Indoor Air Quality Guide

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Indoor Air Quality Guide

Best Practices for Design, Construction, and Commissioning

American Society of Heating, Refrigerating and Air-Conditioning Engineers
The American Institute of Architects
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Detailed Information for Design, Construction, and Commissioning for IAQ

Detailed guidance for each Strategy is available on the CD accompanying this book.

Acknowledgments

The *Indoor Air Quality Guide* provides a long-needed resource to the building community. The project committee (PC) members who wrote the Guide worked extremely hard to pull together practical, technically sound information covering the full range of indoor air quality (IAQ) issues important to practitioners. The authors brought to this project many years of experience in design, construction, commissioning (Cx), forensic IAQ investigation, research, and facilities management. They met 14 times in 20 months and held numerous conference calls. Between meetings, they critically reviewed and digested IAQ research and practical experience, reviewed each others' drafts, solicited input from expert colleagues, weighed reviewer input, and worked very hard to make the information accessible and useful for designers, contractors, architects, owners, operators, and others. In collaboration with ASHRAE's Chapter Technology Transfer Committee, they also developed and presented a satellite broadcast/webcast based on the Guide in April 2009. We want to extend our personal thanks and appreciation to this group for the extraordinary effort they poured into this Guide and for the passion they displayed for providing quality indoor environments for building occupants.

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Martha J. Hewett
Chair, Special Project 200

Andrew Persily
Chair, IAQ Guide Steering Committee

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Abbreviations and Acronyms

AABC	=	Associated Air Balance Council
AAMA	=	American Architectural Manufacturers Association
ACGIH	=	American Conference of Governmental Industrial Hygienists
ADC	=	Air Diffusion Council
AHAM	=	American Home Appliance Manufacturers
AHU	=	air-handling unit
AIA	=	American Institute of Architects
AIHA	=	American Industrial Hygiene Association
AMCA	=	Air Movement and Control Association
ANSI	=	American National Standards Institute
AQS	=	Air Quality Sciences, Inc.
ASD	=	active soil depressurization
ASHE	=	American Society of Hospital Engineers
ASHRAE	=	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	=	ASTM International (formerly the American Society for Testing and Materials)
BIFMA	=	Business and Institutional Furniture Manufacturer's Association
BoD	=	Basis of Design
BOMA	=	Building Owners and Managers Association International
CARB	=	California Air Resources Board
CDC	=	Centers for Disease Control and Prevention
CDHS	=	California Department of Health Services
CEC	=	California Energy Commission
CHPS	=	Collaborative for High Performance Schools
CO	=	carbon monoxide
CO_2	=	carbon dioxide
CoC	=	contaminants of concern
CREL	=	Chronic Reference Exposure Level
CV	=	constant volume
Cx	=	commissioning
CxA	=	commissioning authority
DCV	=	demand-controlled ventilation
DDDF	=	dual duct dual fan
DOAS	=	dedicated outdoor air system
DOE	=	U.S. Department of Energy
DX	=	direct expansion
EDR	=	Energy Design Resources
EPA	=	U.S. Environmental Protection Agency
ERV	=	energy recovery ventilator
EU	=	European Union
FAC	=	filtration and gas-phase air cleaning
FEMA	=	Federal Emergency Management Agency
HE	=	high efficiency
HEPA	=	high-efficiency particulate air
HVAC	=	heating, ventilating, and air conditioning
IAQ	=	indoor air quality
IAQP	=	IAQ Procedure
IEQ	=	indoor environmental quality
IEST	=	Institute of Environmental Sciences and Technologies
IPCC	=	Intergovernmental Panel on Climate Change
ITRC	=	Interstate Technology & Regulatory Council

JCAHO	=	Joint Commission on Accreditation of Healthcare Organizations
MDF	=	medium density fibreboard
ME	=	medium efficiency
MERV	=	Minimum Efficiency Reporting Value
NAAQS	=	National Ambient Air Quality Standards
NAIMA	=	North America Insulation Manufacturers Association
NASA	=	National Aeronautics and Space Administration
NCARB	=	National Council of Architectural Registration Boards
NEBB	=	National Environmental Balancing Bureau
NEHA NRPP	=	National Environmental Health Association National Radon Proficiency Program
NFPA	=	National Fire Protection Association
NFRC	=	National Fenestration Rating Council
NIBS	=	National Institute of Building Sciences
NIH	=	National Institutes of Health
NIOSH	=	National Institute of Occupational Safety and Health
NO_2	=	nitrogen dioxide
NO_x	=	nitrogen oxides
NRCan	=	Natural Resources Canada
NRC-IRC	=	National Research Council Canada Institute for Research in Construction
NRSB	=	National Radon Safety Board
O&M	=	operation and maintenance
OPR	=	Owner's Project Requirements
OSB	=	oriented strand board
OSHA	=	Occupational Safety and Health Administration
OTA	=	U.S. Congress Office of Technology Assessment
PM10	=	particulate matter with a diameter of 10 µm or less
PM2.5	=	particulate matter with a diameter of 2.5 µm or less
PVC	=	polyvinyl chloride
QA	=	quality assurance
RH	=	relative humidity
RTU	=	rooftop unit
SMACNA	=	Sheet Metal and Air Conditioning Contractors' National Association
SO_2	=	sulfur dioxide
SVOC	=	semi-volatile organic compound
TAB	=	testing, adjusting, and balancing
TABB	=	Testing, Adjusting, and Balancing Bureau
TLV	=	threshold limit value
TVOC	=	total volatile organic compound
TWA	=	time-weighted average
UL	=	Underwriters Laboratories
USGBC	=	U.S. Green Building Council
UVGI	=	ultraviolet germicidal irradiation
VAV	=	variable-air-volume
VFD	=	variable-frequency drive
VOC	=	volatile organic compound
VRP	=	Ventilation Rate Procedure
WHO	=	World Health Organization

