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Indoor Air Quality for the HVAC Technician

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According to the Environmental Protection Agency (EPA), we spend about 90% of our time indoors. The EPA has also concluded that the air quality indoors is two to five times worse than outdoors. Poor indoor air quality (IAQ) has been linked to several illnesses, including allergies, headaches, fatigue, asthma and other flu-like symptoms. These issues are prevalent, yet indoor air quality issues often go undiagnosed and unsolved.

Indoor air quality continues to be an extremely important issue, but it is a relatively untapped market for HVAC contractors. Many people suffer from poor indoor air quality, and even though we are not doctors and cannot cure their illnesses, we can improve their indoor air quality. Large retailers report that indoor air quality is a $10 billion dollar industry, and it is still growing. Every year, individuals purchase millions of products, such as dehumidifiers, humidifiers, air cleaners and air purifiers, in an attempt to relieve some IAQ problems.

HVAC technicians and contractors are on the front line regarding indoor air quality. For starters, every cubic foot of air eventually goes through the air-handling unit of the home or building. Additionally, many IAQ products can be connected to the existing HVAC system to help clean the air and remove harmful pollutants. Numerous studies show that inefficient, poorly maintained, and poorly installed HVAC systems initiate or contribute to poor IAQ. In the case that a person has purchased an IAQ product (such as a humidifier or air purifier), it signals to professionals that the customer has a problem and is spending money to try to resolve it. This article discusses some common indoor air quality issues, how to measure them and how to resolve them so customers can enjoy cleaner air.

TYPICAL IAQ ISSUES

IAQ issues can come from a combination of sources inside and outside the building. Pollen can travel

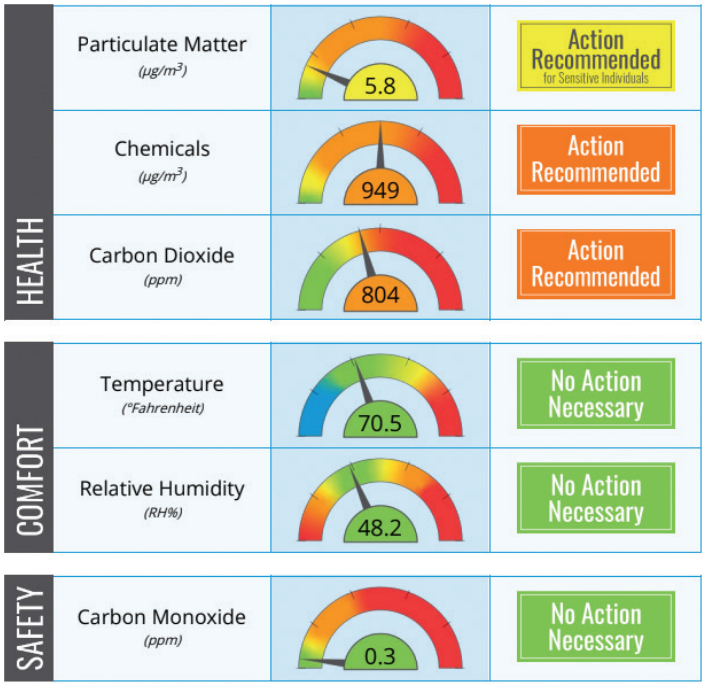

Figure 1 This is an example of a report identifying air pollutants commonly found in homes. Recommendations are offered to help make informed decisions about health, comfort and safety.

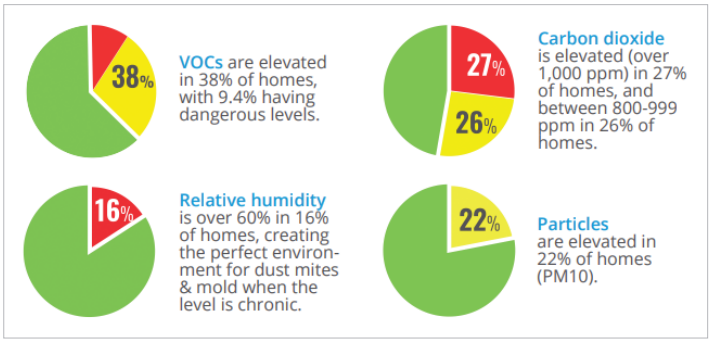

Figure 2 Common home IAQ issues.

indoors and disturb the building occupants' allergies. Other irritants such as fertilizers, lawn chemicals and pesticides can enter into the home during normal day-to-day activities. Items in the building, such as combustion appliances, tobacco byproducts, building materials, household cleaning chemicals, radon, uncontrolled moisture and more, can pose serious health risks. Regardless of the source of the IAQ pollutant, the end result is that they all build up in the building and the pollutants need to be controlled.

An example of an air quality monitor.

The IAQ level in a building can be measured with a handful of parameters, and the good news is that solutions are available to improve the air quality. There are several IAQ parameters, but for the context of the article, we will focus on the following: particles, chemicals, carbon dioxide, and carbon monoxide, humidity, and temperature. These parameters provide a tremendous overall snapshot of IAQ issues of which every building occupant needs to be aware.

