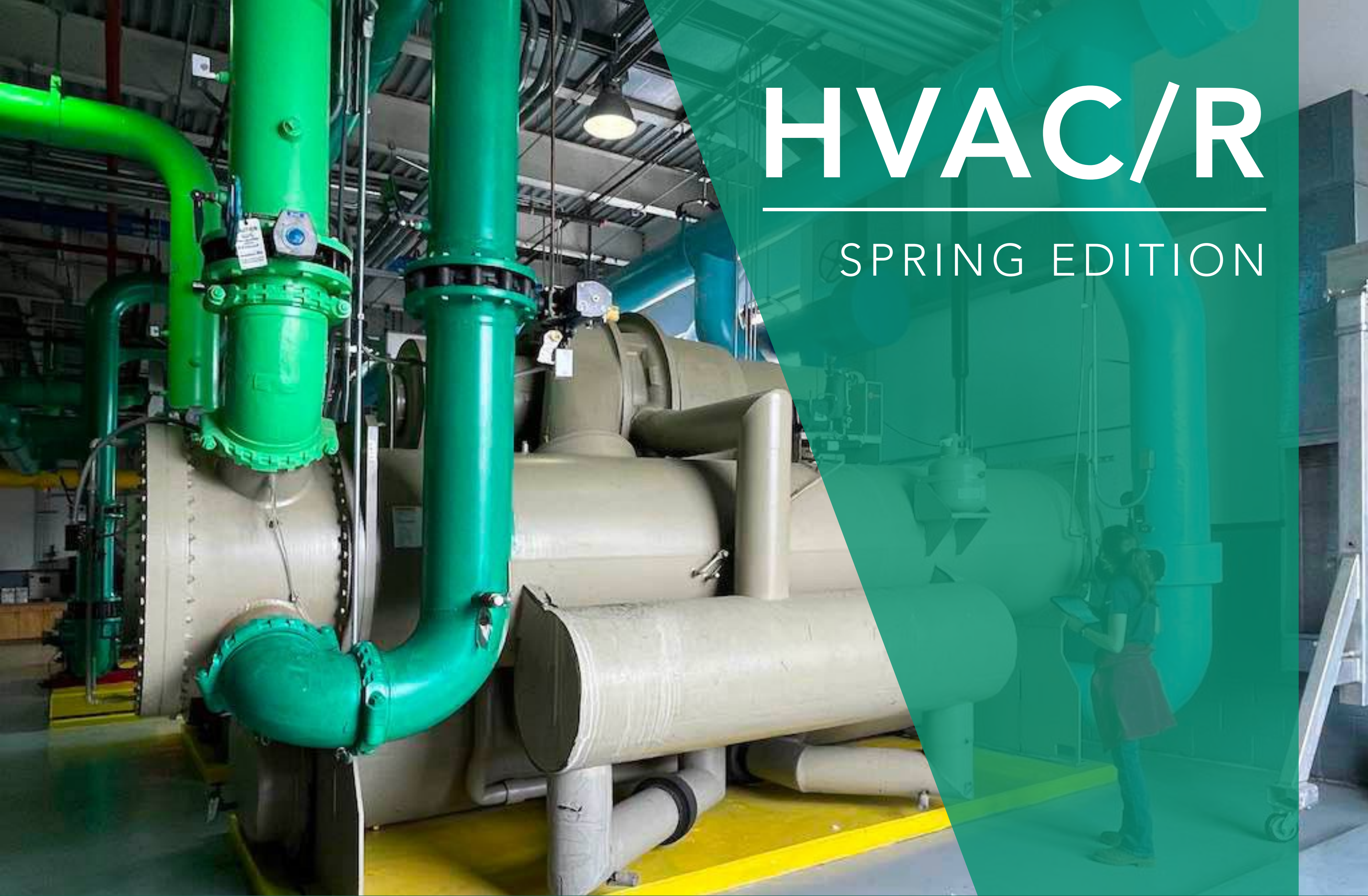


HVAC/R

SPRING EDITION

CONSULTING - SPECIFYING engineer eBOOK

Air Solution COMPANY Cottonwood Filter Screens

Bradley

MYSON

Sensata Technologies

Contents

Different laboratories with HVAC implications, Part 1

Jeremy Barrette walks through several types of laboratories and the HVAC considerations for them

Labs and research facilities house sensitive equipment and must maintain very rigid standards. Heating, ventilation and air conditioning systems in particular require careful planning and design. Most labs require the HVAC system to be fully exhausted, requiring high levels of outside air.

