IAQ GUIDELINES FOR OCCUPIED BUILDINGS UNDER CONSTRUCTION

FIRST EDITION - NOVEMBER 1995

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION, INC.
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FOREWORD

In a cooperative effort to provide SMACNA contractors, architects, engineers, building owners and managers, and the construction industry in general with a well researched, practical publication to assist in effectively maintaining acceptable indoor air quality during building renovation, SMACNA's Building Services Committee has developed this first edition of the *IAQ Guidelines for Occupied Buildings Under Construction.* Additionally, the principles presented here are also applicable to the IAQ problems encountered in occupied areas of buildings during the final phases of new construction.

This project has its roots in a workshop that took place during the IAQ '93 Conference, co-sponsored by SMACNA and other professional organizations. As the conference progressed, it became clear that other than the combined experiences of the presenters and other specialized professionals in attendance, there existed little or no organized technical guidance dealing with the potential health hazards and annoyance related to the practical necessity of carrying on construction activity in occupied buildings.

This publication is intended to present in a clear and concise – yet comprehensive – manner the sources of pollutants, methods of control, and the management techniques necessary to maintain acceptable indoor air quality in occupied buildings under construction.

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TABLES

FIGURES

1.1 OVERVIEW

Poor indoor air quality (IAQ) is more likely to impact the health of building occupants during construction and renovation. Dust and odors migrating out of the work area and into occupied spaces can disrupt normal operation of the facility and, under worst case scenarios, cause injury or illness. While IAQ concerns in most buildings are often comfort issues, environmental changes in occupied buildings undergoing construction can have much more serious consequences. The mere presence of detectable dust or odor from a construction project, even at harmless levels, may trigger occupant concerns based on perceived hazards.

Effective management of IAQ during construction requires designers, contractors, facility managers, building engineers, and the occupants to work together. Conflicts regarding scheduling, budget, and continuing facility operation are best resolved early in the design development phase. Waiting for a mid-project air quality "crisis" (either real or perceived) can be costly to all parties. Delays due to rescheduling contractors and inefficiencies resulting from implementing pollution controls after the work has already started are inevitable results.

The expertise of HVAC along with architectural professionals is essential to the solution of most IAQ problems related to construction. Design of interior construction projects should include a detailed assessment of HVAC systems and relative pressurization, including their relationship to the proposed work. Where steps must be taken to protect building occupants from construction emissions, modifying HVAC operation is often an integral part of the process.

A good construction manager should be trained to recognize activities or conditions which could be detrimental to building occupants. This awareness has become even more critical with the emergence of IAQ-related litigation. While standards for non-occupational air quality are not defined by either OSHA or EPA, specifications in construction contracts or facility leases may address IAQ. In practice, however, IAQ controls are usually based on common sense and good professional judgment. Ongoing documentation of these decisions made to control IAQ and site conditions may be necessary to demonstrate good faith in regard to potential liability. Even where the best IAQ controls are in place, clear communication between all parties and flexibility to adapt to changing conditions are required for successful resolution of problems.

Construction activities potentially impact occupants both in new buildings where work is ongoing after some areas are occupied and in older facilities which are being repaired, modernized, or reconfigured. This manual will focus on those activities that temporarily produce airborne dust, odor, and other potentially harmful contaminants during demolition, construction, and punch list activities. More general IAQ concerns, such as proper design and modification of HVAC systems, are beyond the scope of this manual. The reader is referred to other references published by SMACNA, ASHRAE, and EPA for information on other IAQ issues.

1.2 HOW TO USE THIS MANUAL

No two construction projects are exactly alike. This manual, therefore, emphasizes general concepts and approaches from which the reader can select solutions best suited to a given site. Integrating these control measures with other construction and facility management activities requires an understanding of the entire process.

The remainder of this manual is organized to help answer the following questions:

Section	
2.1	What are the most common sources of airborne contaminants?
2.2	How do air pollutants move through a building?
2.3	How are building occupants impacted by dust and odor from construction sites?
3.0	What IAQ control measures can be effective?
4.0	How can a construction project be planned for good IAQ?
5.0	How can the site be monitored for compliance with IAQ requirements?
6.0	How should IAQ aspects of a construction project be communicated and coordinated with building occupants?

While this manual presents generalized options available to help resolve common construction related IAQ problems, it is not intended to be comprehensive (it doesn't specifically cover all construction processes and pollutants). It is presented as a practical overview, not a scientifically detailed treatment of the subject matter. For large or sensitive construction projects in occupied buildings, it is anticipated that design or industrial hygiene professionals will be needed to select from the available control options and adapt them to site-specific circumstances.

Two final notes:

The term "odor" is used in this text to cover any objectionable or potentially harmful gaseous pollutant. Since pollutants from construction activities tend to be detectable in terms of odor at potentially harmful levels, the simplified reference to "odors and dusts" is made throughout the text to cover all airborne contaminants.

This manual does not address worker protection at the construction job site. Compliance with applicable OSHA standards on safety, workplace exposure to airborne contaminants, etc., is generally required and must be considered when implementing IAQ controls.

2.1 SOURCES OF AIRBORNE CONTAMINANTS

Any construction activity which produces odor or dust can be considered a source of air pollutants and a potential contributor to IAQ problems. Airborne contaminants generally originate from construction activities in the following ways:

The disturbance of building materials during repair or demolition creates dust. Particles are typically airborne during initial work, then settle out on nearby surfaces, only to become airborne again during later activities, such as cleaning. Occasionally, such work will also expose odorous material or microbial contamination such as mold growth (*see* Table 2-1).

Soils	Flooring
Roofing	Paint
Masonry	Ductwork
Concrete	Insulation
Plaster	Ceiling panels
Drywall	

Table 2-1 Materials Which May Release Air Pollutants During Demolition

A second source of air pollutants involves odors or dust originating from products used in the construction process. These include coatings, adhesives, building materials which are applied wet, cleaning agents, etc. (*see* Table 2-2).

Airborne contaminants are also produced by equipment used in the construction process. These may emit combustion products, volatile organic compounds, and dust (*see* Table 2-3).

A fourth category of pollutants from construction activity originates from the disruption of building systems. Damage to any system which results in the release of contaminants (such as steam, natural gas) is a potential IAQ concern. For example, demolition work could eliminate a drain trap, thus allowing sewer gas to enter the building. Another example of system disruption is the release of accumulated dust when ductwork is disturbed, air volume is increased, or fans are cycled off and on because of renovation.

Building Materials	
Concrete (and treatments)	Roofing
Drywall	Insulation
Epoxy flooring	Wood (including pressed and treated)
Cove base	
Wet Products	
Paint (including stains)	Glazing compound
Architectural coatings (including sealants)	Caulking
Acid finish	Grouting
Adhesives	
Furnishings	
Carpeting	Furniture (including natural, pressed, and laminated wood)
Other flooring	Partitions
Wall coverings	
Solutions	
Solvents	Fuels
Cleaning Agents	Pesticides

Table 2-2 Products Which May Release Air Pollutants During Construction

Finally, pollutants can be released from waste construction materials when they are being stored or transported. Where dust, mold spores, or volatile materials (*e.g.*, rags impregnated with solvent) are present, intermixed within waste construction materials, the potential for adverse impact on IAQ increases.

Gasoline/Diesel Powered	
Generators	Saw
Compressors	Welder
Forklift	Troweling machine
Conveyor	Pressure washer
Motor vehicles	Scrabbler
Mixer	
LPG and Other Gases	
Forklift	Cutting torch
Portable heater	Welder
Pitch kettle	Soldering gun
Powder Activated Tools	

Table 2-3 Construction Equipment Which Produces Air Pollutants

Although literally thousands of different chemicals, particles, and microorganisms may be emitted from construction sites, airborne contaminants can generally be placed in one of the following five categories:

2.1.1 Particulates (Dusts and Fibers)

Demolition of most materials without asbestos content generally produces only "nuisance dust" (significant health problems not expected at typical levels of exposure). In most cases, drywall, plaster, concrete, soil, wood, masonry, flooring, roofing, ductwork, pipe, etc., are generally considered to produce only nuisance dust when disturbed, although appropriate NIOSH/MSHA approved respirators and other personal protective equipment should be used to minimize exposure. Similarly, most dry powders used to prepare insulation, plasters, etc., are considered nuisance dust unless rated as strong irritants. (Fiberglass and mineral wool can irritate the skin, eyes, and respiratory tract. Although the long-term health effects of these materials have not been resolved, their irritant effects dictate the use of appropriate protective equipment.) Particulates which may be subject to special regulation include those containing asbestos, PCBs, and lead.