MEASURING IAQ ISSUES

The fundamentals of any successful IAQ program start with testing. Testing is critical to determine "what" type of IAQ issue the customer has and "how" bad it is. Testing should be a standard process of HVAC technicians' service or maintenance calls. Testing should be as commonplace as using a meter for electrical troubleshooting or refrigerant gauges for taking pressure measurements. The average customer is coping with an IAQ issue and is unaware that it can be measured and resolved. Performing an IAQ test on every call will allow the technician to discover these issues and provide better customer service. It is a significant profit center for contractors as competitors are not likely thinking about indoor air quality.

PARTICLES

Particles, also known as "particulate matter," are a combination of solid and liquid particles that can linger in the air. Particles can come in various shapes and sizes. The concern with particles is that some may be small enough to be inhaled in the lungs and pose a severe health risk as they cannot be filtered easily with our nasal passages and sinuses.

Particle size is measured in micrometers or microns, so the larger the number, the larger the particle. For reference, the sunlight shining through partially open blinds when one can "see" dust particles represents a particle size of about 50 microns. The human eye cannot see particles smaller than 50 microns. The number of particles per volume of air represents particle concentration. Particle concentration is generally measured in µg/m^3 or micrograms per cubic meter of air. Smaller particles are the primary concern when it comes to indoor air quality. Unlike dust, soot, and smoke, smaller particles cannot be seen by the naked eye and can cause respiratory issues if inhaled for extended periods.

At 35 µg/m^3, The World Health Organization (WHO) reports that our most vulnerable populations, children and the elderly, are more susceptible to respiratory illnesses from exposure to particles in this range. Most concerning is PM2.5, (particulate matter 2.5 microns in diameter). PM2.5 is considered a fine particle and is listed by the EPA as one of a home's top five health hazards. PM2.5 particles can even irritate the eyes, and they can enter the bloodstream. Chemical reactions, construction activities, and emission from the combustion process can cause PM2.5.

HOW TO CONTROL HARMFUL PARTICLES

Remember, particles can come from an array of indoor and outdoor sources. Activities such as cooking, air fresheners, combustion appliances, cigarette smoke, and cleaning products produce particles inside the home. Particles can also come from unsealed ductwork in an unconditioned space, allowing harmful air from attics and crawlspaces to enter the home and cause IAQ complaints. Particles from outside of the home can come from pollen, fertilizers, wildfires, background air pollution, mold spores, dust mites, and animal and insect activity.

Before implementing any solution to control particles, source control is the No. 1 defense against harmful particles. Source control involves stopping the IAQ issues

where they are created. For example, combustion appliances like gas ranges and gas ovens that vent directly into the home produce harmful particles while they are being used. Source control for this particular appliance would be installing a range hood to evacuate the harmful particles from the home before they can cause an issue. In this example, using an electric range to eliminate combustion related particles may be a long-term solution. The key here is to stop the particles before they have an opportunity to cause an issue.

Other ways to improve particle concentration include duct cleaning and sealing. Duct cleaning is a process that mechanically removes dirt and debris from the duct system, and duct sealing uses glue or tape to seal any openings in the duct systems.

A professional duct-cleaning job involves using a rated vacuum cleaner with a high-efficiency particle arrestor (HEPA) filter designed for duct cleaning. The duct system's openings (supply and return registers and grilles) are sealed, and the duct system is placed under negative pressure to capture the particles loosened and removed from the duct the being cleaned. Compressed air and brushes are passed through the system to agitate and loosen the dirt and debris. As the dirt and debris is loosened, it is picked up and carried by the negative pressure created by the HEPA Vac. The HEPA vacuum will collect and trap the dirt and debris.

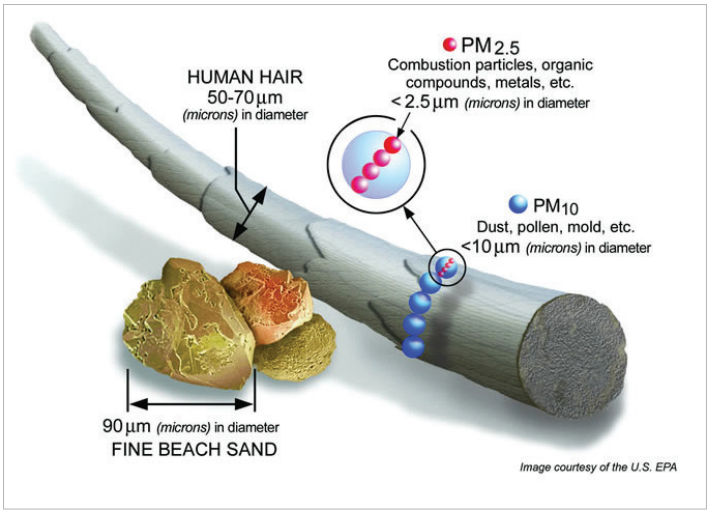

Figure 3 This image compares IAQ contaminants in micron sizes to a grain of sand and a human hair.

