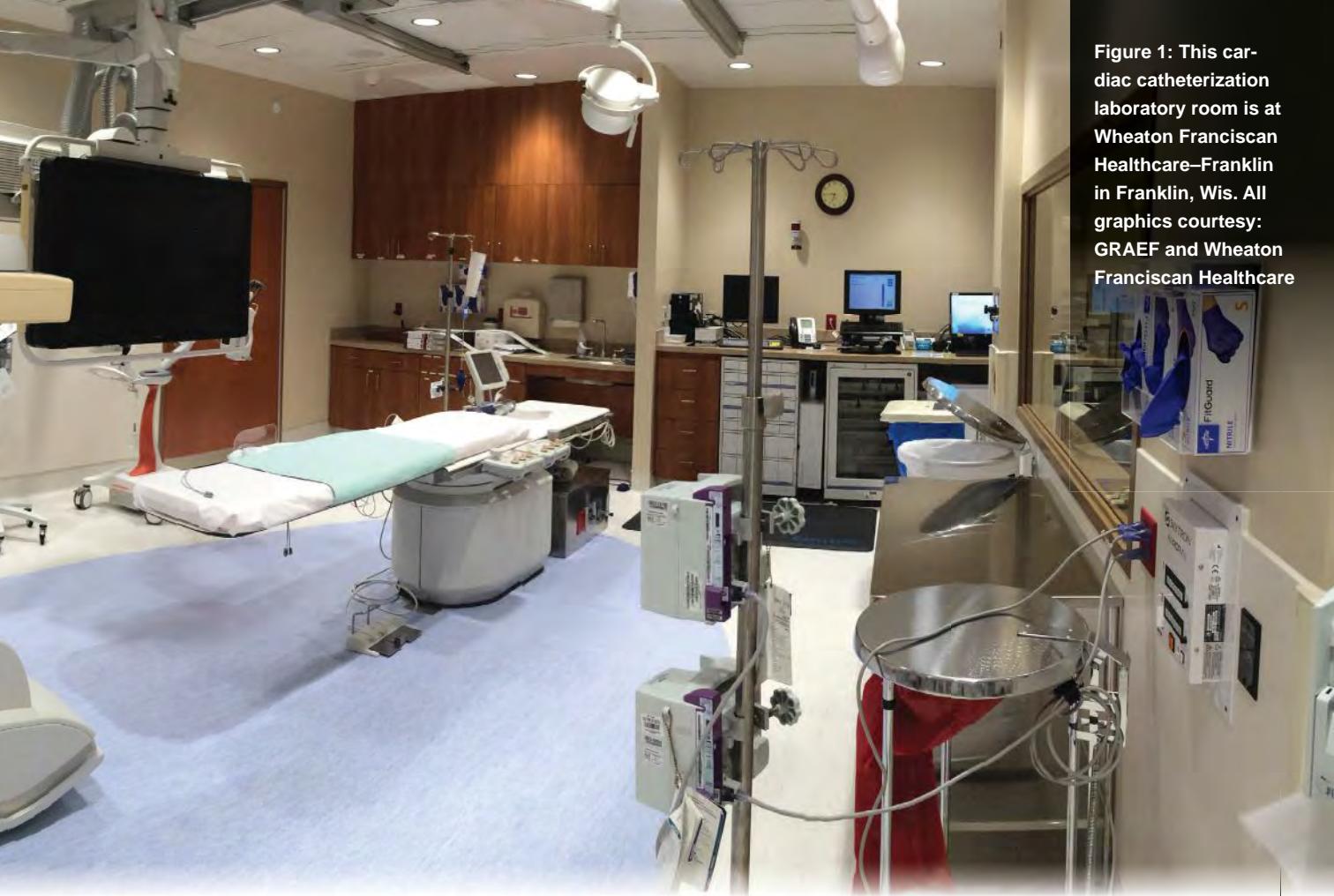




# Indoor air quality in hospitals

Hospitals and health care facilities must comply with ASHRAE and other regulatory standards with respect to air change rates, humidity requirements, and pressurization. ASHRAE Standard 62.1 is the most commonly referenced standard to meet appropriate HVAC system design. Other factors to consider include the use of UV light to reduce hospital-acquired infections, unique air requirements, and outdoor air systems.

