IAQ Building Education and Assessment Model (I-BEAM)

Text Modules: Renovation and New Construction

Important actions to protect and improve IAQ during each phase of the design and construction process are presented in this module.

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Renovation and New Construction
(PDF, 14 pp, 79KB)

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Indoor Air Quality (IAQ)

Project Planning and Documentation

Programming

Establish IAQ design goals. For example, demonstrate that:

- Ventilation of outdoor air is consistent with ASHRAE Standard 62-1999 under all operating conditions.
- Comfort levels are acceptable to most occupants, and consistent with ASHRAE Standard 55, under all operating conditions.
- Significant expected sources of pollutant emissions are isolated from occupants using physical barriers, exhausts, and pressure controls.
- Outdoor air entering the building is protected from contamination from local outdoor sources and from building exhausts and sanitation vents.
- Full documentation of building and HVAC design with design intent for operation and maintenance.
- Provisions for easy access to HVAC equipment requiring periodic maintenance.
- Occupant exposure to construction contaminants is minimized using protocols material selection, preventive installation procedures, and special ventilation and pressure control isolation techniques.
- Building is thoroughly commissioned to insure that all IAQ design goals and related IAQ specifications are met.

Budgeting

Adequate budget to meet the IAQ design goals and specifications should be planned considering:

- Specialized services during each phase as may be needed: design, construction, initial occupancy.
- Time required for thorough commissioning and testing.
- Proper selection of the design team to include IAQ expertise.

Documentation Planning

As documentation accumulates, it should be organized and assembled in durable, moisture-resistant binders. Supplemented by operating and maintenance recommendations, project documentation creates a complete owner's manual for the building, and is good insurance against liability claims. Include:

- Documentation of project planning phase.
- Documentation of site and building design.
- Documentation of HVAC design.
- Documentation of construction and commissioning.
- Documentation of protection during initial occupancy.

Codes and Standards

Identify IAQ codes and standards to be met. For example:

- *ASHRAE Standard 62-1999, Ventilation for Acceptable Indoor Air Quality;*
- *ASHRAE Standard 55-1992, Thermal Environmental Conditions for Human Occupancy*
- *ASHRAE Guideline 1-1996, The HVAC Commissioning Process, can assist in establishing commissioning requirements.*
- *SMACNA Guidelines, 1995; IAQ Guidelines for Occupied Buildings Under Construction*

IAQ-Related Documentation during Project Planning

IAQ-related documentation during project planning would include:

- Building size and location.
- Types of occupants, noting special susceptibilities (e.g. young, elderly, people with asthma or other illnesses).
- Anticipated occupant densities (and potential for increased occupant densities), activities, and use patterns for each space.
- Major pollutant source activities.
- Uses requiring special environmental controls (e.g. computer rooms, libraries).

Site Planning and Design

Site Evaluation

Evaluate and document site conditions that can impact IAQ.

- General climate and site's microclimate, seasonal norms and extremes of temperature, relative humidity, wind speeds and directions.
- Local ambient air quality.
- Adjacent or nearby contaminant sources relative to building site and wind patterns.
- Potential future nearby sources (e.g. vacant nearby site zoned for industrial use).
- Outdoor noise sources.
- Soil and groundwater quality.
- Existing or potential underground contaminant sources (radon, underground fuel tanks, soil gas from landfill).
- Prior site history for potential soil or groundwater contamination (agricultural fertilizers and pesticides, landfill soil gases, toxic wastes from manufacturing plant).

Site Design

Plan the building location, orientation, and major site activities on the site to minimize contamination of the indoor environment. Relevant features should be documented, and noted on design drawings.

- Use setbacks as a means of separation from nearby pollutant sources. Since pollutants disperse quickly, a small increase in setback can mean a substantial decrease in pollutant concentration.
- Use landscaping as a buffer to offsite or onsite contaminants. Be careful not to place plants or soil close to air intakes where pollen, fertilizers or pesticides can

contaminate the air, or where overgrowth can block air entry. Consider full potential after plants have matured.
- Plan the shape and orientation of the building to allow prevailing winds to move contaminants away from the building. Avoid designs that would trap pollutants in stagnant air pockets.
- Provide for good water drainage and grading around the building foundation.
- Locate and design outdoor air intakes away from and upwind of pollutant sources.

Locate onsite pollutant sources away from and downwind of air intakes. Roadways, parking, loading areas, trash and chemical storage areas are typical sources.