Duct sealing is another valuable tool to combat the generation of particles. Especially with the return air duct system, harmful particles can enter the HVAC system through the return air. The return air duct system is generally under negative pressure, making it a prime vehicle for IAQ containments to enter the building. These openings include the mechanical fasteners used to connect duct sections together or the seams where the ducts are joined. Not only can duct leaks create poor IAQ, but they also represent a significant energy waste, as conditioned air is not delivered to its intended location. Before sealing ducts, verify that the ducts are properly sized. Duct systems are generally undersized, and sealing an undersized duct will cause equipment performance issues, damage, and improper air distribution.

Other ways to combat harmful particles can be done through filter upgrades and variable speed blower operation. Several filters are on the market and selecting the proper one can be overwhelming. Proper filtration is a vital tool for removing particles in the air stream. Every cubic foot of air inside a building eventually travels through the HVAC system. A high-efficiency filtration system is a great way to capture harmful particles lingering within the home or building. Filters are rated based on their Minimum Efficiency Reporting Value (MERV) rating. The higher the MERV rating, the more efficient the filter removes smaller particles. To capture particles traveling through the HVAC system, a minimum of MERV 13 should be used. Before making any filter replacement or adjustments, verify that the

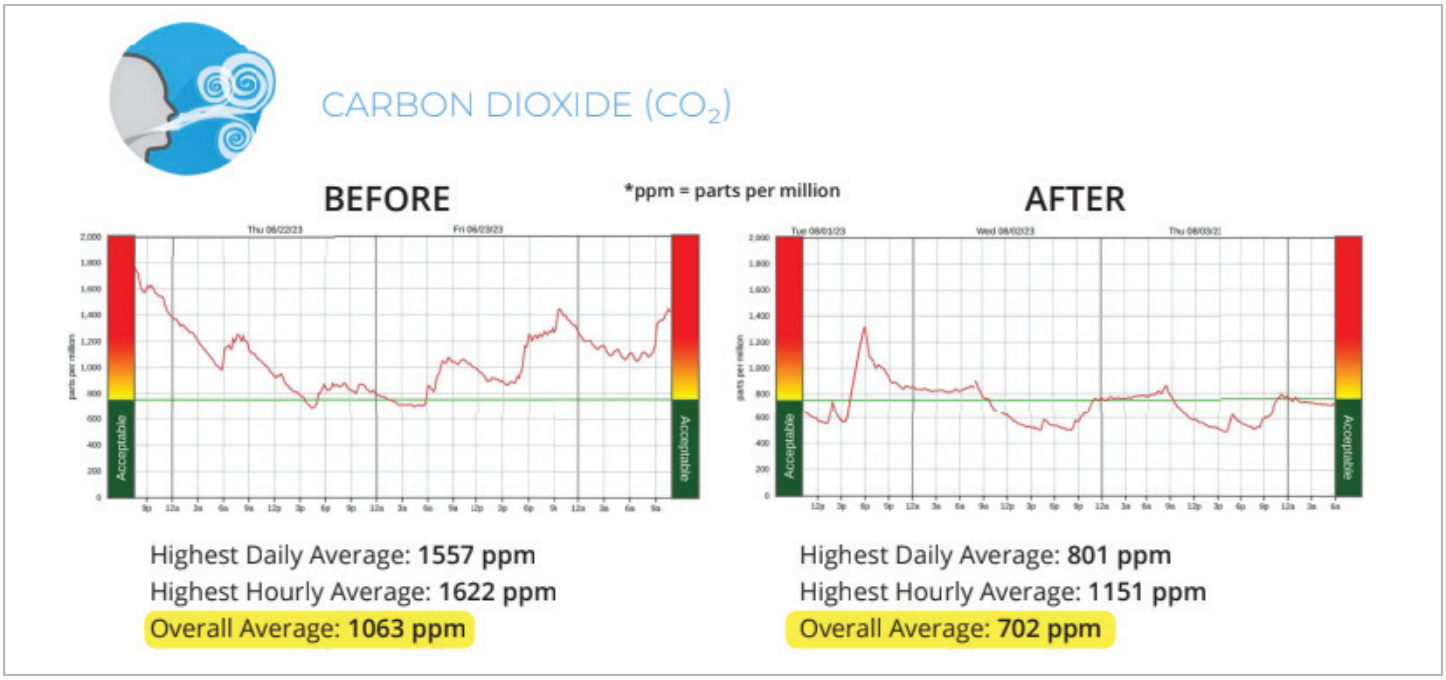

Figure 4 A CO_2 report before and after ventilation is applied.

duct system can handle the specified pressure drop of the more efficient filter and verify that the filter will not impact the operation of the HVAC system. For filtration to be most effective, the blower must run frequently. The HVAC technician and the homeowner must work together to balance the cost of operating the blower motor versus the benefits of consistent filtration. With the introduction of electronically commutated motors (ECMs) into the HVAC market, the cost of continuous operation has reduced significantly in recent years, making constant filtration more affordable.