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**Figure 1:** This cardiac catheterization laboratory room is at Wheaton Franciscan Healthcare—Franklin in Franklin, Wis. All graphics courtesy: GRAEF and Wheaton Franciscan Healthcare

Indoor air quality (IAQ) encompasses a wide variety of factors: temperature, humidity, quantity, presence of chemicals and other contaminants, and the quality of outdoor air brought inside are typical metrics used to define IAQ. The concept of IAQ is especially important with regard to the environments within hospitals and other health care facilities. The patients within the facility and the staff caring for those patients are all directly impacted by the quality of air in the building. IAQ is also a component of sustainable concepts that are incorporated into the design of such facilities. Improved IAQ is a viable goal for overall improvements in building occupant satisfaction at hospitals and other health care facilities.

Patients are the sole reason hospitals and health care facilities are in business. Hospitals have been traced back as far as ancient Egypt and Greece, where temples to Asclepius—the Greek god of medicine, healing, rejuvenation, and physicians—were created to offer medical advice,

discussion, understanding of afflictions, and methods to heal those afflictions. In fact, the “rod of Asclepius,” which is a staff with a snake wrapped around it, is still used as the symbol of medicine to this day. Patient safety and comfort are the top priority of any health care organization.

Medicare and Medicaid account for 55% of all care provided by hospitals, and nonprofit hospitals are required to accept Medicare and Medicaid reimbursement benefits. In 2008, the Centers for Medicare and Medicaid Services (CMS) refused to offer reimbursement for some nosocomial infections (infections that were acquired in a hospital), which had a direct impact on the finances of health care organizations. In 2012, they included additional nosocomial infections to the list of maladies that would not qualify for reimbursement. Patient comfort is reflected in hospital ratings such as Press Ganey Survey rank-

### Learning objectives

- Understand what defines indoor air quality (IAQ).
- Learn why IAQ is an important factor in hospitals and health care facilities.
- Learn what methods may be employed to improve IAQ.

ings and the Hospital Consumer Assessment of Health care Providers and Systems (HCAHPS). Such patient-satisfaction survey results also directly impact the funding CMS provides to health care organizations. As a result, hospitals and other health care facilities have focused on measures to reduce their nosocomial infections and increase patient comfort, with IAQ being one of the components.

The staff is just as important as patients to the viability of health care organizations. Staff for these organizations is comprised of the doctors, nurses, housekeeping, maintenance, administration, etc. The indoor environment impacts the productivity, morale, health, and welfare—and ultimately retention of a facility’s workforce. In a study by Lawrence Berkeley National Laboratory, for instance, they found that improved IAQ improves worker productivity by 0.5% to 5%—a national workforce

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**Figure 2:** Laminar-flow supply-air diffusers are shown in a cardiac catheterization laboratory room at Wheaton Franciscan Healthcare—Franklin in Franklin, Wis.

impact of \$20 billion to \$200 billion. These impacts provide health care organizations the incentive to improve the environment for their workers, and once again IAQ is part of that equation.

Hospitals and health care facilities look to sustainable design concepts to reduce energy consumption and to generally try to represent good stewards of the environment. Additionally, several municipalities and other governmental agencies actually require U.S. Green Building Council LEED certification or LEED-equivalent design efforts for all buildings—including hospitals—under their jurisdictions. The 2003 Commercial Building Energy Consumption Survey (CBECS) identifies that hospitals spend 10 times more on energy use on a per-building basis than other building types—to the tune of \$8.8 billion in energy costs per year. A figure this daunting provides a sizeable target for health care facilities to focus on to reduce costs. Anomalies in an updated CBECS in 2007 led to a revised study in 2012. The results of the 2012 CBECS are expected

to be released at the end of 2015, but there certainly still are savings to be pursued.