2.1.2 Volatile Organic Compounds (VOCs)

VOCs are carbon-based chemical products which may release vapors at room temperature. These vapors may be detected as odors, depending on their concentration and the individual's sensitivity in regard to sense of smell. VOCs are often used as solvents and ingredients in building materials. Odors detected from the following products are considered VOCs: concrete surface treatments, adhesives, paints and architectural coatings, wall coverings, carpeting, vinyl flooring, cove base, roofing compounds, fuels, and spot removers. Most VOCs are considered to be non-toxic or only mildly irritating at typical exposure levels. Although some precautions may be advised, testing to determine specific chemical concentrations present is usually not considered necessary. Some VOCs, however, may cause more severe health problems, even at low levels of exposure, thus they may require more stringent controls.

2.1.3 Combustion Products

Burning of fuels in vehicles, construction equipment, generators, heaters, etc., produces a combination of potentially dangerous gases (*e.g.*, carbon monoxide) and a variety of irritants. IAQ problems may result when these are not completely vented outside the building. Other sources of combustion products include hot roofing kettles, cutting torches, and fasteners shot with powder activated systems. While the general products of combustion tend to be similar, emission rates can vary significantly. For example, gasoline and diesel engines pollute much more than those powered by bottled gas, and well tuned engines pollute less than comparable out of tune units. While the most toxic product of combustion (carbon monoxide) may be odorless, it is usually present in a mixture with odorous contaminants.

2.1.4 Biological Materials

Although normal background levels of bacteria and mold are always present in the building environment, gross contamination must be identified for special handling before renovation activity. For example, a wall cavity which has remained damp (resulting in musty odor and visible growth) might require precautions before demolition. Another example of biological contamination is an accumulation of bird or rodent droppings. In both cases, uncontrolled disturbances could spread potentially allergenic and infectious dust to occupied building areas. During renovation work, incomplete drying of wet areas could also lead to excessive microbial growth.

2.1.5 Other Contaminants

While most pollutants produced by construction activity fall into categories 1-4 (*see* sections 2.1.1 through 2.1.4), other contaminants are sometimes present. These include inorganic (non-carbon-based) chemicals such as ozone from electrical motors, metal fumes from welding and soldering, and ammonia or chlorine from cleaning compounds.

2.2 HOW CONTAMINANTS MOVE THROUGH BUILDINGS

In most construction projects, little attention is paid to the quality of air at the immediate work site as long as pollutants do not exceed OSHA standards. IAQ concerns, however, may focus on detectable odor or dust outside the work area wherever occupants or the public are located. Identifying potential pollutant pathways is important for maintaining good IAQ, designing a construction project, and locating the source of dust or odor in the event of complaints.

The HVAC system itself is often the primary pathway for building air pollutants. Pollutants can enter the system in at least four ways:

1. Through return grilles.
2. Through the mechanical room (drawn into the distribution system by the fan).
3. Through HVAC system intakes located near construction exhaust or outside emissions.
4. Via temporary (construction related) or permanent cross-connections.

In each case, pollutants will circulate to the rest of the air supply zone and may also contaminate adjacent zones. The extent to which contaminants in the HVAC system are actually considered a problem often depends on how much recirculated pollutants are diluted or filtered.

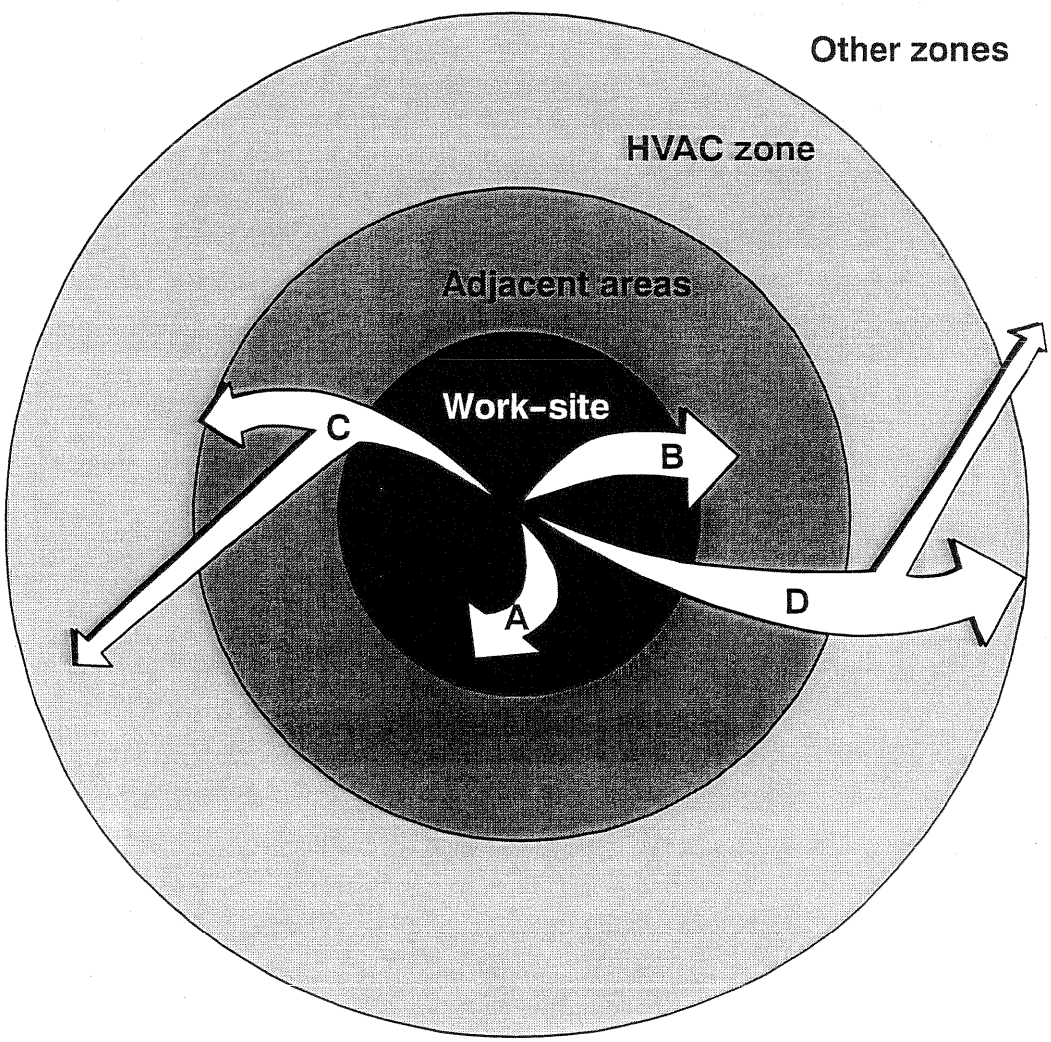
Contaminants may be more noticeable when they move directly from the renovation site to locations of lower pressurization. Pollutants tend to migrate from pressurized areas (*e.g.*, more supply air than return/exhaust air) to areas which are under negative pressure (*e.g.*, more return/exhaust air than supply air). Affected locations are generally close-by and on the same floor. However, relative pressurization may move pollutants to adjacent floors or, through the stack effect, to remote locations on upper floors. Utility chases, abandoned pipes, and similar openings are also pathways which can convey contamination to remote areas of the building under the influence of relative pressurization (*see* Figure 2-1).

The extent to which pollutants will migrate to another area is also related to the size of the opening between the areas and the relative pressure difference between the areas. For example, although some leakage can occur through a small crack, air movement through a larger gap would tend to be greater and through an open door greater still. Demolition work may create new pathways by leaving holes or removing partitions between occupied areas and work locations.