Foreword: Why this Guide Was Written

Buildings are expected to fulfill a variety of requirements related to their function, applicable codes and standards, and environmental and community impacts. Among these requirements, indoor air quality (IAQ) is typically addressed through compliance with only minimum code requirements, which are based on industry consensus standards such as *ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality* (ASHRAE 2007a). Yet IAQ affects occupant health, comfort, and productivity, and in some cases even building usability, all of which can have significant economic impacts for building owners and occupants.

While building owners and building professionals may recognize the importance of IAQ, they often do not appreciate how routine design and construction decisions can result in IAQ problems. In addition, they may assume that achieving a high level of IAQ is associated with premium costs and novel or even risky technical solutions. In other cases, they may employ individual measures thought to provide good IAQ, such as increased outdoor air ventilation rates or specification of lower emitting materials, without a sound understanding of the project-specific impacts of these measures or a systematic assessment of IAQ priorities.

Information exists to achieve good IAQ without incurring excessive costs or employing practices that are beyond the current capabilities of the building professions and trades. This Guide, resulting from a collaborative effort of six leading organizations in the building community[1] and written by a committee of some of the most experienced individuals in the field of IAQ, presents best practices for design, construction, and commissioning (Cx) that have proven successful in other building projects. It provides information and tools architects and design engineers can use to achieve an IAQ-sensitive building that integrates IAQ into the design and construction process along with other design goals, budget constraints, and functional requirements. While some key issues in the field of IAQ remain unresolved, this document presents the best available information to allow practitioners to make informed decisions for their building projects.

The Guide addresses the commercial and institutional buildings covered by ASHRAE Standard 62.1 and was written with the following audiences in mind:

- Architects, design engineers, and construction contractors who can apply the recommended practices during design and construction processes.
- Building owners, developers, and other decision makers who can use this Guide to direct the work of these professionals.
- Commissioning authorities (CxAs) who can ensure that design elements, construction schedules, construction observation, and functional testing are appropriate to meet IAQ-related goals and requirements.
- Product and material specifiers for both new and existing buildings who can choose materials and products with lower IAQ impact.
- Organizations that provide sustainable building rating programs and/or that conduct training for these programs.
- Facility managers and building operators who may use the Guide to understand the IAQ implications of existing systems and operations and maintenance practices.

[1] The six organizations contributing to the creation of this Guide are American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE); American Institute of Architects (AIA); Building Owners and Managers Association (BOMA) International; U.S. Environmental Protection Agency (EPA); Sheet Metal and Air Conditioning Contractors' National Association (SMACNA); and U.S. Green Building Council (USGBC).

Message to Building Owners

Indoor air quality (IAQ) is one of many issues that building owners and developers must address to provide buildings that meet their needs and the needs of the building occupants. While building occupants do sometimes complain about poor IAQ, it is not always on the top of their list of concerns. So why should you worry about IAQ when you have so much else to worry about?

- First, better IAQ leads to more productive and happier occupants. In commercial real estate, satisfied occupants are tied directly to return on investment and bottom-line economics, while in schools and institutional buildings they are tied to learning outcomes and organizational missions. While it is hard to put firm numbers on these benefits, there is increasing evidence of measurable productivity increases and reduced absentee rates in spaces with better IAQ.[1] In considering the economics of IAQ, it is important to note that the salaries of building occupants are the largest cost associated with building operation, dwarfing energy by a factor of 50 or even 100.

- Second, IAQ problems that get out of hand can be quite costly in terms of lost work time, lost use of buildings, expensive building or mechanical system repairs, legal costs, and bad publicity. While extreme IAQ problems are rare, they do occur, and the consequences can be dramatic. Less severe problems are more common and can erode occupant productivity, affect occupancy and/or rent levels, and lead to costs for smaller legal disputes or repairs.