### **Detriments to IAQ**

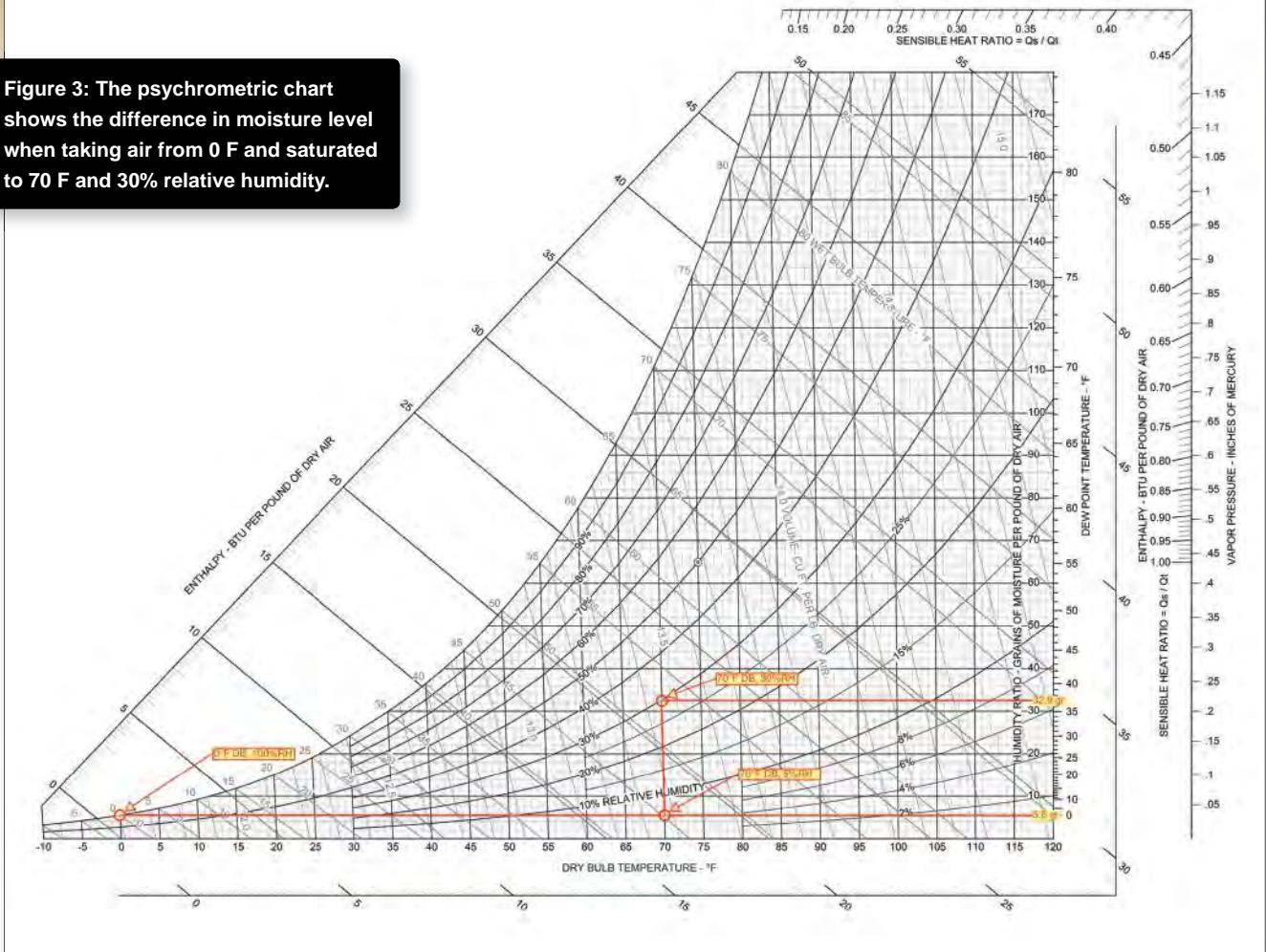
To improve IAQ, engineers and designers must understand the components that can impact it. For health care facilities, these components typically fall into four major categories: the patients, the staff, the building, and the outdoor environment. By looking at each of these categories in depth, designers can develop methodology to ensure detriments to IAQ are addressed and minimized.