Another potential pathway occurs when dust, solvents, and fibers are tracked outside the work area on workers' shoes and clothing, as well as on contaminated equipment. Once outside the work area, these pollutants can become airborne when they are shed from clothing or equipment. The visual appearance of construction dust in otherwise clean office spaces may raise the level of concern about the impact of construction activity on occupied spaces.

Contaminants may remain detectable after emissions have cleared and accumulate in sites remote from their point of origin. For example, dusts can collect in the ducts, and odors can "stick" to surfaces (especially porous materials). Such sites are considered "sinks" (points of accumulation) which can release these pollutants back into the air at a later time.

Evaluation of air contaminant pathways from construction sites is usually limited to areas within the same building. Occasionally, construction emissions may also impact public areas outside the building or be drawn into the HVAC systems of adjacent facilities. Any such exposure should be of concern and controlled to the extent possible.



Typical contaminant migration into occupied building areas:

A. direct exposure of occupants inside work area

B. tracking of contaminants by workers

C. movement into areas under negative pressure

D. recirculation of pollutants drawn into return air system

FIGURE 2-1 COMMON POLLUTANT PATHWAYS FROM CONSTRUCTION SITE

2.3 HOW AIRBORNE CONTAMINANTS IMPACT BUILDING OCCUPANTS

Air pollutants associated with construction activity can affect the health of building occupants. Whether or not symptoms occur is a function of the type of pollutant, the extent to which it accumulates, the duration of exposure, and the sensitivity of the occupants. Of greatest concern are those pollutants likely to cause health problems after brief exposure. Examples include solvents that irritate the eyes, nose, and throat; asphyxiants, such as carbon monoxide; and common allergens, such as mold spores. Acute reactions to pollutant exposure are usually nonspecific (symptoms could be due to a variety of other causes in addition to poor air quality). Where symptoms are nonspecific, both a medical diagnosis and a detailed environmental survey may be needed to determine if a person actually became ill because of construction emissions. Hypersensitive individuals may react to common pollutants at levels where most people are unaffected. In cases of true hypersensitivity, it may be impossible to identify specific pollutant sources and no level of exposure may be considered acceptable (*e.g.*, some asthmatics). Under such circumstances, it may be advisable to keep hypersensitive individuals as far away from construction activity as possible.

The following illustrates health problems caused by emissions from construction sites:

- An asphalt roofing kettle was located near the HVAC intake. Occupants detected pungent odor and reported irritation of the eyes, nose, and throat, with some also experiencing headaches.

- The demolition phase of a suspended ceiling replacement in an office bay was conducted overnight. Employees returning in the morning observed dusty surfaces. Many were annoyed, and several reported sneezing and itching.

- A gasoline-fired generator was located adjacent to a mechanical room to support construction work. Odors were detected in the zone served by the air handler. Several occupants reported dizziness, nausea, and headaches.

- Adhesive and paint odors were noticeable to employees entering a remodeled office suite. Two contact lens wearers experienced eye irritation.

- While a wall was being replaced, dampness and mold growth are observed. An occupant of a nearby room subsequently complained of a series of severe asthma attacks.

- Diesel-powered equipment was used in the renovation of an underground garage. Occupants using a connected stairwell occasionally experienced headaches and eye irritation.

- Lead-based paint was stripped from a partially occupied gymnasium. Visitors observed a visible haze in the air and expressed concern about possible lead poisoning.

Since occupant exposure to air pollutants from construction activity tends to be brief, the focus is generally on acute rather than chronic health problems (*see* Table 2-4. Chronic diseases, such as cancer, apparently clustered in a building's population are almost always coincidence rather than due to the presence of carcinogens in the building environment. However, certain substances known to cause cancer under some circumstances may be regulated to reduce the risk of exposure to negligible levels.

While construction projects can create health problems, many occupant complaints involve nuisance or comfort concerns. In such situations, odor and dust are detectable but not in amounts known to be harmful. Occupants may still perceive unhealthy conditions, however, particularly where there is a fear of the unknown (*e.g.*, due to lack of information on the construction work in progress), underlying political concerns (*e.g.*, poor relations between building occupants and management), or previous exposure from past renovations. Other contributing factors may involve temporary reductions in comfort when construction work disrupts HVAC systems and generates noise that interferes with occupant activities (*see* Table 2-5).

2.4 PLACING CONTAMINANT EXPOSURES IN PERSPECTIVE

Air is never pollutant-free, even in the cleanest of buildings. Thus, any air samples should be expected to contain contaminants such as volatile organic compounds (VOCs), particulates (dust), and bioaerosols (bacteria and fungi).

Underventilation	• Minor symptoms due to stuffy air (no strong sources)
Minor irritant	• Eye irritation due to use of cleaning solvent
Allergen	• Asthma due to mold growth
Major health hazard	• Carbon monoxide poisoning • Legionnaire's Disease
Chemical hypersensitivity	• Individual reaction to trace contaminants at routine concentrations

Table 2-4 IAQ Health Complaints

Building Environment	Physiological	Psycho-Social
• Thermal discomfort *hot/cold; dry/ muggy; stuffy/ drafty*	• Contagious illness *common respiratory infections, etc.*	• Stress *job, personal, etc.*
• Physical factors *lighting; noise; ergonomics*	• Medication side effects *fatigue, headache, dry mouth, etc.*	• Psychosomatic symptoms
• Nuisance conditions *unusual odors; visible dust or staining*	• Clustering of random health events *cancer, miscarriage, etc.*	• "Sick Building" rumors
• Other exposure routes *drinking water; food; skin contact*		

Table 2-5 Other Contributors to Health Complaints Sometimes Attributed to Airborne Contaminants

While OSHA standards have been set to minimize the possibility of significant illness in healthy adults exposed over a typical work shift, there are no such standards for the general population indirectly exposed to the same contaminants. Building occupants have a wide range of sensitivity with minor, temporary symptoms potentially occurring at levels much lower than the OSHA standards. While OSHA standards are typically based on exposure to one pollutant at a time, building occupants are generally exposed to a mixture of pollutants. Thus, normal background and harmful levels of airborne contaminants cannot be precisely distinguished. In practice, acceptable IAQ is usually based on conditions achievable with available control measures and is verified by the absence of complaints.

Air sampling is seldom used to regulate building construction projects. Where sampling is conducted, it is often based on general indicators of IAQ (composite measures of total dust, VOCs, or bioaerosols) rather than identification of all specific chemicals and microorganisms. Exceptions occur when designated hazards are likely to be present in harmful amounts (*e.g.*, asbestos removal).

Air quality assessment of a construction project can be based on:

1. Types of dust or odor produced by:
   - materials being demolished;
   - products used in construction; and
   - equipment used in construction.
2. The presence of any pollutants which are a recognized hazard should be handled with specific precautions as noted on Material Safety Data Sheets (MSDS).
3. A determination of the times and locations occupants are most likely to encounter dust and odor from the project (*see* section 2.2).
4. The amount and duration of exposure generally expected in these situations.

2.5 HAZARD ASSESSMENT

A hazard assessment need not predict specific concentration values and can simply show the relative magnitude of environmental problems presented by the various construction phases. An assessment of a typical renovation project could thus be presented as follows:

- Removal of asbestos-containing material in the mechanical room and lead-based paint in the lobby could present an exposure hazard unless conducted under full containment.
- Occupied areas adjacent to active work sites may occasionally detect small amounts of nuisance dust and odor (no health effects likely with the possible exception of hypersensitive individuals).
- Odors from enamel painting of executive office doors could be annoying and irritating to nearby occupants for up to two days.

While all three findings suggest that control measures are needed, these can now be prioritized and selected to most efficiently ensure a safe environment for building occupants (*see* the following chapters for more detailed guidance).

3.1 OVERVIEW

Many methods are available to maintain IAQ during construction or demolition. The pros, cons, and limitations of each available option should be considered to identify the most effective and most efficient approaches for a particular job. In general, the choices involve:

- Containing the work area;
- Modifying HVAC operation;
- Reducing emissions;
- Intensifying housekeeping;
- Rescheduling work hours; or
- Moving occupants.