HVAC can look different, depending on the setting that it is in. First, Jeremy Barrette, principal at Affiliated Engineers Inc., walks us through different types of laboratories and the different HVAC considerations for those instances in this partial transcript from the Aug. 11, 2022, webcast "HVAC: Labs and research facilities." This has been edited for clarity.

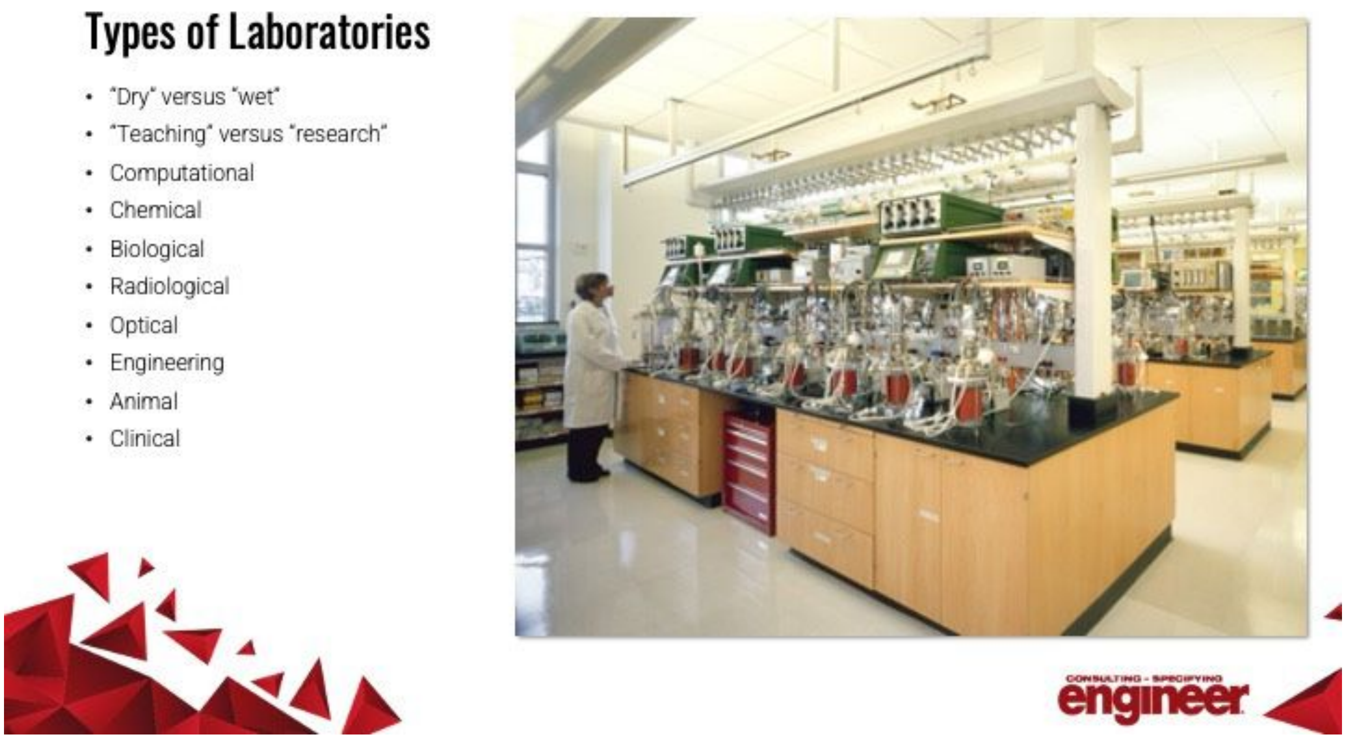
Laboratory types

Jeremy Barrette: A laboratory is a facility that provides controlled conditions in which scientific or technological research experiments measurement may be performed or teaching of various sciences is provided. However, sometimes when we're looking at a project, there may be something that's called a laboratory, which may not actually be one. For instance, I've seen learning laboratories applied as a term in different projects, but it actually just ends up being a classroom.