Building and HVAC Design

Building Envelope

The building envelope will affect thermal comfort, HVAC capacity requirements, lighting quality (daylight) and view, potential infiltration of outdoor (or underground) contaminants, and moisture.

- Conduct thermal, moisture, and air migration analysis of envelope for maximum control.
- Use windows to provide daylight and views.
- Minimize radiant heat gains and losses through glass or uninsulated surfaces that will cause discomfort or unduly complicate HVAC design.
- Prefer thermally efficient building shells to increase thermal comfort and reduce HVAC loads and capacity requirements (reduce first costs).
- Avoid glare from windows or skylights.
- Use, and insure proper installation of, insulation to avoid cold spots with associated problems of condensation (mold) and thermal drafts.

Space Planning

Plan space uses to maximize the potential for isolating occupants from sources of contaminant through physical distance, physical barriers, exhaust systems, and pressure control.

- Identify all major sources of pollutants that may exist during occupancy.
- Plan spaces to isolate occupants from source contaminants.
- Provide for adequate exhaust; consider supplying loop of exhaust ductwork to facilitate later hookups.
- Develop pressure map to insure that contaminants from sources do not contaminate surrounding areas.
- Locate spaces with special environmental control needs where these needs can be efficiently accommodated.

HVAC Design

General Design Provisions

The HVAC system is critical to the building's ability to provide thermal comfort and ventilation of building contaminants. Outdoor air ventilation rate and indoor climate conditions should meet the design requirements (e.g., ASHRAE 62-1999 and ASHRAE 55-1992) under all operating conditions, including peak and minimum load.

Plan HVAC zones (with single thermostat) so that the thermal demands of all spaces within each zone are similar during all seasons. When different spaces having different thermal requirements are in the same zone, occupant discomfort is inevitable and solutions to complaints will be difficult (or impossible). Avoid placing thermostats in direct sunlight, near equipment or other heat sources, or on exterior walls.

Plan heating and cooling capacity to satisfy the peak (design) conditions that occur under extreme or worst-case conditions. Capacity requirements should be calculated considering both the sensible (heat) and latent (humidity) loads. Peak latent load may occur at subpeak sensible load. Capacity requirements should be calculated based on the outdoor airflow and thermal comfort requirements adopted in the design goals (e.g. ASHRAE 62-1999 and ASHRAE 55-1992).

Consider separate dehumidification prior to cooling, or energy recovery systems to improve performance and energy efficiency and reduce capacity requirements and therefore first costs. If humidification is needed, steam is preferred as a moisture source. The source of steam should be from potable water to avoid contamination from additives to boiler or steam water supplies.

Energy efficient building design, lighting, and HVAC design can reduce capacity requirements and lower first costs. (Energy Star)

Selected Design Provisions of ASHRAE 62-1999

ASHRAE Standard 62-1999 also identifies specific measures that should be taken to IAQ problems as they relate to the ventilation system. These measures are included elsewhere in I-BEAM, but it is useful to know that they are part of the ASHRAE Standard

Table 6.1 Selected Provisions of ASHRAE Standard 62-1999

Section No.	Standard
5.5	**Protect make-up air from sources:** Make-up air inlets and exhaust air outlets shall be located to avoid contamination of the makeup air. Contaminants from sources such as cooling towers, sanitary vents, vehicular exhaust from parking garages, loading docks, street traffic should be avoided. This is a special problem in buildings where the stack effect draws contaminants from these areas into the occupied spaces.
5.5	**Soil gases:** Ventilation practices that place crawlspaces, basements, or underground duct work below atmospheric pressure will tend to increase radon concentrations and should be avoided. (1)
5.6	**Microbial contamination of ducts:** Ventilating ducts and plenums shall be constructed and maintained to minimize the opportunity for growth and dissemination of microorganisms through the ventilation system.
5.7	**Stationary indoor sources:** collection and removal shall control contaminants from stationary local sources within the space exhaust as close to the source as practicable.
5.8	**Fuel-burning appliances:** Fuel-burning appliances, including fireplaces located indoors, shall be provided with sufficient air for combustion and adequate removal of combustion gases. The operation of clothes dryers and exhaust fans may require introduction of additional makeup air to avoid interference with fuel-

