to both factors simultaneously. This translation of IAQ insight into market advantage is a significant opportunity for energy service companies in an increasingly competitive marketplace. Building owners and operators can benefit from addressing IAQ issues while procuring performance contracting services.

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