Projects may use more than one of these measures (simultaneously or phased in) as a major renovation progresses.

3.2 HVAC PROTECTION

All HVAC equipment must be protected from collecting not only dust but also odors (which can "stick" to porous materials in the system and later be released). The design of each system must be evaluated in detail to determine how it may be affected by odor and dust from the project (including site egress, staging areas, etc.). Specific HVAC protection requirements generally apply to either the return side, central filtration, or supply side of the system.

3.2.1 Return Side

The return side of an HVAC system is, by definition, under negative pressure and thus capable of drawing in nearby construction dust and odor. When planning any construction project, special attention must, therefore, be paid to the location of any return vents, return ducts, ceiling plenums, return shafts, VAV plenum intakes, window units, and transfer vents as well as that portion of the air handler which is upstream of the central fan.

- When possible, the entire system should be shut down during heavy construction or demolition.

- The system should be isolated from the surrounding environment as much as possible (*e.g.*, all tiles in place for a ceiling plenum, duct and air handler leaks repaired) to prevent induction of pollutants.

- All return system openings in (or immediately adjacent to) the construction area should be sealed with plastic.

- When the system must remain operational during construction, temporary filters should be added where necessary (*e.g.*, on grills to return air shaft). All filters must receive frequent maintenance and be replaced at end of project.

- When the general system must remain operational, the heaviest work areas can still be dampered off or otherwise blocked if temporary imbalance of the return air system does not create a greater problem.

- The mechanical room should not be used to store construction or waste materials.

3.2.2 Central Filtration

Where major dust loading is expected to impact operating HVAC systems, consideration should be given to upgrading filter efficiency. For example, filters with 60 to 80% dust spot efficiency may provide increased protection, if minimum airflow can be maintained. Where other control options for construction related odors are not deemed effective, consideration may be given to filtration with media such as activated charcoal or potassium permanganate.

3.2.3 Supply Side

Diffusers, VAV boxes, and ducts may be adequately protected in most cases where the above measures are implemented. When the system is off for the duration of construction, diffusers and window units should also be sealed in plastic for further protection. Ducts, diffusers, and window units should be inspected upon completion of the work for the amount of deposited particulate present and cleaned where needed. If significant dust deposits are observed in the system during construction, some particulate discharge can be expected during start-up. When such a discharge is only minor, delaying reoccupancy long enough to clean up the dust may be sufficient. In more severe cases, installing temporary coarse filters on diffusers or cleaning the ducts may be necessary. The condition of the main filters should be checked whenever visible particulates are discharged from the system.

3.2.4 Duct Cleaning

An HVAC system has excessive dust or debris when an accumulation of particles can be observed under (not on) diffusers, or ventilation is restricted. Consideration should be given to cleaning the ducts and associated equipment during renovation when either an old system with pre-existing dust build-up must be rehabilitated or a clean system becomes contaminated due to inadequate protection during the construction process. In either case, a decision whether and how to clean the ducts should be based on a detailed visual inspection of the system. Both highly specialized equipment and professional expertise are needed to ensure that dust is effectively removed and contained. The sequence in which duct cleaning occurs in the overall construction process needs to be carefully considered to avoid recontamination.

3.3 SOURCE CONTROL

The most effective type of pollution control is generally at the source. A variety of options may be available depending on the type of products and equipment needed for a given construction project. Costs are job specific and beyond the scope of this manual. When any of the following control options appear to be feasible, costs should be compared to other measures (pathway interruption, intensified housekeeping, occupant relocation, and scheduling changes) when designing a construction project.

3.3.1 Product Substitution

In response to recent IAQ concerns, many manufacturers have been formulating or providing lower emitting products. Low emitting products are provided by the following suppliers:

- Carpet
- Adhesives
- Paints
- Caulks
- Cleaning solutions
- Wall coverings
- Furniture.

Although solvent content is often reduced, air quality advantages may be limited (*e.g.*, most paints and adhesives stop significant offgassing within a few weeks anyway). Product emission data is often available from manufacturers and can be stated either as total VOCs or by specific compound. The time period of the testing is important (emissions should be expected to decline). Cost and performance of products having different emitting rates should be compared (including any costs of special HVAC operation or delayed occupancy as a result of offgassing concerns).

The use of products emitting lower amounts of odor and VOCs may not be critical if the work area is isolated from building occupants and the space will be ventilated for several days before reoccupancy. The advantages of lower emitting products are most evident under the following circumstances:

- Occupants are nearby while product is being applied or installed.
- Odor pathways exist from the work area to occupant space.
- Reoccupancy of the work area must occur very quickly (leaving insufficient time for the materials to offgas).

NOTE: "Bake-outs" of new material are sometimes advocated as a control for offgassing. Heating of furnishings and construction materials is generally not recommended due to questionable effectiveness and potential for damage.

3.3.2 Modifying Equipment Operation

Use of equipment may need to be restricted in order to meet IAQ objectives. This could involve substituting cleaner equipment or simply changing operating procedures. Examples of such controls include:

- Restricting traffic volume or prohibiting idling of motor vehicles where emissions could be drawn into occupied areas.
- Switching from diesel to bottled gas for equipment such as generators or fork lifts (emissions are cleaner but still potentially harmful under some circumstances). Use of electric fork lifts and other equipment should be considered when feasible, since they do not burn fossil fuels, thus eliminating exposure to combustion gas emissions.
- Switching equipment such as chain saws from gasoline-powered to electric (job may take longer due to reduced performance).
- Cycling equipment off when not needed.

3.3.3 Changing Work Practices

- For some demolition tasks (*e.g.*, paint stripping) there may be techniques available which produce less airborne dust.
- Some painting techniques release less odor.
- Some cleaning practices raise less dust (*see* section 3.5).

3.3.4 Local Exhaust

Pollution sources can be directly exhausted to the outside. This may be done through an exhaust system already available in the building or more often by a portable fan vented to the outside and attached to the work site by flex duct. Depending on the nature of the material and the location of the exhaust, special filtration of the exhaust may or may not be necessary. Any emissions to the outside must be in compliance with applicable regulations and should be directed well away from intakes.

3.3.5 Air Cleaning

Where exhaust is not feasible, local recirculation of air through a portable air cleaner may be effective. The type of filter should be suitable for the material being controlled (*e.g.*, charcoal or potassium permanganate for many odors, a moderate to high efficiency filter for dust).

3.3.6 Cover or Seal

VOC emissions are a result of evaporation from an exposed surface. Reducing the exposed surface reduces emissions. For example:

- An enclosed tanker is preferable to an open kettle for roofing.
- Containers of wet products should be kept closed as much as possible.
- Waste materials which can release odor or dust should be covered or sealed.
- A surface which is a persistent odor source may be controlled by applying a sealer.

3.4 PATHWAY INTERRUPTION

As an alternative to costly source controls or evacuation, practical methods are often available to simply prevent air movement from the work site to occupied space. Interruption of potential contaminant pathways can thus be a very attractive control option. Once major pathways are identified for a given project, five different factors may be manipulated to achieve environmental control:

- ***Depressurize the work area.*** This can be accomplished by adjusting the balance of the existing HVAC and exhaust systems or installing portable exhaust fans. Construction worker comfort may have to be a secondary consideration when cutting off conditioned air to the work site becomes necessary to help establish a negative pressure environment. Some ventilation of the construction space will still be needed to dilute contaminants. This may be provided by air drawn into the work site from adjoining areas.

Air exhausted to achieve negative pressure may or may not need to be filtered, depending on the nature of the materials, location of the exhaust, and any applicable regulations. Care must be taken not to exhaust air where it can be drawn back into the building.

When increasing the amount of air supplied to the occupied space, it is imperative that the HVAC system itself remains protected from construction emissions.

As a general rule, the work site should be exhausted at a rate at least 10% greater than the rate of supply in order to maintain an effective negative pressure.