Ventilation is a silver bullet for many IAQ issues, and there are many techniques and methods to implement ventilation to control IAQ. Ventilation is the process of bringing fresher air from outdoors, and this fresher air dilutes the particle levels in the air. To illustrate, think about a sugary drink that is too sweet. The typical reaction would be to add water to dilute the drink to improve its taste. Bringing fresh air from outdoors will dilute the harmful particles and reduce the contaminant levels within the building. Ventilation is essential, and it should be designed by technicians who deeply understand ASHRAE Standard 62.2 "Ventilation for Single-Family Dwellings." The contractor and the homeowner must work together to design the system to manage the trade-offs between the energy used for ventilation and the benefits of excellent indoor air quality.

CHEMICALS

Like particles, several government and health organizations consider chemicals to be a concern for indoor air quality. Chemicals mentioned here in this article are described as volatile organic compounds (VOCs). VOCs are carbon-based compounds that can be artificial or naturally occurring. The chemicals from gas or the vapors from the chemicals can be created easily at standard temperatures and pressures. Similar to particles, long-term and high doses or chemical exposure can often lead to respiratory illness and asthma, and they can also trigger allergic reactions. VOC vapors come from chemical compounds like solvents, adhesives, glues, stored fuels, construction materials, carpeting, furniture and standard cleaning chemicals. Formaldehyde and benzene are two very common VOCs in many household items we use.

Chemicals are also measured in the air and like particles, chemicals have concentration levels where adverse health reactions will take place. Chemicals are measured based on the containment per unit measurement of air. According to the AirAdvice Indoor Air Quality Field Guide, "Chemical pollutants are generally a cause for concern when average levels are above 500 micrograms per cubic meter of air." At this level or above, chemical exposure may cause the following: pink eye, nose and throat irritation, headache, allergic reaction to the skin, shortness of breath, liver problems, nausea, vomiting, bloody nose, fatigue, and dizziness.

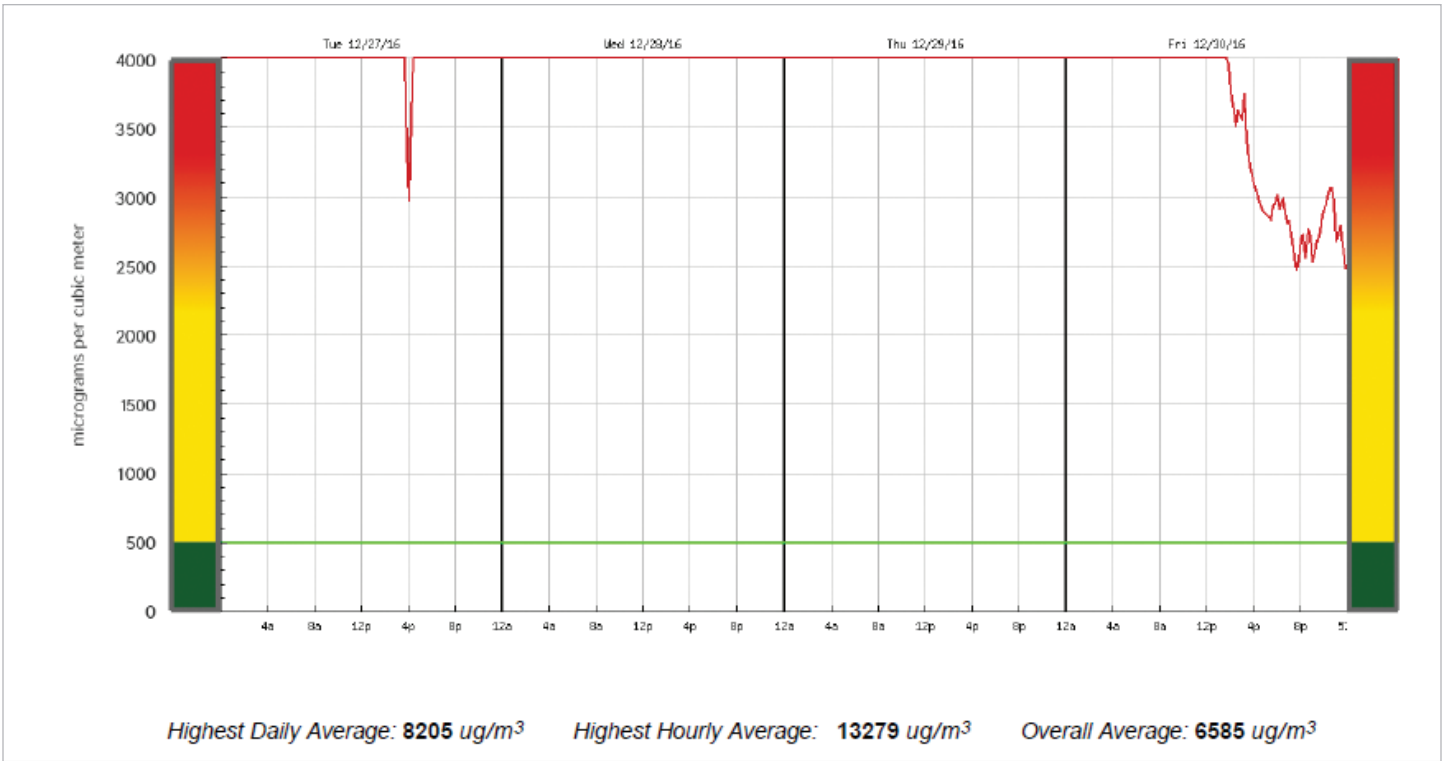

Figure 5 Daily air quality report by the hour.