Patients may be one of the main reasons to improve IAQ, but they also are a considerable source of air contaminants. The patients are at these facilities because of various health concerns, which can include infections, viruses, and other diseases. Patient coughing can introduce contaminants into the air and onto adjacent surfaces. Bodily fluids as a result of wounds, infections, incontinence, and other reasons can be transferred from the patient to clothing, bedding, and other surfaces.

Wounds and other infections and diseases, as well as various medical procedures, can introduce objectionable odors into the air.

Facility staff is typically in immediate contact with all of the contaminants identified as being generated by the patient. Hand-washing, the use of gloves, and the proper disposal of soiled gloves, bandages, and dressings are important components of a facility's hygiene protocol that, when not followed, introduce the potential to spread the contaminants generated by the patient. A facility's staff doesn't just include those with direct patient interaction. Housekeeping employees responsible for keeping the building clean is another source of IAQ contaminants based on their methods and use of chemicals for cleaning and disinfecting. Carting of trash and other waste products can offer a source of particulate contamination to the air if the waste is not covered properly. The chemicals used for cleaning can introduce objectionable odors into the indoor environment. If the cleaned surfaces don't dry properly, they can provide an opportunity for mold growth.

**Figure 3: The psychrometric chart shows the difference in moisture level when taking air from 0 F and saturated to 70 F and 30% relative humidity.**



The building itself can offer other sources detrimental to good IAQ. The ductwork used to distribute air throughout the facility can become dirty over time and trap various contaminants such as dust, dirt, and even biological organisms. Moisture from HVAC humidification can condense within the duct system. Moisture can also seep into various building components from breaches in the building envelope, concealed leaks, or even overspray from the cleaning process. This moisture can instigate mold growth over time, which is often undetected until the problem becomes substantial. Even the transportation of dirty linens throughout the building can present a detriment to IAQ.

Outdoor air, on the surface, would hardly seem to be considered a potential detriment to IAQ. While outdoor air is introduced into buildings to freshen the IAQ, its ability to actually improve it is dependent on the conditions of the air and from where it is drawn. Vehicle traffic and emergency-generator exhaust are two very common contaminants that can be drawn in with

the outdoor air. Keeping in mind that IAQ also comprises temperature and humidity, too much hot, humid air that exceeds the building's air-handling systems' capabilities to condition it will result in temperature and humidity within the building that are outside of the desired range. Insufficient (where not enough filtering is provided) or deficient (where filters have not been properly replaced when necessary) filtration within the air-handling systems also offer the opportunity for various contaminants to be distributed via the airstreams throughout the building.

#### Maintaining acceptable IAQ

There are several codes, standards, and guidelines available that provide guidance on the airflow rate, temperature, and humidity to be maintained for various health care spaces. "Code minimum" is just that—the bare-minimum levels that must be provided for the inspector to grant occupancy. If a facility relies on funding from Medicare and Medicaid, then CMS requirements (see below) will also need to

be achieved. If a facility is being designed to LEED standards, further standards related to airflow and filtration must be met.

ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality, which was originally issued in 1973 (as Standard 62) and is currently the 2013 edition, is a recognized industry standard that directly addresses IAQ. This standard is also referenced by LEED rating systems. The standard addresses air temperature, relative humidity, contaminants, air-distribution systems, and pressurization. It also includes requirements specifically identified for health care occupancies.