- ***Pressurize occupied space.*** Increasing supply air and/or reducing return/exhaust air in building areas remaining occupied during construction will help exclude airborne dust and odors. While HVAC systems generally shut down at night, consideration should be given to temporarily extending the fan schedule. Overnight pressurization could help prevent dust and odor from migrating into the space. When increasing the amount of air supplied to the occupied space, it is imperative that the HVAC system itself remains protected from construction emissions. Any temporary rebalancing during construction should be carefully planned and executed.

- *Erect barriers to contain construction area.* Barriers can range from simple dust curtains for jobs generating only minor amounts of nuisance dust to a continuous plastic seal around the site, allowing for only the controlled inflow of make-up air (commonly required for asbestos removal). For non-asbestos projects, the extent of the barrier should be based on the materials involved and the implications of dust and odor escaping from the site. If such a release is not considered a hazard and can be easily corrected by housekeeping, then a partial barrier or sealing of holes may be sufficient. Where no odor or dust can be tolerated outside the work area, a barrier approaching that required for asbestos projects may be needed. Barriers must be designed in conjunction with favorable pressure differentials. Pressurization can only be achieved with a real partition between areas with pressure differences. In general, full containment of a work site with barriers, capping of return air ducts, and the application of negative pressure may be needed for spaces undergoing significant renovation, but usually not for minor remodeling.

- *Relocate pollutant sources.* When project equipment or staging areas coincide with critical air flow pathways, IAQ problems can result. In some cases, equipment can simply be moved to a more favorable location in regard to air quality. For example, in a roofing job, tar kettles can be located as far away from intakes as possible. Mechanical equipment might be refurbished outside or in a shop in order to relocate emissions from the building. Special care must be taken to protect mechanical rooms with air handling equipment (*e.g.*, store construction products and waste materials elsewhere).

- *Temporarily seal the building.* Where construction emissions are occurring on the roof or adjacent to a building, contaminants may be drawn in through the outside air intake or (if the building is under negative pressure) other entries or cracks. If contaminant levels are unacceptable and there is no better alternative (*e.g.*, source control, temporary intake relocation, or rescheduling), then sealing of intake dampers may be necessary. This should be weighed against the creation of stuffy conditions (hopefully of only very short duration) and could be contrary to the building code. Special activities in the building that require outside air for dilution may have to be temporarily discontinued (*e.g.*, occupied space could become negative with respect to area with hazardous materials). Control of the outside source may also necessitate closing or sealing exterior doors, the top of the elevator shaft, etc.

3.5 HOUSEKEEPING

As dust accumulates at a construction site, it will become airborne when disturbed by nearby activity. Similarly, spills or excess applications of products containing solvents will increase odors at a construction site. Finally, leaving the work site wet or even just damp for more than a day could result in the growth of mold and bacteria. Attention to site cleaning is, therefore, important to maintaining IAQ during construction. These specific actions may be applicable in regard to controlling contaminants at the work site:

- Suppressing dust with wetting agents or sweeping compounds.

- Increasing the cleaning frequency for dust.

- Switching to a more efficient dust collection method (*e.g.*, a damp rag, wet mop, or vacuum equipped with a high efficiency particulate filter or wet scrubber will discharge less material back into the air than conventional vacuuming, sweeping, or dusting).

- Ensuring that all surfaces (including higher ledges, behind furniture, and inside mechanical equipment) are kept clean. This can be facilitated before the start of renovation by either moving contents out of the work area or covering them.

- Removing spills or excess applications of solvent-containing products as soon as possible. Care should be taken as to selection of spot removers and cleaning agents near occupied areas (in general, products should be low odor emitters or used after hours with sufficient ventilation).

- Removing accumulated water and keeping work areas as dry as possible (using dehumidification if necessary).

- Vacuuming with HEPA filtered vacuum cleaners prevents aerolization of settled dust.

- Protecting porous materials such as insulation from exposure to moisture

  NOTE: Items which remain damp for more than a few hours may need to be replaced.

Cleaning requirements are more stringent when hazardous materials are involved. For example, current NIBS guidance for stripping lead-based paint includes the following:

1. Daily site cleanup with proper bagging and disposal of debris.

2. Damp wipe any tools leaving site with detergent solution.

3. When work is completed, HEPA vacuum all affected areas, wash with a detergent solution, and HEPA vacuum again when dry.

4. Repeat until area passes visual inspection and then seal surfaces.

5. Repeat step 3.

6. New building materials or furnishings are not allowed in the area until it passes clearance tests (based on surface wipes).

3.6 SCHEDULING

Another control option is to ensure that construction activity and building occupancy do not overlap in time. For many projects, the immediate work area is vacated to prevent safety hazards and work disruption. Although reoccupancy may occur anytime after substantial completion of the work, IAQ concerns may suggest waiting until detectable odors and dust are eliminated (*see* section 5.4 on reoccupancy criteria).

For many major renovation projects, a 48-hour period of continuous ventilation after final installation and cleaning will result in an acceptable environment for reoccupancy. Where possible, the renovation site should be maintained under negative pressure during this period to prevent odor migration into adjacent areas.

For some projects, vacating a buffer zone around the work area may also be needed to ensure that no odor or dust is detectable in the occupied space. The size of such a buffer zone will depend on the potential air quality problems presented by the project, the availability of temporary space, and HVAC system zoning. When necessary control measures are disruptive to conducting normal building activity, it may be advantageous to vacate the entire building.

When relocating occupants, attention should be paid to environmental conditions in temporary facilities. For example, IAQ in a modular unit could be worse than IAQ at the construction site due to inadequate ventilation and offgassing from new materials.

A potentially costly but sometimes necessary option is to conduct activities with a high pollution potential during off hours. For example, if roofing emissions cannot be excluded from the building, the work might have to be performed on an evening shift. Similarly, any work which disrupts the HVAC system or introduces odor into the system should be done during unoccupied hours when possible. Where offgassing odors are a major concern, work may have to be completed at the beginning of a weekend in order to allow new products time to air out sufficiently. Where occupants cannot be relocated, starting time may need to be delayed until late morning in order to accommodate clean-up of late night construction work.

The above measures assume that occupants are being moved or construction work is being rescheduled in order to avoid potentially harmful exposure to the general population. When a construction project is adequately controlled and one or two hypersensitive individuals remain concerned about IAQ, moving those individuals for the duration of the project is often the most economical and effective solution.

4.1 PROJECT ORGANIZATION

4.1.1 Assigning Responsibilities

Many parties can be involved in a major renovation project, including the property owner and manager, HVAC operator, tenant representative, design professionals, health and safety professionals, and, of course, the various construction trades. Unless there is continuing cooperation between these parties, air quality problems are likely to occur.

All members of the project team should have defined responsibilities regarding IAQ. The role of IAQ coordinator might be assigned to the project manager, construction supervisor, inspector, safety officer, or tenant representative. Periodic team meetings should be scheduled to include specific consideration of IAQ issues.

Workers from each trade should be given a briefing on what measures are being taken to protect IAQ and how these measures will be enforced. Foremen should have a complete knowledge of containment procedures and other specific controls as well as back-up contingency plans to be implemented in the event of a failure. They are responsible for having their workers effectively implement the IAQ plan.

4.1.2 Initial Planning

A pro-active renovation program should incorporate early identification of emissions which are likely to occur during the project. Each phase of work should then be categorized as to the potential severity of emissions (in terms of both potential toxicity and the quantity likely to be generated), proximity to occupants, and the availability of controls.

While a typical team preparing renovation plans includes expertise in architecture and engineering, an additional person experienced in the control of air contaminants–such as a Certified Industrial Hygienist (CIH)–may be needed to anticipate IAQ aspects. Once the basic project specifications have been proposed, input from this environmental specialist will help identify hazardous materials for special handling, critical pathways through which contaminants could move into occupied space, and available control options.

The planning team can then integrate these indoor environmental concerns into the overall project, balancing costs, owner and tenant needs, and construction logistics. Procedures must then be developed to guide contractors as well as building O&M personnel toward achieving acceptable IAQ during renovation. Schedules must also ensure that activities are performed in proper sequence to facilitate the control of potentially airborne contaminants in the most cost-effective manner.