HOW TO CONTROL CHEMICAL EXPOSURE

Source control is still the best defense against any IAQ issue, including chemicals. The EPA has several behaviors or actions the building occupants can take to reduce the likelihood of illness due to chemical exposure. Remember that many daily household products have high amounts of chemicals, so follow the labels and instructions carefully. Another excellent practical behavior is to properly discard any partially full containers of old or unneeded chemicals. Other practical advice from the EPA on using chemicals includes buying limited qualities and avoiding mixing chemicals not specially designed to be mixed. Lastly, avoid storing chemicals without caps or containers.

After source control measures are taken, the harmful chemicals must be captured, destroyed, or diluted through ventilation. Chemicals in the air can be captured using a filtering media with activated charcoal or carbon. Activated charcoal or carbon traps the chemicals using a chemical force or absorption force, which removes the chemicals from the air stream. For the capturing technique to work effectively, the blower on the HVAC system must be operating so the chemical can be removed from the air stream.

Chemicals in the can be destroyed using a photo catalytic oxidizer or (PCO) device. A PCO device is installed in the HVAC system ductwork. As airflow is circulated throughout the duct system, the PCO will work to destroy the chemicals until they are broken down into harmless elements, Co_2 and water vapor. The PCO device uses a UV light and a catalytic oxidizer to accomplish this reaction.

Ventilation is another great solution to "handle" chemicals inside the buildings. Like the particles above, ventilation plays the same role with particles as it does with chemicals.

CARBON DIOXIDE

Another common IAQ issue is high carbon dioxide (CO_2). Carbon dioxide is a gas that is naturally produced by combustion. The majority of CO_2 in homes comes from the breathing done by humans and animals. According to a study by Portland State University of more than 300,000 tests performed with IAQ monitors, CO_2 is the most common IAQ pollutant. The study concluded that 62% of homes tested had elevated action levels. The Environmental Protection Agency (EPA) has coined the term "sick building syndrome," which expresses symp-

toms that include fatigue, headache, breathing difficulties, nausea, poor vision and itchy skin.

High CO_2 has also been linked to poor work performance and reduced concentration from children in school settings.

The EPA recommends a maximum concentration of 1,000 ppm; however, levels above 750 ppm are still of concern. The higher level of carbon dioxide means that a significant portion of the air we breathe has been in someone else's lungs; this is called the "rebreathed fraction."

Higher carbon dioxide levels are directly linked to a building's ventilation rate—tightly constructed buildings where ventilation was not a design consideration experience high levels of carbon dioxide. When building owners make strides to weatherize or reduce the energy consumption of their building, many of the weatherization tasks, such as air sealing, reduce the amount of natural fresh air that a building has available. Often, when weatherization work is performed, and ventilation is not a specific concern addressed with a mechanical ventilation system, indoor air quality becomes a more significant hazard due to the lack of fresh air for building occupants.

Carbon dioxide is also a byproduct of the combustion process. The HVAC technician should pay close attention to verify that the increase in CO_2 is not coming from a back-drafting or poorly operating combustion appliance. We will discuss this more in the carbon monoxide section.

HOW TO CONTROL CARBON DIOXIDE

With carbon dioxide, "dilution is the solution." Another age-old building science saying that helps the HVAC technician think about solving IAQ issues with ventilation is the saying "to eliminate, ventilate." Like particles and chemicals, ventilation is another key ally in combating poor IAQ, namely carbon dioxide. As with the other parameters, ventilation will bring relatively fresh air into the structure, reducing the concentration of carbon dioxide. Some ventilation systems are set up with sensors that will detect increasing levels of CO_2, activating the ventilation system. This technique helps reduce the energy consumption needed to ventilate the structure properly. VOCs and CO_2 are frequently found together in tight homes that do not have proper ventilation. The sources

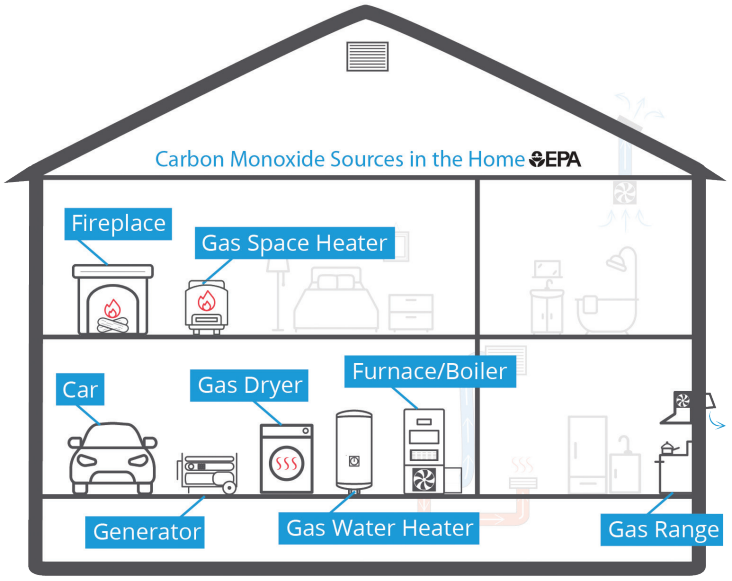

Figure 6 This illustration shows some common CO sources in the home. Combustion testing can identify improperly operating combustion appliances or outside CO sources.

that generate CO_2 are relatively small, but CO_2 will build up over time.