Before we get into design specifics and codes, we want to do a high-level review of different types of laboratories and what their requirements may be. This is not an ex-

Back to TOC

Back to TOC



There are many different types of laboratories that have various design requirements. Many times, a lab will have more than one type. Courtesy: Consulting-Specifying Engineer

haustive list, and certainly laboratory types generally fall in more than one category. These days, it's rare that there is only one type.

Computational laboratories are for data driven research or what you might hear referred to as a dry laboratory. They may range from anything from an open office, to a high-end computing farm with data centers. They may be co-located in other laboratory space, but one thing that we would consider here is there is a need for a 100% exhaust, if it's more office space, that may not be a requirement. Generally, we're looking at the cooling capacity for the equipment in the space.

Chemical laboratories are spaces where different hazardous, toxic, flammable caustic liquids, compounds and gasses are used for research. These typically require chemical fume hoods or other exhaust devices such as bench-top, snorkels, ventilated storage cabinets or gas cylinder cabinets. These are typically a 100% exhausted space, especially if we are dealing with fume hood in the laboratories. Our design consideration is for personnel protection, in which the fume hood is that first wave of defense, the exhaust for those devices, and then the associated makeup air to those exhaust. Then, dealing with the exhaust needs of those storage, whether it be chemical, flammable storage cabinets or hazardous gas cylinder cabinets.

Biological laboratories are more biology driven research, where we're working with different infectious diseases, either cell or tissue culture, protein samples, physical specimen samples, things of that nature, these spaces are usually outfitted with bio safety cabinets or laminar flow tables. The design conditions for these can vary greatly because those bio-safety cabinets can be purely recirculated within the space, and then we're just looking at the heat rejection. They could be 100% exhausted or a blend of the two. However, the rooms themselves typically are 100% exhausted.

Then, we're looking at low air velocities and making sure our containment of those cabinets is correct. Depending on what the research is working with, we may also have HEPA filtration in the exhaust stream — the bag out type of filtration. The considerations for protection of the personnel from what they're working with, protection of the samples from contamination, and again, that laminar low velocity airflow to get the proper containment in the cabinets.

Back to TOC

Radiological laboratories are spaces that are working with radiological or radioactive materials or processes that are generating radiation. These spaces may have a combination of fume hoods and glove boxes. It could be bio-safety cabinets, linear accelerators and things of that nature. We have to look at the exhaust stream here and see if there is a need to have special treatment and filtration again, because if there are radioactive materials that are being worked with. These spaces are generally 100% exhausted.

We're working with personnel protection, not only the ones within the space, but also personnel outside of that specific room. There

Back to TOC

Back to TOC

may be shielding in the walls, floors and ceilings involved. The proper storage and disposal of those radioactive materials is important too.

Optical laboratories are where different imaging, spectroscopy, microscopes or different research involving lasers, may be performed. Typically, clean, stable airflow locations are optimal with low velocity airflows, temperature and humidity stability. To do that, a lot of times we're pushing our air changes up, recirculating some of that air — although we may still be partially exhausting these spaces. The design considerations here are for stable conditions and low velocity airflow. There can also be a pretty high sensible heat load from all of the equipment in this space that needs to be considered as well.

Engineering laboratories is a broad category. Different spaces for manufacturing and testing, machining, electronics, nanotechnology, robotics and energy studies can fall into this category. These spaces can vary from very shop-like, like a machining room or welding space, to clean rooms of varying levels, to high bay kind of warehouse shop spaces.