	burning appliances.
5.8	**Exhaust outlet:** Combustion system, kitchen, bathroom, and clothes dryer vents shall not be exhausted into attics, crawlspaces, or basements
5.11	**Relative humidity to control microorganisms:** Relative humidity in habitable spaces preferably should be maintained between 30% and 60% to minimize growth of allergenic or pathogenic organisms.
5.12	**Microbial contamination in HVAC equipment:** air handling unit condensate pans shall be designed for self-drainage to preclude the buildup of microbial slime. Provisions shall be made for periodic in-situ cleaning of cooling coils and condensate pans.
5.12	**Humidifier controls:** Steam is preferred as a moisture source for humidifiers, but care should be exercised to avoid contamination from boiler water or steam supply additives. If cold water humidifiers are specified, the water should originate from a potable source. Care should be taken to avoid particulate contamination due to evaporation of spray water.
6	**Contaminants:** Indoor air should not contain contaminants that exceed concentrations known to impair health or cause discomfort to occupants.
6.1.3.1	**Exhausted sources:** Rooms provided with exhaust air systems, such as kitchens, baths, toilet rooms, and smoking lounges, may utilize air supplied through adjacent habitable spaces to compensate for the exhausted air.
6.1, Table 2	**Office equipment:** Some office equipment may require local exhaust.
Forward	**Operation of the building:** Conditions specified in the Standard must be achieved during operation of buildings as well as in the design.
5.12	**Preventive Maintenance:** Air handling and fan coil units shall be easily accessible for inspection and preventive maintenance.
(1) This is true of any soil gas, such as sewer gases, or VOCs from underground storage tanks, contaminants for solid waste dumps, etc.	

HVAC Commissioning (Pre-Design and Design Phase)

See ASHRAE Guideline 1-1996, *The HVAC Commissioning Process* for detailed recommendations.

- Commissioning is a process to insure comprehensive planning, thorough documentation, and systematic implementation of plans.
- Commissioning begins in the pre-design phase, lasts throughout the construction process and into initial occupancy of the building.
- Systems may need to be re-commissioned periodically over the life of the building, particularly when changes in occupancy or equipment occur.
- Commissioning itself is an expense, but since it eliminates many problems, which add to construction costs, it need not add cost to the total construction budget. For example, commissioning the San Francisco Public Library was funded out of monies originally budgeted for contingencies.
- Commissioning can significantly increase energy efficiency and improve the indoor air quality of the final building.

HVAC Commissioning Planning

- Establish HVAC design criteria.
- Document HVAC design criteria and systems description.

- Prepare commissioning plan.
- Establish verification procedures.
- Document requirements for commissioning process:

Reports and submittals

- Drawings and schematics
- Checklists
- Operating and maintenance data
- As-built documentation

Exhaust of Indoor Sources and Pressure Control of Sources (Also see Section in HVAC Chapter)

Where major indoor sources are expected, exhaust ventilation and proper pressure control should be planned. Systems with direct exhaust from sources that also generate heat (e.g. copy machines) may also reduce HVAC energy requirements.

- Provide adequate exhaust for all localized sources of contamination.
- Plan for proper airflow and pressure control around sources.
- Seal return air plenum from exhaust air.
- Plan adequate source of make-up air (may be transferred from surrounding spaces).
- Insure room is under negative pressure relative to surrounding spaces and return air plenum.
- Smoking rooms should have 60 cfm of exhaust per person calculated at maximum capacity.

General Air Circulation and Pressure Differentials

The patterns of air circulation and flow, between outdoors and indoors, from basements and crawl spaces, between floors, and between spaces on each floor may be more important to IAQ than the HVAC system or system components. Air circulation patterns showing areas of positive and negative pressure should be drawn for the building as a whole, and for all occupied spaces and major source areas.

The flow of outdoor air into the building must be planned to slightly exceed the total airflow out of the building from all exhausts, combustion flues, and stack effect exfiltration to insure that the building is positively pressurized, to avoid infiltration of outdoor pollutants. (In cold climates the risk of condensation in the building envelope increases if the building is pressurized so that moisture control may be the dominant concern in planning pressure relationships.)

Consider air flow and pressure relationships under worst case scenarios (e.g. kitchen exhaust fans running full in cafeteria. Consider the effect on a neighboring print room, or a boiler room where backdrafting of the flue is a possibility.

Avoid underground ducts or a duct through crawl spaces where possible.

Prefer ducted returns. Non-ducted returns complicate system balancing resulting in the potential for areas of stagnant air, undesirable pressure relationships, and contamination of the return airflow.

Develop a program statement that defines the range of possible occupant densities, activities and layouts to allow the designer to plan flexibility or sufficient capacities for future changes. Specify alterations to the system that can be accommodated under the HVAC design used, and what changes to the system would be required.