CARBON MONOXIDE

Carbon monoxide (CO), also called the "silent killer," is given this name due to its features. Carbon monoxide is an odorless, colorless, tasteless, poisonous gas that is impossible to detect without instrumentation. It results from incomplete combustion and it does not take large doses of exposure to be harmful. Regarding IAQ issues, CO can be generated in the home and inhaled by the building occupants. If carbon monoxide is elevated, notify the building owner immediately, and based on your training and company procedures, help the client understand its hazards. Carbon monoxide bonds to the blood at a rate about 200 times faster than oxygen does. When exposed to it occupants may complain of headaches, dizziness, chest pain, nausea and other flu-like symptoms, and if exposed to higher levels, death.

The permissible level of carbon monoxide varies based on the agency and authority having jurisdiction (AHJ). Follow local codes and company policies to comply with local rules and regulations. The Environmental Protection Agency (EPA) utilizes the following action levels: A maximum exposure of 9 ppm for eight hours and 35 ppm for one hour. The Building Performance Institute (BPI) requires an evacuation of the premises and a call to emergency services at 69 ppm and above. It is important to note that carbon monoxide levels may also spike

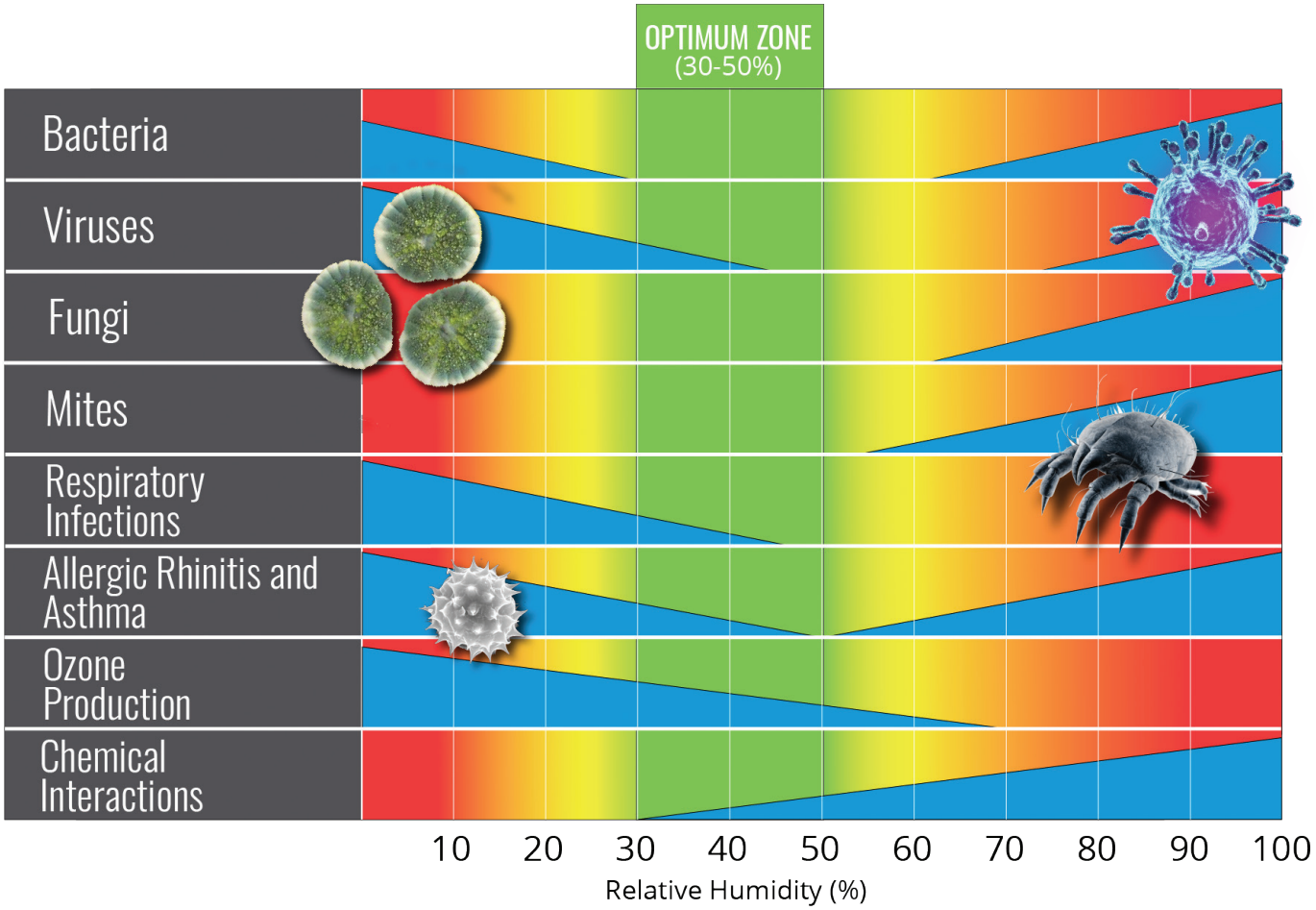

Figure 7 Relative humidity levels can create ideal conditions for micro organisms. Controlling humidity is another important consideration when managing IAQ.

during everyday activities like cooking, so be sure to understand the situation regarding elevated CO levels.

HOW TO CONTROL CARBON MONOXIDE LEVELS

When evaluating combustion appliances, the HVAC technician should ask two questions related to CO that must be verified: Are the combustions supposed to be vented outside; and are they producing unsafe levels of carbon monoxide? These two essential items to check circle back to source control, the best defense for healthy IAQ. A properly operating vented combustion appliance should not generate unsafe levels of carbon monoxide. The appliance should be removed from service if it creates an unsafe condition. Vented combustion appliances must be installed correctly to avoid the possibility that the combustion gases come back and enter the home. Other appliances that vent into the people's space, like gas ranges or ovens, must be serviced consistently to verify that the CO levels produced are below acceptable codes and standards. Additionally, combustion appliances that vent directly into the building should be accompanied by an appropriately sized and working exhaust fan that takes the harmful pollutants to the outdoors.

HUMIDITY