Animal laboratories are where either behavioral or medical research is occurring. These vary from holding spaces like the compact cage racks you see there in those images to surgery spaces, and the surrounding support spaces for cage cleaning, bedding and feeding. These spaces may also have a bio-containment requirement. They may be BSL-2 or BSL-3. So, there can be cascading pressurization of the spaces. These are 100% exhausted spaces.

In some cases, the animal holding devices are directly connected to exhaust or they may recirculate within the room. They can also have fume hoods and bio-safety cab-

inets in these spaces. The spaces are designed with the first consideration is for the ethical care and comfort of the animals, which generally involves high air change rates for odor removal, and temperature and humidity control.

Clinical laboratories are where human patient samples are analyzed for medical diagnoses. These spaces vary greatly and have fume hoods, bio-safety cabinets, grossing stations and different analyzing equipment. There can be a lot of different space needs; biohazard, bio-containment, chemical exhaust in a lot of spaces that have high equipment heat loads.

These spaces are primarily designed for the protection of the samples to not get cross-contamination, as well as for protection of the staff working on those samples. In some cases, there may be dealing with infectious samples as well.

CFE Media

Since its founding in 2010, CFE Media and Technology has provided engineers in manufacturing, commercial and industrial buildings, and manufacturing control systems with the knowledge they need to improve their operational efficiency. CFE delivers the right information at the right time around the world through a variety of platforms.

Back to TOC

Air Solution
COMPANY
Cottonwood Filter Screens

Pulley Mount Air Inlet Filter Screen

Protecting cooling towers from airborne debris simply doesn't get any easier than this. Simply raise the filter screen and it will stop airborne debris at its point of entry thus protecting the entire loop (Fill, Sump, Strainers & Heat Exchangers). Also diffuses sunlight to help thwart algae growth. The non-stick surface enables easy cleaning without removal from the tower. Simply spray with a garden hose - even rain can rinse the filters clean. Saves maintenance time & effort, helps reduce water treatment chemical cost, reduces energy cost at the tower & chiller and contributes to green building initiatives.

WEST CHESTER, OH | FARMINGTON HILLS, MI
800-819-2869
www.airsolutioncompany.com

The Easy Way to Increase Cooling Efficiency on Crossflow Cooling Towers

Randy Simmons
Air Solution Company

Metaphorically speaking, the Fill Pack and Heat Exchanger in a cooling tower system is what the lungs and heart are to the human body; when either fail or, aren't working fully, it effects other parts of the body and one's health suffers. Similarly, when a cooling tower Fill Pack and Heat Exchanger isn't kept clean, the heat exchange process doesn't work efficiently, and the health of the cooling system and its supported systems (environmental/process) suffers due to reduced heat transfer.

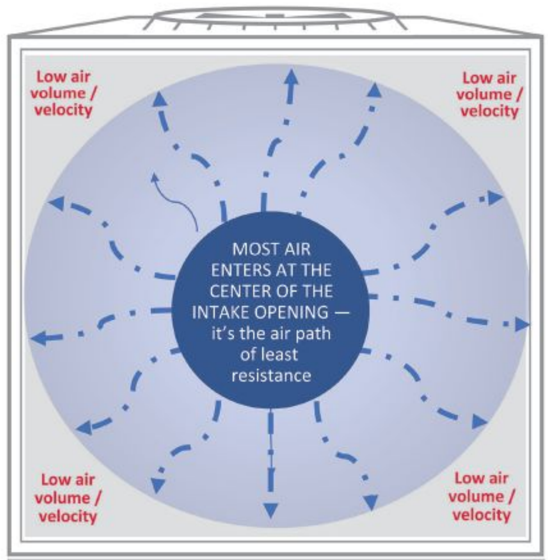
Cooling systems that rely on cooling towers to dissipate heat in a process or environmental application accomplish this by drawing in massive volumes of air and water into the cooling tower — as the water in the loop travels through the Fill Pack on its way back to the water basin, air is simultaneously pulled through the fill pack causing some of the water to evaporate — it is through this evaporation that heat is released.