ASHRAE Standard 170: Ventilation of Health Care Facilities, first published in 2008 and currently in its 2013 revision, was specifically created for the health care environment. This standard is referenced by the Guidelines for Design and Construction of Health Care Facilities published by Facility Guidelines Institute. The standard goes into greater detail than ASHRAE Standard 62.1 as it relates to the health care environment. It provides

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design standards on filtration, air movement, ventilation, humidity, etc. for various health care-specific spaces.

The Guidelines for Design and Construction of Health Care Facilities, published by Facility Guidelines Institute, commonly referred to as simply “FGI Guidelines,” and previously known as “AIA Guidelines,” has been in existence in various forms since 1947. This document offers design guidelines for all design aspects of a health care facility—architectural, mechanical, electrical, etc. As of the 2010 edition, FGI Guidelines have referenced ASHRAE Standard 170 (noted above) for IAQ design and includes the standard as an appendix. Note that the 2014 edition of the FGI Guidelines is divided into two separate documents: Guidelines for Design and Construction

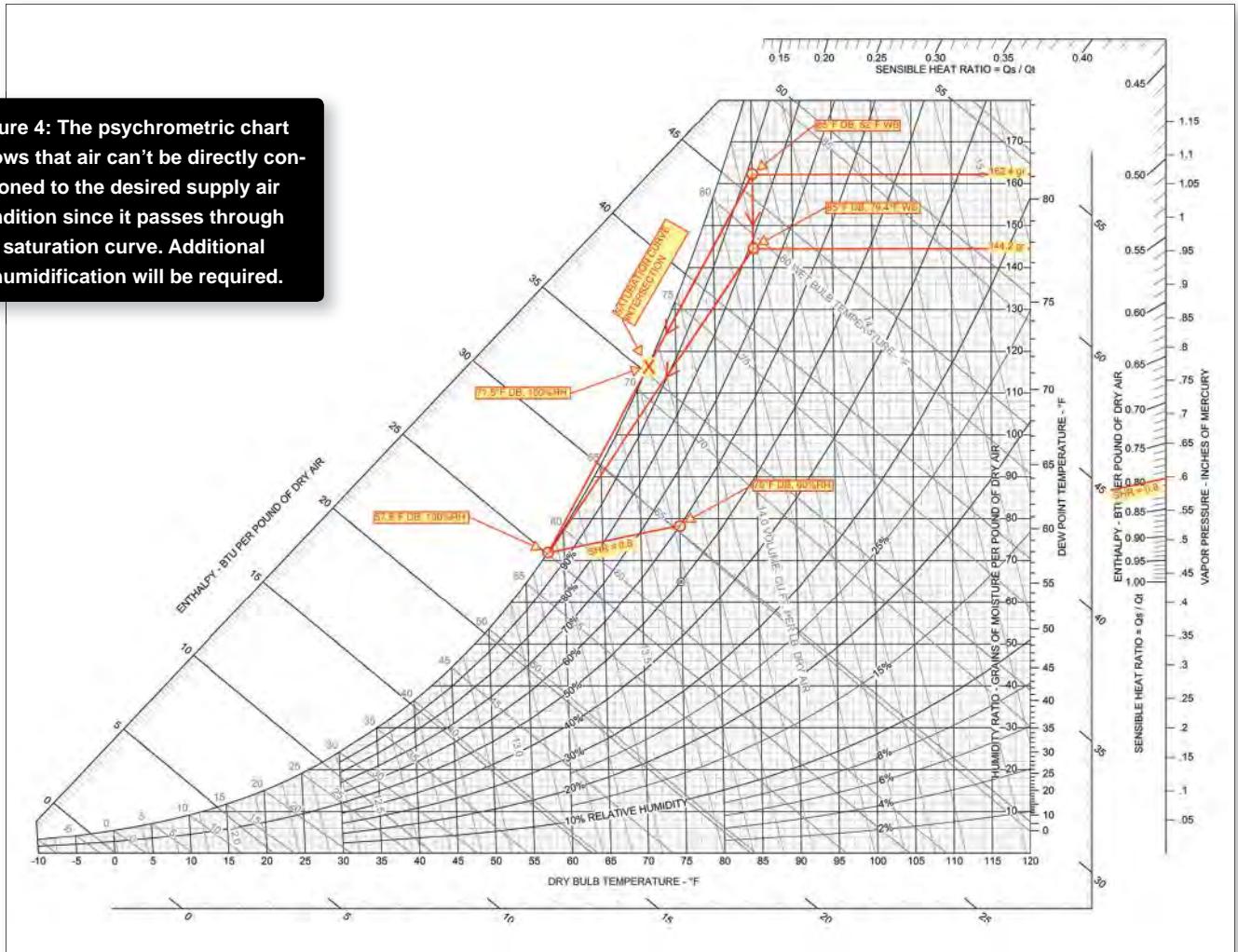
of Hospitals and Outpatient Facilities and Guidelines for Design and Construction of Residential Health, Care, and Support Facilities. Both of these documents refer to ASHRAE Standard 170.