It is important to note that humidity or dampness is considered the single greatest source of IAQ issues and is often only considered a comfort issue. Improper humidity levels are another IAQ and comfort concern. Depending on the climate region and the mode of the HVAC system, humidity or lack thereof can have serious consequences, such as poor occupant comfort and health issues, and the durability of building materials. Humidity makes up much of the total comfort that building occupants experience. "Relative humidity" is defined as the amount of moisture contained in the air compared to the amount of moisture that the air can hold. This ratio, expressed as %RH, is a critical IAQ parameter that every technician should check.

According to American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE), humidity levels should be between 35%–60%. Personal comfort

is the best in this range but has other benefits. The humidity chart shown in Figure 6 shows the optimal humidity zone. Bacteria, viruses, fungi, mites, respiratory infections, allergic rhinitis, and asthma occurrences are minimal when humidity is in the optional zone. A level under 35% can cause occupant complaints of dryness, including itchy skin, increased allergy symptoms and a host of other problems.

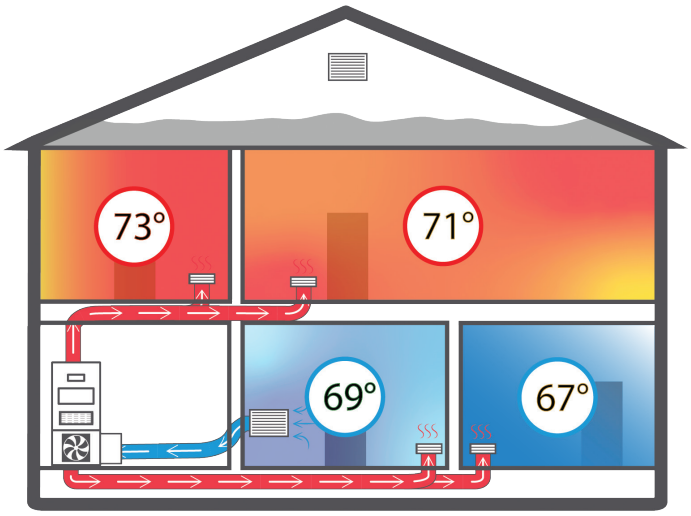

Figure 8 Controlling temperature starts with the fundamentals of designing and performing a proper heat loss/heat gain calculation.

Excessive humidity levels also wreak havoc on the building and pose other health problems. Moist air or relative humidity levels above 60% create ideal conditions for mold to colonize and grow. Testing humidity is critical and should be done with every service call. As you work with your clients, you may find them trying to cope with humidity problems. Look for stand-alone dehumidifiers and humidifiers. These devices may indicate that the humidity levels are not in the optimal range and that the occupants may be experiencing some discomfort.

HOW TO CONTROL HUMIDITY LEVELS

Many issues cause humidity problems and source control is the key, as is the case with many other IAQ issues. In cold climates during the winter months, dryness or a lack of humidity may be the complaint. As a forced air system warms the air, its relative humidity is reduced. Dry air has many side effects, including dry skin, eyes, electrostatic discharge (static shock) as well as other issues. To combat dryness in a structure, a humidifier adds moisture to the air to increase the relative humidity. A humidifier can be used alone or with a forced air system. In either case, moisture is introduced into the environment to increase the relative humidity. Low humidity levels in the building can indicate that the building shell is excessively leaking. High air infiltration rates (air leaking into a structure) allow air from the outside to leak in. This cool dry air from outside, which may have low relative humidity to start, replaces the building's air several times per hour. As a result, the building may require a humidifier since the conditioned and treated air was pushed out of the structure.