4.1.3 Ongoing Management

Maintaining IAQ during renovation is often more a management challenge than a technical one. Traditional management principles can be used to get the project team to "buy in" to the concept of good IAQ. Leadership by the facility or project manager is crucial to the achievement of the goal. Timely information is also needed throughout the project to help assess the effectiveness of the IAQ measures taken.

Specific management tasks where IAQ should be considered include:

- Developing project budget
- Reviewing progress schedules
- Inspecting completed aspects for acceptability
- Overcoming opposition or indifference to the IAQ plan
- Changing the IAQ strategy where needed to achieve more effective results
- Responding to occupant concerns
- Commissioning.

4.2 SELECTING IAQ CONTROLS

Most projects allow for considerable discretion on what, if any, IAQ controls are to be followed. Decisions on how dust and odors will be kept out of occupied space are best made in the early planning stages. After determining basic project objectives, the following questions should be answered within the context of the available budget:

- What products, equipment, and procedures are acceptable?
- Are modifications needed to normal HVAC operation?
- What is the optimum schedule, taking into account both construction and facility needs?
- When should the work area be considered safe for reoccupancy?

The final selection of IAQ controls should then be developed from the following process:

Step One: Identify all potential sources of odor and dust. This should include all aspects of the job, from initial site preparation to final punch list. Pollutant sources may originate with each of the following:

a. Any existing building material which will be disturbed (the presence of any microbial growth or chemical contamination must be considered).

b. Any product which may create odor or dust during the construction or clean-up process. (Read and follow container precautions, especially for products marked "use adequate ventilation" or "use only outdoors or in a well ventilated space.")

c. Any equipment which will produce combustion products or other detectable emissions.

d. Odor or dust which could result from the disruption of existing systems (*e.g.*, sewer gas, discharge of particulates from ductwork).

e. Waste materials which are being transported or stored.

Step Two: Locate occupied areas potentially affected by the project. This requires knowledge of:

a. Specific building areas used by occupants.

b. HVAC zones receiving recirculated air from construction site.

c. Areas adjacent to sources of odor and dust.

d. Other potential pathways (*e.g.*, up stairwells or elevator shafts).

Step Three: Identify construction activities likely to produce detectable odor or dust in occupied areas. Based on the results of Steps One and Two, only some sources will actually be detectable in critical areas.

Step Four: Classify potential IAQ problems by severity. To simplify evaluation, related sources can be combined (*e.g.*, the application of various paints and glues may present similar odor control issues unless one work area is close to particularly sensitive occupants). Worst-case scenarios should generally be assumed when evaluating potential hazards (controls should then be effective for the full range of operating conditions). Based on available information, odor and dust sources can be classified in one of three categories:

Class 1: These are air pollutants expected to have only a nuisance impact on exposed occupants. Health effects should only occur in the case of very sensitive individuals. An example is a small-scale wall relocation that will produce only small amounts of dust which contain no recognized hazards such as asbestos, lead, etc.

Class 2: These are air pollutants which could cause a moderate but temporary health impact in some occupants. An example is dust and odor from the removal and replacement of carpet or demolition of multiple walls and ceilings.

Class 3: These are more hazardous air pollutants which could cause severe, acute, or chronic illness. Examples include disturbance of products of combustion, asbestos fibers, heating of roof tar, application of enamel paint, mixing of epoxy resins, non-vented operation of gasoline or diesel-powered equipment, and dust from lead-based paint.

Step Five: Identify available control options. Measures selected should help to minimize the release of dust and odor into occupied areas. The stringency of control required should be based on the above hazard classifications (tightest control needed for Class 3, etc.). All available controls should be considered for planning purposes, including:

- Protection of HVAC systems
- Substitution of lower emitting products
- Modification of equipment for lower emissions
- Local exhaust or air cleaning
- Covering or sealing emissions
- Pressurizing occupied space
- Erecting barriers
- Relocating sources
- Temporarily sealing off outside sources
- Dust suppression
- Increasing cleaning frequency or efficiency
- Vacating buffer zone around work sites
- Restricting work to off-hours
- Moving hypersensitive individuals.

Projects involving certain designated hazardous materials, such as asbestos or lead-based paint, may involve minimum environmental protection requirements. For additional information and assistance (legal and technical) in such cases, *see* the list of references in Appendices A and B.

Step Six: Select specific control measures. These should be sufficient to meet the project IAQ objectives (*e.g.*, keep detectable dust and odor out of occupied space) in keeping with the degree of hazard involved (minimal controls for Class 1, moderate for Class 2, etc.). IAQ controls must be compatible with the project budget and facility operational requirements. Final selection should be based on the most efficient approach which will adequately protect the occupants. In some cases, the size or location of work areas may need to be modified for optimum environmental controls. (*See* the example project planning checklist in Appendix C.)

5.1 IAQ STANDARDS

Most office building workers expect a pollutant free work environment. The presence of construction dust and odors in office spaces is often considered unacceptable and may give rise to nuisance and health complaints, even when the levels of exposure are minimal. For this reason, construction-related air contaminants should be prevented from entering office areas.

At the time of this publication, there are no mandatory standards in most jurisdictions defining unacceptable levels of specific pollutants in regard to IAQ. Furthermore, it is usually impossible to set specific IAQ criteria for a construction project because exposure cannot be easily measured. Indoor pollutants are always present in complex mixtures with each specific contaminant often at a parts per billion level and none dominating from a health viewpoint. For broader pollutant categories (*e.g.*, TVOCs [total volatile organic compounds]), guidelines are not based on actual toxicity.

Factors other than specific pollutant levels often provide a more realistic basis for deciding if IAQ is acceptable. For example, goals for acceptable IAQ can be stated in terms of ventilation, comfort, sanitation, and control of potentially significant sources of emissions. Examples of general building air quality performance goals that are not based on contaminant concentrations include:

- Demonstrate ventilation to be consistent with ASHRAE 62-2001 to the extent allowed by existing equipment and design.
- Achieve comfort levels acceptable to most occupants.
- Maintain both mechanical equipment and building surfaces in reasonably sanitary condition.
- Isolate significant emission sources from occupied space.
- Control major sources of contamination promptly.
- Conduct operations, maintenance, and construction activity to minimize occupant exposures.
- Achieve comfort levels acceptable to most occupants (using ASHRAE 55-1992 as a guideline).

Most of these issues can be assessed by inspection and regulated by work practices, and do not specify measurements of pollutants.

5.2 SURVEILLANCE CRITERIA

Monitoring of construction projects through air sampling is generally not effective. In the majority of cases, it is simply not practical to develop a sampling strategy which will measure the right pollutant at the right time. When the building owner, tenant, or contractor wishes to document how a construction project relates to IAQ, the best information is usually obtained by observing a combination of work practices and "IAQ indicators." IAQ indicators are changes in building conditions which are detectable by the sense of smell or sight. For example:

- An unusual odor in the occupied space (not normally present).
- Visible haze in the air.
- Visible accumulation of dust on exposed surfaces.
- Staining on surfaces (*e.g.*, from soot or mold growth).
- Incorrect pressurization allowing pollutants to move into occupied areas (determined by observing direction of air movement with smoke tube).

In addition to periodically documenting IAQ indicators, a job inspector can also verify that work practices intended to protect IAQ are being followed. Such observations might include that:

- Occupants have been moved from critical area.
- Low-emitting products have been used.
- Frequent housekeeping has prevented dust accumulation at the site.
- HVAC protection measures have been followed.
- Dust barriers have been properly erected.
- Portable exhaust fans are being used.
- Water leaks, spills, and other sources of moisture have been controlled.

- Precautions on product labels or MSDS are being followed (note that "use adequate ventilation" addresses air circulation to maintain safety for workers in the immediate area but does not cover IAQ concerns such as off-site odors and hypersensitive individuals).

- Porous materials are protected from moisture
  NOTE: If they become damp, they must be dried within a few hours, or replaced.