To qualify for Medicare and Medicaid reimbursement, CMS requires that facilities meet the requirements established by NFPA 101: Life Safety Code. NFPA 101 includes by reference additional NFPA Standards: NFPA 90A: Standard for the Installation of Air-Conditioning and Ventilating Systems and NFPA 99: Standard for Health Care Facilities (now the Health Care Facilities Code) are just two examples of relevant referenced standards. Even if these standards aren’t explicitly included in the applicable codes for the facility’s location, most health care facilities look to CMS for reimbursement and

must comply with their design requirements as well.

While the U.S. Dept. of Health and Human Services’s Centers for Disease Control and Prevention (CDC) has many policies and procedures established for the operational side of health care facilities, they also offer documents such as Guidance for Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks, which was published in May 2002. This document offers direction on how to prevent or minimize chemical, biological, and radiological contaminants from impacting the facility’s ventilation systems. Since hospitals are often referred to as “defend-in-place” occupancies, the safety and quality of the indoor environment becomes paramount in many operational environments.

**Figure 4: The psychrometric chart shows that air can’t be directly conditioned to the desired supply air condition since it passes through the saturation curve. Additional dehumidification will be required.**



## Methods to maximize IAQ

Clean, fresh air is likely the first thing that comes to mind when one considers the concept of good IAQ—such as the coziness and aroma of a remote open field on a warm spring day. When reviewing the various standards and codes that dictate the amount of fresh air necessary for the space, ensure that you design to the one that requires the greatest volume to ensure that all of the applicable codes and standards are met. When designing the system that delivers fresh air to spaces within a building, be sure to analyze the entire path of the fresh air, identify contaminant sources in that path, and employ measures to mitigate those contaminants.

The path the fresh air takes through the building starts at the point where it enters the building. Intakes should be located to prevent contaminants from being drawn in. Most codes and standards dictate minimum distances from vehicle traffic and building exhaust. However, these minimums don't take into account such things as building geometry, prevailing winds, and other site-specific conditions that may require the designer to consider greater separation. Diesel-generator exhaust could be 100 ft away from an intake, but if the wind and elevations are just right, the fumes could still be drawn into an intake. Sloping the top to an area well intake could help prevent a contaminant from being placed on top of the area well and then remaining in place to be continually drawn into the system—the slope would cause the contaminant to roll off of the intake. Be sure to carefully analyze the location and configuration of the air-distribution system's outdoor-air intakes to minimize the chances for contamination.

Once the outdoor air is drawn into the system, it needs to be filtered. The applicable codes and standards will provide the minimum requirements for filtration based on what spaces are being served by the system. There are several types of filters to consider. Particulate filters are rated in terms of efficiency with a minimum efficiency reporting value, or MERV. MERV ratings, as established in ASHRAE Standard 52.2: Method of Testing General Ven-