High relative humidity is not ideal either. During the summer months, the air conditioning system is responsible for maintaining the proper humidity levels in the building. High relative humidity can come from internal sources, such as bathing or cooking, and it can come from external sources, such as bulk water (water for large leaks), and foundation issues, such as high hydrostatic pressure on foundation walls. Source control is critical for controlling high relative humidity. If you stop the leaks, you stop the issue of high relative humidity.

In addition to source control, an appropriately sized and maintained air conditioner will help keep humidity levels in the optimal range. Oversized air conditioners lack the runtime needed to dry the air, and as a result, the relative humidity will remain high enough to reach uncomfortable levels. Customers may report that the air is "clammy," meaning it feels moist to the skin. Poorly maintained air conditioning systems will also have the same effect. High relative humidity comes with challenges, and humidity ranges outside the optimal range also contribute to many of the same issues as dry air. To cope, many people may purchase a dehumidifier to reduce the moisture within the structure. As with humidifiers, dehumidifiers can be standalone or operate in conjunction with the HVAC system. Dehumidifiers work to reduce the humidity levels of the air in the same manner a traditional air conditioner would remove moisture.

TEMPERATURE

Many individuals do not readily determine temperature as an IAQ concern, yet it is the chief IAQ component. When measured from the IAQ standpoint, temperature is a crucial parameter to determine if the HVAC system is operating correctly or if there are building issues causing a temperature issue. According to ACCA's *Manual J* (Residential Load Calculation), heating systems are designed to maintain a temperature of 70°F and cooling

systems 75°F. Many customers cope with an unbearable room or area of their home. A temperature measurement may reveal several issues that can be resolved. A temperature measurement can indicate hot-laden air coming into the home from an unwanted area like an attic. Temperature measurements could also help to discover disconnected or leaking ducts. In some situations, ducts need to be insulated, and taking temperature measurements may reveal that they were never insulated or that the insulation is degraded. Testing may further reveal that a building has deficient insulation in the building shell or that it needs to be professionally air sealed.

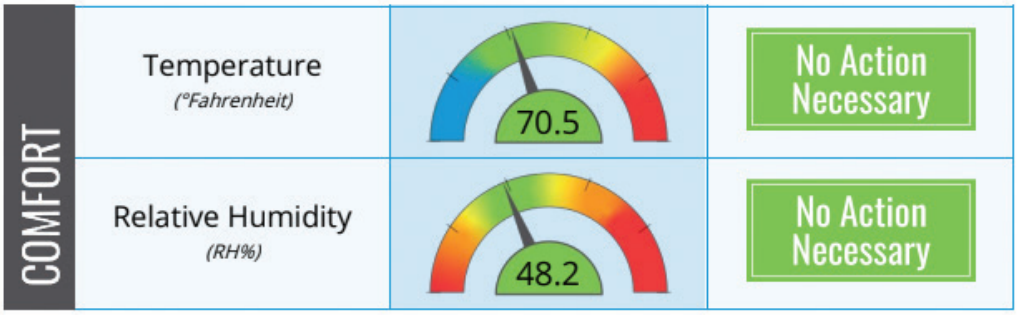

Figure 9 This is an example of IAQ parameters affecting comfort. Recommendations are offered to help make informed decisions about health, comfort and safety.

HOW TO CONTROL TEMPERATURE

Controlling temperature starts with the fundamentals of designing and performing a proper heat loss/heat gain calculation. The complement to every load calculation is a good duct design, with the ducts being appropriately sized, sealed and balanced. Other complaints with temperature can be solved by zoning different areas using airflow or separating equipment dedicated to a specific area to improve comfort. Lastly, temperature complaints may be caused by the building itself through excessive air leakage or poor insulation. Without testing temperature, many of the items may be overlooked.

TEST IN—TEST OUT

IAQ remains an essential but often neglected aspect of the HVAC industry. Using this straightforward procedure to diagnose and solve IAQ issues can help both techs and their customers. Test in and test out. What is measured is what is changed, so measuring IAQ issues on every call will help clients understand that they have an IAQ problem that can be fixed.

Very often, one particular issue may show up as several IAQ parameters. For example, if a family recently just cooked dinner and you tested for IAQ issues, you may find elevated particles, carbon monoxide, humidity, temperature and carbon dioxide. Understanding IAQ may help identify the cause of elevated levels and whether or not a specific activity contributed to the readings. As solutions are crafted, carefully research products being used to verify that they are "safe" and "effective." To deliver the best possible results and total customer satisfaction, "test out" to verify that the solution created an improvement.

Remember that some solutions may take weeks to improve the air quality, so consider this when conducting post-retrofit testing. Customer education is also essential. Avoid making claims to improve the client's health or to cure them. Remember, the solutions will "improve the air quality," meaning overall occupant well-being.

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