**Creating and Maintaining Good Indoor Air Quality**

Good indoor air quality (IAQ) management has become paramount in the construction industry as study after study shows that employee productivity and health are directly related to the quality of air being delivered inside the workplace environment. The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) is an organization founded in 1894 which researches and publishes standards for the IAQ. In 1973 ASHRAE first published Standard 62 (now Standard 62.1) which specifies minimum ventilation rates and other measures for new and existing buildings that are intended to provide indoor air quality that is acceptable to human occupants and minimizes adverse health effects. The new Standard 62.2 covers residential occupancies which were formally grouped with Standard 62.1.

As buildings become smarter due to advancements in technology and new building codes require minimum air change rates within occupied buildings, the IAQ industry is growing. Strategies such as CO2 monitoring, demand-controlled ventilation, ventilation energy recovery, dedicated outdoor air systems, ultraviolet germicidal irradiation, displacement ventilation and underfloor air distribution are becoming more commonplace due to the positive effect on building operations, lower energy costs and improved IAQ. A study published by Navigant Research, a company which provides in-depth analysis of global clean technology markets, forecasts that revenue for IAQ monitoring and management technologies will increase to over $5.6B by the year 2020.

Contaminants can come from outside as well as from inside the building. There are several different origins of contaminants such as entrained contaminants that come from outside the building and are introduced through the HVAC system or other intakes and openings into the building.

The intake of Outside Air (OSA) for a system is covered prescriptively by the building codes. Distances to flues, vents, exhaust discharges or any elements that would generate harmful or odorous conditions are given as a minimums for locations of OSA intakes. For many circumstances these code prescribed minimums do not provide adequate guidance for the proper location of OSA intakes. Gas phase contaminant emitters are the most problematic relative to this issue. An example of this would be the placement of diesel engine generators. Not only are odors an issue but exceeding exposure limits of carcinogens for the building occupants is also a major concern. Early on in the project, at the schematic design phase, emitters of this kind must be identified and analyzed to prevent unintended consequences. There are computational fluid flow software programs that can be utilized to perform a computer model of the surrounding intakes and emitters that can predict odor potential and estimated exposure levels. Many consulting firms specialize in this area and should be consulted to perform this analysis. Scaled models of the existing or proposed conditions can be developed in an effort to predict exposures but this is not as common, as the fluid flow programs have become much better at predicting results and can be done at a fraction of the cost.

This analysis can be applied to any of the following emitter types:

- Diesel Engines (Generators)
- Natural Gas Fired Equipment Flues
- Open Cooling Towers
- Food Preparation Exhausts
- Fume Hood and Bio-Safety Hood Exhausts
- Sewage Pump Station Vents
- Grease Interceptor Vents
- Animal/Live Stock Areas

This is a good investment for the project team, and detailed analysis is strongly recommended for determining the placement of these emitters relative to OSA intakes and openings into the building.

Indoor contaminants can be an even bigger problem for the occupants of the building. These include processes that take place in a laboratory, infectious patient isolation rooms, odorous rooms for storage of soiled linen or contaminated items to name a few. The first level of containment is to remove the contaminants at the point of generation. This is done with the use of fume hoods and bio-safety cabinets in a laboratory. Functions that need to be contained to protect the occupants are performed within the hood to capture the contaminants directly and exhaust them outside the building through a dedicated exhaust system for the type of contaminant being generated. The discharge for these exhaust systems needs to be high on the building with adequate airflow stack velocity to create the required plume height out of the stack. This assures that adequate dispersion of the contaminant will not allow reintroduction of the contaminant back into the building or create unsafe concentrations adjacent to the building.

Often the processes that generate contaminants are not in a laboratory setting where manufactured hoods are available for the protection of the occupants. These applications are industrial in nature and can include welding, plating, painting, manufacturing processes, sterilizer equipment discharge and oncology functions within a hospital. These types of contaminant generators are endless. For industrial types of contaminant mitigation, the “Industrial Ventilation Handbook” published by the American Conference of Governmental Industrial Hygienists can be consulted to design custom hoods and devices to provide good capture of localized contaminants within a building space. The practices within the Handbook provide guidelines for the development of hood design and capture velocities to be used to establish the inlet velocity at the exhaust system intake to ensure good capture of the contaminant at the point of generation.

The second level of defense against contaminants is to segregate the potential contaminants into spaces that do not directly communicate with adjacent spaces. The contaminated spaces would then be 100%

exhausted to the outside of the building with special consideration of placement of the discharge relative to the building intakes and openings to prevent reintroduction into the building. This coupled with capture hoods, either manufactured or custom designed, can provide a great deal of protection to the building occupants.

Once you have identified the zones of the building that will need 100% exhaust, it is imperative to have good air balance between these spaces and adjacent spaces of the building that require protection. Positive airflow to the adjacent spaces, that do not contain contaminants, needs to be maintained and variable volume control for the air system should be employed to assure positive air balance relationships between the contaminated room and clean spaces of the building. Hospitals utilize air volume offset for the most spaces except for infectious patient isolation rooms where pressure control is frequently used since vestibules are usually included in the space design. Volumetric control is more predictable in a hospital setting, as most spaces do not have vestibules as in a laboratory setting or a clean room environment. This makes it more difficult to achieve a pressure relationship between the dirty and clean rooms as there is not a stable reference point to take a pressure reading, as within a vestibule between the clean and dirty spaces.