Important Note:
The greater the Fill-to-Air exposure, the faster and more efficient the evaporation and the lower the temperature of the returned water at the basin.

The greater the Fill-to-Air exposure, the faster and more efficient the evaporation and the lower the temperature of the returned water at the basin.

(Interestingly, Cooling towers perform the mechanical equivalent of the human body cooling system; when one sweats, the air passing over the skin causes the perspiration to evaporate, thus pulling the heat away from the body resulting in cooling — when goosebumps naturally form on the skin, it's the body's way of increasing surface-to-air contact which speeds evaporation and cooling.)

Towers *Without* Intake Filtration Have Less Fill Utilization



The further away you get from the center of the tower, the lower the air volume and velocity entering the cooling tower fill; upper and lower corners have the lowest air volume and velocity entering the fill.

The laws of physics tell us that air always moves by taking the path of least resistance — hence, the air draft created by the giant fans on top, pull air into the tower, through the fill and out the fan in a roughly tubular formation. The path of least resistance is typically the center of the intake opening/Fill Pack and where the highest air-volume/velocity will be found. As you move further from the center, air volume and velocity decreases, resulting in reduced Fill efficiency and evaporation around the edges and corners of the Fill. (See Fig #1 above)

Selecting the Correct Filtration Method.

When cooling towers are certified for designed cooling performance, they are certified based on how they will be delivered from the factory without filtration. Increasing

Back to TOC

Back to TOC

capacity and efficiency beyond its design usually requires a design change commonly requiring resizing the fans/water supply and/or adding more modular cells.

One thing is certain, the cleaner the Fill/Strainers and Heat Exchangers are kept, the better and more efficient the cooling will be — this of course means that on-going maintenance is critical for optimal cooling tower performance no matter its designed capacity.

Because cooling towers are gigantic air scrubbers that captures airborne debris floating past the draft zone — the debris can circulate and clog the fill, plug strainers, heat exchangers and blow-down valves, restricting water-flow and causing significant loss in cooling capability.

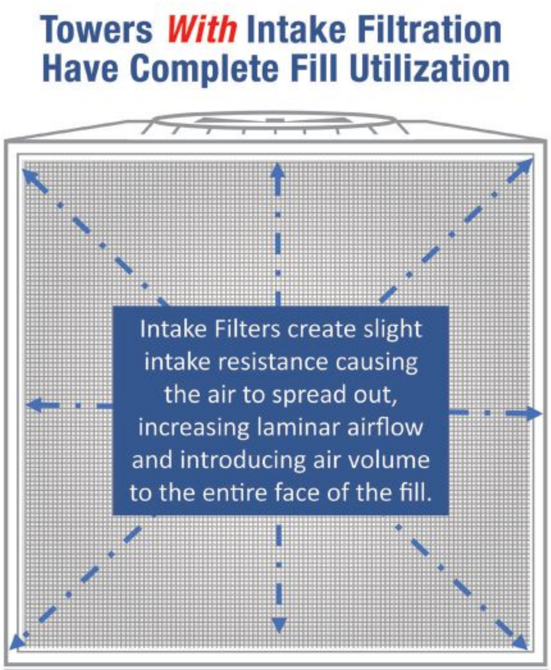
It's important to realize that optimizing the ecology and operational efficiency of a cooling tower is best accomplished by combining good physical maintenance with a chemical water treatment regimen and some form of filtration. Chemical treatment specifically targets organic matter, suspended solids/bacteria/water PH and conductivity, while filtration systems are designed to capture larger debris that can impact cooling performance.

> **Over 90% of fouling is a direct result of airborne debris being pulled into the cooling tower.**

There are two general technologies used for filtration: **Side Stream Water Filtration** and Air Intake Filtration Systems (also called Cottonwood Filter Screens). Engineers designing NEW cooling systems or retrofitting existing systems, should understand that in most towers, over 90% of fouling is a direct result of airborne debris being pulled into the cooling tower. If you are considering a cooling system which includes Side Stream Water Filtration, it's important to realize that it won't protect

Back to TOC

the Fill Pack, nor fully protect Strainers and Heat Exchangers — it is there to help manage airborne and waterborne debris only AFTER it gets into the tower.