tilation Air-Cleaning Devices for Removal Efficiency by Particle Size, range from the lowest efficiency at 1 to the highest efficiency at 16. Filters with a MERV rating of 1 are based on retaining particles larger than 10 microns (dust and pollens), while filters with a MERV rating of 16 are based on a filter's efficiency at retaining particles as small as 0.3 microns (smoke and bacteria). High-efficiency particulate arrestance (HEPA) air filters and ultra-low particulate arrestance (ULPA) air filters have efficiencies even greater than those identified in ASHRAE Standard 52.2 and are given MERV ratings in the 16 to 20 range. HEPA filters are 99.97% efficient at removing particles 0.3 microns in size and ULPA filters are 99.999% efficient at removing particles 0.02 microns in size. Particulate filters are typically provided in pleated media, bag, and cartridge types. In critical spaces, filters are not just used in the air-handling equipment, but also at supply diffusers or grilles, which are the point of air delivery to the space, where they act as the last line of defense to keep contaminants from entering the space.

Gas-phase filters are chemical filters. The most common types of gas-phase filters for general filtration at hospitals and other health care facilities use either activated carbon or potassium permanganate (often referred to as "purple pellets"). Consider the use of gas-phase filters when it is impossible or impractical to locate intakes sufficiently away from irritating, corrosive, or odorous airborne contaminants.

Electronic air filters typically either incorporate charged plates or wires. They electrostatically charge the particles as they pass to aid in arresting the conveyance of the particles. This type of filter generally works best on particles that are less than 10 microns in size. Electronic filters that incorporate charged plates don't require regular media replacement, but do require regular cleaning. Electronic filters that incorporate charged wires still require particulate filters, but because of the charge the filter life is extended due to the charge's impact on arrestance efficiency.



**Figure 5:** An electronic air filter is shown in a typical air handling unit at Wheaton Franciscan Healthcare—Franklin in Franklin, Wis.

UV radiation is a means to disinfect rather than filter. In air-distribution systems, UV radiation most often is applied to cooling coils to reduce fungal growth, though it also can be used on ductwork and insulation. Studies have shown that UV radiation has a significant impact on fungal contamination. Not only does the elimination of fungal contamination directly improve IAQ, but also the reduction of fungal growth on cooling coils increases the efficiency of the coils by keeping more of the heat-transfer surface exposed to the airstream. Decreased fungal growth on cooling coils also helps reduce air-pressure drop across the coil, which in turn reduces the amount of fan energy required to move air through the distribution system.

## Humidification and dehumidification

As the air moves through the air-handling system, it typically passes through heating and cooling coils to adjust the air temperature as necessary to meet the design conditions. Keep in mind, however, that both temperature and humidity are component metrics for IAQ.

In colder climates, it's likely that additional means of humidification will be necessary to maintain the recommended minimum relative humidity levels in

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various health care spaces per the pertinent codes and standards (see Figure 3). Air at 0 F has, at most, 5.6 grains of water per pound of dry air—100% relative humidity. Without adding any moisture to air at this condition and raising the temperature to a room temperature of 70 F, the resultant relative humidity dramatically drops to approximately 5%. Most of the codes and standards require a minimum relative humidity of 30% for critical spaces, such as operating rooms and intensive care. Therefore, humidification must be added to the airstream to compensate for the lack of moisture.

To add humidification, steam injection is typically preferred in health care applications. It is recommended that “clean steam”—free of water treatment chemicals—be used for humidification because the steam is injected directly into the air stream. Atomizing humidifiers are an option; however, care must be used in deciding to use this type of humidification for health care, as they inject moisture droplets directly into the air-distribution system where moisture could potentially collect on the interior surfaces of the duct-

work, providing a potential source for biological growth.

Additionally, the location of any type of humidifier in the air-distribution system should be carefully analyzed to ensure the discharge of the humidifiers does not condense on any of the system’s filter media. Data for humidifier dispersion assemblies includes the “absorption distance” of the assembly. The absorption distance is the linear length of air travel that it takes for the steam to be fully absorbed into the airstream. Straight, unobstructed duct should be provided to fully encompass this distance.