Consideration also needs to be given to the architectural design of these spaces. The number of exits and openings to adjacent spaces and the relative tightness of the construction will determine the amount of positive airflow that will be required to maintain a volumetric or pressure offset between clean and dirty spaces. Whether or not sweeps and gaskets are needed on the doors of these spaces, (especially when dealing with odors) should be considered. Full height walls above the ceilings of these spaces is recommended. The need for vestibules between dirty and clean spaces to maintain a stable air or pressure balance must be considered early on in the project so that ample program space is dedicated to this function. Additionally, return air plenums should not be allowed to communicate with ceiling spaces above dirty isolated areas by creating full height plenum walls above the ceiling.

Something that is often over looked is the generation of biologicals on the cooling coil surface of an HVAC system. The use of ultraviolet lights within HVAC systems is becoming more prevalent and widely used eespecially in high humidity regions. Even if the client does not want to include UV lights to begin with, the designer should include space and power for them to be implanted at any time in the future. The use of these devices is required to be interlocked with the access to the air handling equipment as they can be harmful to the maintenance staff if exposed for even brief periods of time.

Another useful tool in the IAQ tool belt is Demand Control Ventilation utilizing CO2 & VOC monitoring as the control parameter. This can insure that the levels of CO2 & VOC's never go beyond an acceptable level. The control system can be overridden to introduce more OSA to the space to prevent exposing occupants to unacceptable levels of these contaminants. Tracking of these parameters is of great value to determine the buildings base ventilation demand rate that is needed to offset indoor generated contaminants even during low occupancy levels. This can then be coupled with required ventilation rates during high occupancy periods to predict adequate ventilation levels so that the system does not fall behind in meeting the occupant demand.

IAQ can be compromised during the construction of a new building and also within an existing building during a remodel. Containment and sealing of the duct system components from fabrication until placement at the site is absolutely necessary and should be verified by good tracking processes with adequate records of each piece of the system. During the installation process ductwork should be kept sealed at the unfinished portions of the system at all times during construction to prevent construction debris from entering the HVAC system.

Conducting construction within an occupied building requires an even higher level of care than new construction.  Within a hospital, Infection control is the main driver for practices to reduce the risk of infection for patients within the healthcare environment.  The use of temporary containment structures with negative pressure fan systems and HEPA filtration of the exhaust is vital.  These temporary spaces must have monitoring devices that record the negative pressure of the temporary containment space to prove the effectiveness of the containment structure on a continuous basis.  Other methods that reduce the risk of infection are walk off sticky mats at entrances and exits of the temporary enclosures.  The use of vestibules for the construction workers to gown and dispose of contaminated gowns when entering and leaving the containment structure is good practice.

For any strategy to work the system must be set up correctly.  Commissioning and maintenance of the system is critical to meet and maintain the systems ventilation requirements.  Keeping the ventilation system design simple with minimum components and control sequences,  will help reduce the risk of the system performing poorly over its lifespan.

One way to accomplish this is to have a dedicated fixed minimum outside air damper for the system so that there is no need to adjust for the minimum amount of outside air when the system is not in economizer mode.  Once the system is tested and balanced the minimum OSA quantity damper is set and does not need to be reset or adjusted going forward unless there is a change of function.  When the economizer dampers fail or there is an issue with cooling or heating the building satisfactorily, the OSA dampers are often adjusted closed and the building is starved of the required OSA quantity.  By having a minimum OSA damper that is tested and verified at the end of the project, the risk of this can be reduced greatly.  A simple check and alarm of the OSA, RA and Mixed air temperatures can verify that the proper amount of minimum OSA is being delivered to the system through this dedicated OSA damper at all times.

Commissioning plays an important role in ensuring IAQ requirements meet the intent of the design engineer. Division 1 specifications typically define the role of both the contractors and the commissioning agent. The commissioning agent is brought on board early in the design phases and provides review of the construction documents at certain milestones of the HVAC design development. Once the project is awarded to the contractor they are tasked with creating an IAQ plan for the commissioning agent to review and approve. This IAQ plan may require a pre-occupancy "flush out" of the HVAC system to ensure that the air being delivered to the building is free of any dust or chemicals that may be residing in the equipment or ductwork and void of volatile organic compounds (VOC) that originate from building materials commonly used in construction including adhesives, wood and plastic laminates, furniture and paint. Short term and long term exposure to VOC's can cause irritation to the eyes, nose and throat as well as headaches and nausea. VOC's also increase the risk of cancer, liver damage and harm to the central nervous system. Other areas that the commissioning agent considers are temperature, humidity and outside airflow levels. Technology helps the commissioning agent through trend logging of the controls that are installed as part of the project and through field verification utilizing data logging. All of the results are compiled and reviewed to ensure the IAQ requirements are verified prior to the occupancy of the building.

Several points need to be considered in creating good IAQ for any project or building. As we have discussed identification of contaminates during the design phase, whether they are inside or outside the building, is very important. For outdoor contaminants, placement of the intakes and discharges of the building are important relative to other emitters that may be present at the building location. Indoor contaminants need to be isolated and captured at the source with either manufactured or properly designed hoods or capture devices. Architectural features must be implemented as the leakage and configuration of dirty spaces is key to the HVAC system's success in supporting good IAQ. For ongoing performance, initial commissioning of the building systems and ongoing monitoring of IAQ parameters is very important.  Monitoring $CO_2$ and VOC levels and the simplification of control strategies and equipment components will make certain that the building can maintain the commissioned level of IAQ throughout its lifetime.