Building occupants can also provide assistance in determining if dust and odor controls have been adequate. Any complaints should be addressed immediately with a thorough inspection to help identify any source and pathway. If the complaint is valid, additional control measures should be considered. During a job inspection, occupants can be routinely interviewed as to whether they have encountered any unusual dust or odor. The timing and location of occupant observations can be very helpful in identifying an intermittent building odor problem.

Air sampling can play a role in monitoring sensitive projects (*e.g.*, where hazardous materials are present or occupant concerns are significant). In such cases, the sampling strategy must be designed to reflect the range of conditions (both critical peaks and typical averages). Baseline sampling is needed prior to construction and, as a control, in areas without construction. Wherever air sampling is conducted, it is important to also document work practices and IAQ indicators to help place the results in perspective.

A project checklist should be used during inspections to document site conditions and the status of IAQ controls. An example checklist can be found in Appendix D.

5.3 ENFORCING SPECIFICATIONS

Enforcement of work practices and air quality criteria should begin with education of construction personnel. Supervisors must be presented up front with the project's IAQ goals and the means for achieving them. On-site inspection must stress consistency and fairness in enforcing work practices. Criteria for warning and job shutdown should be understood ahead of time. In some cases, work might not be allowed to continue until IAQ concerns are successfully resolved in a previously affected area.

5.4 REOCCUPANCY CRITERIA

During heavy demolition or construction, nearby occupants are often moved from the work area. General practice is to move them back as soon as possible without detailed consideration of IAQ. In some instances, lingering odor and dust from recent activity then result in occupant complaints.

In some situations where lead-based paint is stripped or disturbed during demolition (*e.g.*, in public housing), there are specific testing requirements to be met before a work site can be cleared for reoccupancy. Wipe samples of measured surfaces must be submitted for laboratory analysis. If the lead content is not below HUD/EPA guidelines, the area must be recleaned. Similarly, following asbestos removal, air samples must meet an acceptable fiber concentration before the work area is released.

In situations not involving hazardous materials, such as lead or asbestos, sampling for specific pollutants associated with general demolition or construction is not recommended. However, criteria based on general IAQ indicators may provide a basis for verifying that conditions are returning to normal background. In this context, general observations can be used to determine if the area can be reoccupied.

Dust: The work site should be cleaned until there is no visible haze in the air and no settled dust on surfaces.

Odor: Ideally, there should be no detectable odor upon reoccupancy. This can often be accomplished by ventilating the site (continuously, if possible) for a period of time (*e.g.*, several days) after final cleaning. In situations where IAQ is not an absolute priority, odor of low intensity might be tolerated at reoccupancy if continued monitoring shows that it is eliminated within several weeks.

HVAC systems should be restored to good operating condition prior to reoccupancy. This will often involve rebalancing the system to ensure that it meets current occupancy needs. All ventilation and air distribution systems should be reasonably clean of dirt and debris (based on a detailed visual inspection.) The system should be started up before occupancy to confirm acceptable space conditions in regard to the control of odors, dust, ventilation, and thermal comfort.

For larger renovation projects, IAQ should be an integral part of the recommissioning of HVAC systems. This might include verification that mechanical equip-

ment has been cleared of construction contaminants and that systems have been rebalanced to meet new occupancy needs. For additional information on the commissioning or recommissioning process, *see* SMACNA's *HVAC Systems Commissioning Manual*, 1994.

5.5 PROJECT DOCUMENTATION

Concerns for liability dictate that efforts to address IAQ during construction be documented to demonstrate good faith. In this respect, IAQ controls in project specifications and communications between parties should be identified and saved. Similarly, inspection and any test results should clearly reflect site conditions. Occupant complaints should also be documented, including any findings by the investigator.

6.1 OCCUPANT EDUCATION

Educating office workers about the health effects of low level exposures to construction related dust and odors is helpful in preventing complaints and keeping minimal exposures in perspective. Building renovation is a disruptive and often traumatic period for occupants. Fear of environmental exposures may become a major factor, especially when unexplained emissions of odor or dust occur in occupied spaces. This may lead to unfounded complaints, rumors, and, in the worst case scenario, the spread of hysteria.

Preceding any major renovation project, potentially impacted occupants should be given a brief description of the work planned and precautions being taken for air quality protection. Any occupant concern should be discussed at this point and resolved, whenever possible. Occupants whose history suggests they may have adverse reactions (*e.g.*, be allergic to dust, chemicals) should be accommodated where possible. As demolition and construction progress, occupants should be periodically updated.

6.2 COMPLAINT RESPONSE

Despite careful planning and oversight, environmental incidents are sometimes unavoidable. A contingency program, including prompt response and clear communications with occupants, is essential at such times. Where exposures appear to have been limited to the nuisance category, explanations of the actual health risks should be made by qualified persons, such as an occupational physician or industrial hygienist. Actual health risks should be presented in proper perspective. Renovation work may need to be stopped until potentially significant health issues are resolved. Whether or not exposure can be attributed to construction activities, construction delays and added expenses for testing and evaluation can result from significant or continued occupant reported symptoms and concerns over poor IAQ.

The following illustrate typical IAQ problems and solutions associated with common construction activities.

7.1 MINOR OFFICE RECONFIGURATION

7.1.1 IAQ Issues

- How should potential contaminants from drywall, adhesive, and paint be handled?
- Should the work be done at night or during the day with controls?
- Will the existing HVAC system need to be modified in order to properly ventilate the two newly created work areas?

7.1.2 Chosen Option

The project was performed during the day, exhausting air to the exterior (portable fan in window, creating negative pressure) during dusty or odorous activities. Drop cloths and intensive housekeeping effectively contained dust. Local ducts and VAV boxes were inspected to verify cleanliness before closing the system. All supplies and returns were sealed with plastic. The HVAC system was modified to serve the two new rooms.

7.2 MAJOR CARPET REPLACEMENT

The existing carpeting is glued to the slab and must be stripped. The entire floor is scheduled for replacement with all furniture removed from the work area. The HVAC system can be shut off for this floor.

7.2.1 IAQ Issues

- Negative pressure needs to be maintained to prevent odor and dust from affecting occupants on adjacent floors.
- Stripping operations can be performed with natural gas or propane equipment. Can equipment exhaust be effectively removed from the building?
- Should windows be removed?
- Can existing exhaust risers be utilized for removal of odor and solvents?
- When should the adhesive application be performed?
- With minimal dust generation potential, should effort be expended to seal supplies and returns?

7.2.2 Chosen Option

This project was performed with two windows removed and exhaust fans installed to provide cross-ventilation and direct the stripping dust and adhesive odors outside. The HVAC was turned off and the grilles were covered with plastic. Pressure checks at other floors and stairs showed all air moving to work zone. A low solvent, water-based adhesive was selected along with a carpet meeting EPA voluntary emissions criteria. Exhaust fans were run extended hours the evening after carpet installation to remove adhesive solvents and new carpet odors.

7.3 ROOF REPLACEMENT

The roofing system is failing, with large tears allowing water to penetrate into the offices directly below. The built-up roof consists of felts and asphalt over a concrete slab. Two stairs serve the roof.

7.3.1 IAQ Issues

- Would disturbance of moldy roof and ceiling materials cause air contamination?
- What considerations should be given to the placement of the kettle?
- Should this operation be performed during occupied hours?

7.3.2 Chosen Option

Prior to roof and ceiling demolition, each area was checked for visible microbial growth. Interior plastic barriers were erected as needed to prevent migration of spores, and work areas were sanitized following demolition. Roofing installation was performed during the day with precautions to prevent odor and dust from contaminating occupied space. The kettle was located away from intakes and doors. The debris chute was covered and the dumpster located away from the HVAC intakes. Roofing workers were requested to use only one set of stairs. This stair had mats and extra housekeeping and was sealed from other areas.

7.4 HOSPITAL RENOVATION

A hospital laundry is to be converted into staff offices, with the exception of two end rooms which are to be separately ventilated as isolation facilities for the treatment of tuberculosis (TB) patients. The area is located adjacent to the Intensive Care Unit (ICU) and below Operating Rooms (OR). Each area is controlled by a separate air handler located in a common mechanical room, which also must be modified for the renovation. Demolition will involve the removal of old paint, plas-

ter, and drywall and dismantling of ductwork and piping. The ICU and OR must remain in continuous operation and contaminant-free.