In humid climates, it’s likely that additional means of dehumidification will be necessary to maintain the recommended maximum relative humidity levels in various health care spaces per the pertinent codes and standards (see Figure 4). Outdoor air at 85 F dry-bulb and 82 F wet-bulb temperature starts out at a relative humidity of nearly 90%. Assuming a sensible heat ratio of 0.80 and a space condition of 75 F and 60% relative humidity (rh), the supply air must be brought down to approximately 58 F saturated. The psychrometric path between the outdoor air condition and the supply air condition is not linear as the outdoor air crosses the line of saturation at approximately 72 F. As such, a means to further dehumidify the air must be implemented.

The two most common methods for dehumidifying air are either to sub-cool the air stream to maximize condensation (moisture extraction) and then reheat the air to achieve the desired supply air temperature, or to introduce some sort of desiccant into the air stream. For example, a desiccant wheel could be used to allow the humid air stream to pass over the desiccant, which will extract the moisture. The desiccant can then be “recharged” by a separate heated air stream. Designers, however, must use care when going the extra step and considering an energy-recovery wheel for humidity control in health care facilities. Because there is an inherent potential for a small amount of bypass air between the two air streams, many jurisdictions will not allow systems

to use a wheel to transfer energy between supply and exhaust air streams.

## Distributing quality air

Once the air has been brought into the building from a clean location, been filtered appropriately, heated or cooled to the proper temperature, and humidified or dehumidified as needed, it must then be distributed to the various spaces throughout the building. The applicable codes and standards will dictate the minimum amount of fresh air ventilation and total air exchanges needed for the various health care spaces. For example, ASHRAE Standard 170-2013 and the 2014 FGI Guidelines indicate that patient rooms must have a minimum of 2 air changes/hr (ACH) of fresh air ventilation and 4 ACH of total air movement. Class B operating rooms must have 4 or 6 ACH, depending on room type, of fresh air ventilation, and 20 ACH of total air movement.

While the quantity of air distributed to the space is important, from an air-quality standpoint, space pressurization is perhaps even more important. Designers must be certain that the air quantities are balanced so that air travels from the cleanest spaces (such as operating rooms) to the dirtiest spaces (such as soiled utility or decontamination rooms).

IAQ is an important component to the design of any building, and it’s vital when designing a hospital or health care facility. Proper consideration must be taken to ensure that clean, fresh air is brought into the building, that the air is maintained within specific parameters for temperature and humidity, and that the air is not allowed to contaminate other spaces as it is routed back through the system. The standards and components referenced herein will give you a good start in the right direction. **csel**

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**Figure 6:** A louvered low-return grille in a cardiac catheterization laboratory room at Wheaton Franciscan Healthcare—Franklin in Franklin, Wis.



## **HOSPITAL ACQUIRED INFECTIONS:** **MAKE HVAC PART OF THE SOLUTION, NOT PART OF THE PROBLEM.**

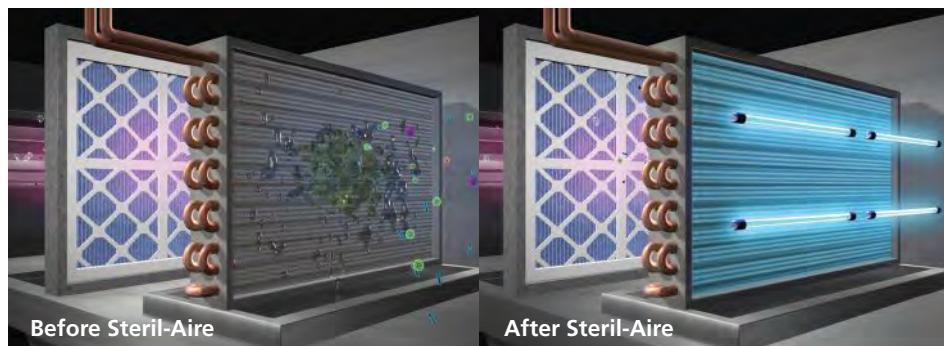
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