This document presents a wealth of practical information on how to design and construct buildings with better IAQ without large financial investments or untested technologies. While the Guide is full of information on design and construction to control moisture, reduce contaminant entry, and provide effective ventilation, probably the most important message for the owner/developer is to put IAQ on the table at the very beginning of the development and design processes. Including IAQ in the earliest discussions with the architect and the rest of the project team will make it easier and more effective to provide good IAQ at lower or even no added cost.

By the time a building's schematic design is complete, many opportunities to achieve good IAQ have been foreclosed, which can easily result in unintended consequences or expensive and inadequate "force fitting" of solutions. When IAQ, energy efficiency, and other project objectives are considered together at the initial design phases, design elements for each objective can be mutually reinforcing rather than at odds with one another.

[1] For a good overview of research quantifying IAQ health and productivity impacts, visit the IAQ Scientific Findings Resource Bank at http://eetd.lbl.gov/ied/sfrb/sfrb.html. The IAQ-SFRB is jointly administered by the U.S. Environmental Protection Agency and Lawrence Berkeley National Laboratories.

Introduction

Why Good IAQ Makes Sense

Indoor air quality (IAQ) is one of many factors that determine building functionality and economics. IAQ affects building occupants and their ability to conduct their activities; creates positive or negative impressions on customers, clients, and other visitors to a building; and can impact the ability to rent building space. When IAQ is bad, building owners and managers can find themselves devoting considerable resources to resolving occupant complaints or dealing with extended periods of building closure, major repair costs, and expensive legal actions. When IAQ is good, buildings are more desirable places to work, to learn, to conduct business, and to rent.

The High Cost of Poor IAQ

The costs of poor IAQ can be striking. There have been many lawsuits associated with IAQ problems, though most are settled with no financial details released. However, some publicly disclosed cases have involved legal fees and settlements exceeding $10 million. For example:

- In 1995, Polk County, Florida, recovered $47.8 million in settlements against companies involved in the construction of the county courthouse (including $35 million from the general contractor's insurer), due to moisture and mold associated with building envelope problems. The original construction cost for the building was $35 million, but $45 million was spent to replace the entire building envelope, clean up the mold, and relocate the court system.
- Occupants of a courthouse in Suffolk County, Massachusetts, received a $3 million settlement in 1999 following a series of IAQ problems associated with a combination of inadequate ventilation and fumes from a waterproofing material applied to the occupied building.

Numerous IAQ problems have also occurred in private-sector buildings, but these tend to be settled out of court and are therefore not in the public record. As in public buildings, the causes of the problems vary and the settlement costs can be very expensive. A conservative estimate puts the lower bound of litigation costs during the early 2000s well over $500 million annually.

IAQ directly affects occupant health, comfort and productivity. Well-established, serious health impacts resulting from poor IAQ include Legionnaires' Disease, lung cancer from radon exposure, and carbon monoxide (CO) poisoning. More widespread health impacts include increased allergy and asthma from exposure to indoor pollutants (particularly those associated with building dampness and mold), colds and other infectious diseases that are transmitted through the air, and "sick building syndrome" symptoms due to elevated indoor pollutant levels as well as other indoor environmental conditions. These more widespread impacts have the potential to affect large numbers of building occupants and are associated with significant costs due to health-care expenses, sick leave, and lost productivity. The potential reductions in health costs and absenteeism and improvements in work performance from providing better IAQ in nonindustrial workplaces in the U.S. are estimated to be in the high "tens of billions of dollars annually" (EPA 1989; Fisk 2000; Mendell et al. 2002).[1]

Despite these significant impacts, many building design and construction decisions are made without an understanding of the potentially serious consequences of poor IAQ and without benefit of the well-established body of knowledge on how to avoid IAQ problems. While controlling indoor pollutant levels and providing adequate ventilation and thermal comfort have motivated the design and use of buildings for centuries, awareness of and concerns about IAQ have increased in recent decades. However, in most cases IAQ is still not a high-priority design or building management concern compared to function, cost, space, aesthetics, and other attributes such as location and parking.

Given the very real benefits of good IAQ and the potentially serious consequences of poor IAQ, building owners, designers, and contractors can all benefit from an increased focus on providing good IAQ in their buildings. This Guide can enhance all parties' ability to design, construct, and operate buildings with good IAQ using proven strategies that do not incur significant additional costs.

What is Good IAQ?

This Guide is intended to help architects, contractors, and building owners and operators move beyond current practice to provide "good IAQ." Good IAQ is achieved by providing air in occupied spaces in which there are no known or expected contaminants at concentrations likely to be harmful and no conditions that are likely to be associated with occupant health or comfort complaints and air with which virtually no occupants express dissatisfaction. It includes consideration of both indoor air pollution levels and thermal environmental parameters. However, the limits

[1] Other research related to impacts of IAQ is available at the IAQ-SFRB at http://eetd.lbl.gov/ied/sfrb/sfrb.html.