7.4.1 IAQ Issues

- How can contaminants be prevented from entering the ICU (across the hall or through AHU) and the OR (through penetrations, stairwell, or AHU)?
- Preliminary review suggests that lead-based paint, cove base adhesive, cutting torch operation, and welding represent potential hazards. How should emissions be controlled?
- Handling of waste materials could be a source of dust and odor. How should this be managed?
- How can the renovated area be confirmed to have good air quality before being occupied?
- Should the work be done at night or during the day with a more complex set of logistics and controls?
- Will the existing HVAC system need to be modified to properly ventilate the newly created work areas?

7.4.2 Chosen Option

Due to the sensitivity of this project, barriers and negative pressure were maintained for the duration of work in each area. This included complete isolation of the for the ICU and sealing of penetrations from the work area, construction of asbestos removal type barriers, and placement of HEPA-filtered, portable exhaust fans in the exterior. Within the containment, appropriate personal protection was worn (*e.g.*, during lead-based paint removal and welding). The AHU for the work area was shut down and all supply and return vents sealed with plastic. Electrical rather than fuel-powered equipment was used for cutting, welding, and materials movement.

Following demolition, all surfaces, including HVAC equipment, were cleaned and sanitized. Wipe samples demonstrated compliance with lead-based paint clearance criteria before materials for reconstruction were brought into the work area. When all work was completed, all mechanical and building surfaces were reinspected and met visual inspection criteria before the contractor was released from the project.

Low emitting products were specified for paints, adhesives, carpets, and furniture. Maximum ventilation was provided continuously to the new office space for two weeks before and two weeks after occupancy. The testing and balancing contractor confirmed that the TB treatment rooms met criteria for isolation.

This Appendix is included for informational purposes only. It is not part of the requirements or recommendations of this document. For further information on IAQ:

The following document is available from:

Superintendent of Documents,
Government Printing Office
P.O. Box 371954
Pittsburgh, PA 15250-7954
Fax: 202-512-2250

Building Air Quality: A Guideline for Building Owners and Facility Managers, U.S. Environmental Protection Agency and the National Institute for Occupational Safety and Health (1991), S/N 055-000-00390-4. A practical guide to developing an IAQ program and resolving IAQ complaints. How to conduct a building evaluation and select corrective measures.

The following documents are available from:

SMACNA
4201 Lafayette Center Drive
Chantilly, VA 20151-1209
703-803-2980

SMACNA, *Indoor Air Quality*, Second Edition, 1993.

SMACNA, *HVAC Systems Commissioning Manual*, First Edition,1994.

Other references available:

Hays, Steve M., *Indoor Air Quality Solutions and Strategies*. McGraw-Hill, Inc., New York, NY, 1995.

American Conference of Governmental Industrial Hygienists, *Guidelines for the Assessment of Bioaerosols in the Indoor Environment*, Cincinnati, OH, 1989.

To order, call: 513-742-2020.

Rafferty, Patrick J., *The Industrial Hygienist's Guide to Indoor Air Quality Investigations*, American Industrial Hygiene Association IAQ Committee, Fairfax, VA, 1993.

To order, call: 703-849-8888.

U.S. Environmental Protection Agency, *Guidance for Controlling Asbestos-Containing Materials In Buildings*, 1985, EPA 560/5-85-024.

To order, call: Toxic Substance Control Act (TSCA) Hotline: 202-554-1404.

National Institute of Building Sciences, *Lead-Based Paint: Operations and Maintenance Work Practices Manual for Homes and Buildings*, Washington, DC, 1995.

To order, call: 202-289-7800.

This Appendix is included for informational purposes only. It is not part of the requirements or recommendations of this document. For assistance with IAQ issues:

National Institute of Occupational Safety and Health

Phone: 800-356-4674

- Current information on exposure assessment and control
- Copies of NIOSH Health Hazard Evaluations and Criteria Documents
- Request for Federal inspection of work site.

U.S. Environmental Protection Agency, IAQ Clearinghouse

Phone: 800-438-4318

- Literature on indoor air quality issues
- Contact with EPA researchers studying emissions from building materials and furnishings.

Your State and Local Health Department

- Advice and possible field assistance in resolving questions of exposure to indoor air contaminants.

American Conference of Governmental Industrial Hygienists (ACGIH). Publications on IAQ and related topics.

ACGIH
1330 Kemper Meadow Drive
Cincinnati, OH 45240
Phone: 513-742-2020

American Industrial Hygiene Association (AIHA). List of industrial hygiene consultants and AIHA-accredited laboratories able to perform IAQ assessments.

AIHA
2700 Prosperity Avenue, Suite 250
Fairfax, VA 22031-4307
Phone: 703-849-8888

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The planning and inspection checklists included in this Appendix cover a range of building systems and projects. These lists may be useful in documenting problem areas, identifying responsibility, communicating the problem to the responsible party, and serving as follow-up reminders.

The checklists are generic and include a list of items, not all of which are applicable for every project. Therefore, the lists should be used as generic masters, to be revised to suit the needs of specific equipment and systems in specific projects. Some items will not be relevant and should be deleted from the project checklists. Other items may need to be added.

It would be normal for companies managing construction activities to come up with their own set of master checklists, stored on computer, adding to them as variations are encountered. These can then be edited for specific projects very quickly and put into project files for printing and distribution.

Planning Checklist

Project/Phase/Area _____

_____

_____

_____

1.0 Potential Emissions	Source	Class
1.1 Materials disturbed		
1.2 New products		
1.3 Equipment operation		
1.4 System disruption		
1.5 Waste materials		

2.0 Pathway	Affected Areas	Worst–Case
2.1 HVAC recirculation		
2.2 Direct exposure		
2.3 Negative pressure		
2.4 Tracking		

3.0 Controls	Options	Comments
3.1 HVAC protection		
3.2 Product substitution		
3.3 Equipment modification		
3.4 Local exhaust		
3.5 Air cleaning		
3.6 Covering/sealing		
3.7 Negative Pressure		
3.8 Barriers		
3.9 Source relocation		
3.10 Dust suppression		
3.11 Upgraded cleaning		
3.12 Buffer zones		
3.13 Off-hours		
3.14 Move hypersensitives		

Instructions

For larger projects, review by phase or area (do separate checklist for each).

1.0 *See* text sections 2.1 and 4.2. Select Class 1, 2, or 3.

2.0 *See* text sections 2.2 and 4.2. Describe area and/or attach floor plan. Note approximate occupancy during impact. Discuss worst-case scenarios (emissions/occupancy/pathway).

3.0 *See* text Chapter 3 and section 4.2. Note pros and cons of each option.

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The checklists are generic and include a list of items, not all of which are applicable for every project. Therefore, the lists should be revised to suit the needs of specific equipment systems in specific projects. Some items will not be relevant and should be deleted from the project checklists. Other items may need to be added.

It would be normal for companies managing construction activities to come up with their own set of master checklists, stored on computer, adding to them as variations are encountered with some regularity. These can then be edited for specific projects very quickly and put into project files for printing and distribution.

General Inspection Checklist

(This can also be revised into a project-specific format.)

Project _____

Status _____

Date _____

Inspector _____

Contractor(s) _____

1.0 Active Work Areas	**Location**	**Odor?**	**Dust?**
1.1 Materials disturbed			
1.2 New products			
1.3 Equipment operation			
1.4 System disruption			
1.5 Waste materials			

2.0 Potentially Affected Areas	**Location**	**Odor?**	**Dust?**
2.1 HVAC recirculation			
2.2 Direct exposure			
2.3 Negative pressure			
2.4 Tracking			

3.0 Controls	Description	Status
3.1 HVAC protection		
3.2 Source control		
3.3 Pathway interruption		
3.4 Housekeeping		
3.5 Scheduling		

4.0 Occupant complaints/observations

5.0 Occupant complaints/observations

A

B

C

D

E

H

I

L

M

O

P

Q

R

S

V