Carefully analyze location of supply and return air grills for all occupied spaces, as well as the throw capacity of diffusers, and airflow pathways. Map the anticipated airflow patterns to insure proper air mixing (or plug flow airflow if that is planned). Avoid short-circuiting of supply air to return air. Also avoid dead spaces (e.g. provide for a 2-3 inch air space between the floor and workstation partitions to facilitate air circulation).

Filtration

Particle pollutants cause mucus membrane irritation and other effects, and can foul ventilation system components and reduce efficiencies. Fine particles comprise only a small portion of the total particle mass, but constitute the overwhelming majority of the number of particles. Filtering larger particles is most important for protecting equipment, while filtration of finer particles is most important for human health and comfort.

Filtration efficiency for a given filter will vary with particle size. Thus, a filter rated as 40% efficient by the ASHRAE dust spot method will have about that efficiency for large (above 2.5 microns) and very small (0.01 microns and less) but have close to zero efficiency at 0.1 to 0.5 microns.

- Specify specific filter rating in the moderate or higher efficiency range, and design system for anticipated pressure drop.
- Low efficiency filters (e.g. ASHRAE Dust Spot rating of 10%-20%), if loaded to excess, will become deformed and even “blow out”, leading to clogged coils, dirty ducts, reduced indoor air quality and greater energy use.
- Moderate efficiency filters (e.g. ASHRAE Dust Spot rating of 40%-65%) have more body, are easier to insure a tight fit, and are less subject to blow out.
- Higher efficiency filters are often recommended as a cost-effective means of improving IAQ performance while minimizing energy consumption.
- Filter installations should be designed for ease of inspection and replacement, and to minimize bypass airflow.

Air Cleaning

Air cleaning may be considered as a means of control for specific contaminants experienced from a nearby outdoor source, or an unusual indoor source. Air cleaning mediums (e.g. treated charcoal, potassium permanganate) should be chosen carefully to insure effective target contaminant removal.

Materials Evaluation and Selection

Selecting Materials

Work with manufacturers to select products with the desired emission profile, and develop a strategy to minimize building contamination during installation. Require information about emissions from manufacturers. Manufacturers have both a marketing and liability motivation to test their products. Testing laboratories and emission testing protocols are rapidly developing. In selecting materials, investigate the materials potential to pollute the indoor environment in four key areas:

1. Release of particles, fibers, or chemicals inherent in the material selected.
2. Potential ability of chemical molecules or particles in the air to adsorb (physically attached) to the material and be released later (e.g. during warm weather or when disturbed).

3. Potential for microbial growth on material surfaces.
4. Maintenance or refurbishing requirements requiring chemical treatment that can become pollution sources.

- Wet-applied" materials such as caulks, paint, adhesives, are of particular concern because of the high emission rates experienced while curing.
- Fast drying materials offer greater flexibility in developing strategies to minimize contamination of other building materials.
- Materials used in areas, which are likely to become moist, or wet (e.g. kitchens/showers, downstream from cooling coil, area around humidifier) can foster microbial growth if a carbon source is available. Easily cleaned, smooth surfaces are recommended.
- Use of fibrous material, including fiberglass insulation in ducts, requires careful consideration of the potential for soiling. Soiled fiberglass will take on moisture much more rapidly than clean fiberglass creating the potential for microbial growth. Particles provide carbon, and the fiberglass matrix provides self-sheltering surfaces for microbial growth.
- Fleecy materials covering large areas, such as carpeting, fabric upholstery, textile wall coverings, or ceiling tiles, all can adsorb chemical and particle contaminants during the finishing stage of building construction, and release it later after occupancy. When wet, these surfaces also foster microbial growth.

Strategies for Selection and Installation of Materials

- Identify target products of particular concern, considering potential emission rates, toxicity, and quantity used.
- Gather information from manufacturers, suppliers and other sources.
- Require specific testing, if necessary, of emissions over time.

Select and/or negotiate for materials with low emissions and quick decay rates where possible. Use this information to determine strategies for the sequence of installation and the ventilation strategies during installation. Negotiate pre-shipment storage techniques that accelerate emissions of partitions, carpets and similar materials prior to installation. Sometimes perforated containers can serve to facilitate off gassing during shipment.

Construction

Many IAQ problems occur as a result of poor construction practices, change orders, or field orders. Monitoring all work is critical to good IAQ.

Monitoring the Construction/Renovation Process

Monitor field orders, shop drawings, and change orders impacting IAQ specifications and designs. Check deviations from construction documents. Monitor IAQ specifications during progress by inspections, and check that products and materials specified are being used.

- Obstacles or construction debris in ventilation airflow paths.
- Proper installation of insulation, HVAC equipment, ductwork
- Monitor HVAC system testing and balancing as it occurs.
- Monitor contaminant isolation and control strategy during construction/finishing.

Emission Control During Construction/Renovation

Protect current and future occupants during construction.

- Accelerate emissions of wet products by using high ventilation.

- During high emission periods, protect workers and increase ventilation.
- Delay installation of adsorbent (fleecy) materials such as carpet, furniture, or ceiling tiles until emissions from other construction contaminants (e.g. wet product emissions) have dissipated. Otherwise, these materials will adsorb the contaminants and later release them during occupancy.
- Protect ducts from construction dust and debris. Keep ducts clean.
- Delay occupancy until emissions have subsided.
- Continue high ventilation rates for a significant period after occupancy.

Isolation of Construction / Renovation Contaminants When Occupants are Present

An isolation strategy is usually a necessary condition for effective IAQ control, but it is made more feasible to achieve when pollutant emissions are also controlled through material selection and installation strategies.

- Establish a complete physical enclosure to the construction zone.
- Seal all return ducts to insure that contaminants do not enter the HVAC system.
- Using existing and temporary exhaust fans (negative air machines) establish a containment zone under significant negative pressure (e.g., 5 to 10 Pa. or 0.02 to 0.04 w.g.). The supply air to the construction area may also need to be shut down.
- Monitor pressure relationships to insure that the containment zone is under significant negative pressure, and that the construction zone beyond the containment area is under negative pressure relative to all surrounding occupied spaces on the same and on adjacent floors.
- Insure that exhausted contaminants do not re-enter the building through open windows or the air intake of the HVAC system.
- Maintain the occupied spaces under positive pressure relative to the outside.

After Construction

Check the Building Envelope

Check the integrity of the entire building envelope by performing the following:

- Flood test flat roof systems for leaks (do not exceed design live loads).
- Inspect flashing for signs of leakage.
- Inspect doors and windows for operation and weather-stripping.
- Inspect windows and solar equipment (e.g. solar shades) for proper installation and solar angle.
- Verify that outdoor air is not entering the building through openings near loading dock or other sources of pollution.

Commissioning of HVAC System (Construction Phase)

Proper commissioning in the construction phase insures that the building is built correctly and that it works right before occupancy. See ASHRAE Guideline 1-1996, *The HVAC Commissioning Process* for detailed recommendations.

- Test and balance system.
- Test system performance under full and part load conditions.
- Test outdoor airflow at breathing zone in the occupied spaces under full and part load conditions.
- Review system operation and documentation.
- Test pressure relationships consistent with an air pressure map showing areas of planned positive and negative pressure.
- Assemble all relevant parties to discuss system; answer any questions about system sequences, set points, and operation; and review all documentation prior to

submittal.
- Insure that part of the documentation includes operating and maintenance procedures, and an air pressure map.
- Submit documentation.
- Train operational and maintenance personnel on all the operating and maintenance practices required for the particular HVAC system and other systems in the building.

Initial Occupancy After or During Construction/Renovation

Protocol for Ventilation System Operation under Initial Occupancy Conditions

Special HVAC strategies should be employed for an extended period after initial occupancy.

- Extend hours of ventilation system operation.
- Increase outdoor air fraction and operate at reduced temperatures during occupancy.
- Increase outdoor air fraction during unoccupied periods.
- Measure key contaminants such as formaldehyde and total volatile organic compounds (TVOC) as a means to judge when the HVAC system can return to normal operation.
- Run HVAC continuously and increase outdoor air fraction during first hot weather period.

HVAC Verification under Occupancy Conditions

Verify system components are all operational and system meets performance requirements under all operating conditions (full and part load) when the building is occupied.

- Verify outdoor air louvers are open and working correctly.
- Verify that all interior spaces are receiving design quantities of outdoor air.
- Verify that fans in air handling units operate continuously during occupied periods.
- Verify that all supply registers/diffusers, and return grills are open and unobstructed. Adjust diffusers to insure proper mixing and to avoid drafts on individual occupants.
- Verify the operation of all VAV boxes according to design.
- Verify that local exhaust grilles and hoods are operating correctly.
- Check for backdraft from all combustion appliances under worst case scenarios.
- Check air pressure relationships according to original plans.

Indoor Air Quality Evaluation

Evaluate IAQ by conducting a building walkthrough to identify problems. Talk to occupants to identify problems.