Intake filter screens create minor air resistance at entry, increasing laminar airflow which forces the air to spread out over the entire face of the intake opening — resulting in increased fill utilization and lower water temperature at the basin.

In contrast, **Air Intake Filter Screens** are an effective, low cost approach that mounts over the intake opening stopping debris at its point of entry, keeping it out of the system in the first place and helping to reduce maintenance and water treatment chemical cost.

In addition to stopping airborne debris at it's point of entry, Cottonwood Filter Screens by design, slightly increases airflow resistance causing the air to spread out over the entire intake opening resulting in an increase in "Laminar Airflow." In other words, it creates a "Wall of Air" that fully covers the intake opening thus exposing the entire fill pack to more air volume and velocity versus not using screens and having lower Fill Pack utilization. (See Fig #2 above)

Increasing laminar airflow using Cottonwood Filter Screens is very significant because it naturally increases the efficiency of the Fill Pack in two ways. First, it provides greater Air-to-Fill exposure over the entire Fill Pack thus increasing the evaporative capacity of the Fill and Second, it stops airborne debris from infiltrating the Fill, Basin, and Heat Exchanger for optimal performance all season long.

Back to TOC

So, what's the big upside of this? Cottonwood Filter Screens increase the evaporative capacity of the Fill, reducing water temperature at the basin by 1 to 2 degrees Fahrenheit beyond its original design temperature. This translates into a significant reduction/elimination in downtime, lost productivity and energy savings.

Cottonwood filter screens help reduce water temperature at the basin by as much as 1-2 degrees F beyond the design temperature.

When considering filtration options, the following questions should be asked.

- What filter systems (air vs. water) provides the greatest overall benefit given the operating environment?

- Which system provides the greatest filtration surface area *(this can directly impact frequency of cleaning — the smaller the filter, the more frequently it needs cleaning).*

- Specifically what parts of the cooling system does each filtration method protect vs. the other?

Back to TOC

- What is the cost associated with downtime due to heat exchanger or cooling tower fouling or clogging? *(Knowing this will help you justify filtration system cost)*

- Can filtration be installed without shutting down the cooling tower? *(If the cooling tower must be shut down for installation, you need to factor lost productivity into the cost of your filtration system if it's not being installed during shutdown periods).*

- What is the cost associated with both the filter and installation?

- How easy is the system to install and maintain — Air vs. Water Filtration?

Answering the above questions will help you to fully understand your options and to make the best choice.

If one isn't currently using filtration as part of the cooling system, then any filtration is better than nothing, however, selecting a solution best suited to the operation should be the goal and that requires knowing what kind of debris is the problem and where it is getting into the system. As previously stated, "Over 90% of debris entering a cooling tower is Airborne not Waterborne." As a rule of thumb: "Don't select an air intake filter to solve a waterborne problem." And, conversely, "Don't select water filtration to solve an airborne debris problem."

Randy Simmons is President at Air Solution Company.

For additional information, call 1-800-819-2869
or visit **www.airsolutioncompany.com.**

Back to TOC

How building automation, controls help HVAC systems

Learn how buildings can become smarter using building automation systems and building controls

The technological advances in the heating, ventilation and air conditioning industry over past two decades has helped building systems operate in a more energy-efficient manner. There is no shortage in the building industry of buzz words such as "smart buildings" or "green buildings."

However, it is important to note that, regardless how energy-efficient a building is, if the building is not a net zero building, then the systems within that building will still use energy and, in many cases, significant amounts of energy. The latest draft version of the 2018 Commercial Buildings Energy Consumption Survey issued by the U.S. Energy Information Administration states that since 2012,

"The number of buildings has grown by 6% and floorspace by 11% and newer buildings are larger, on average, than older commercial buildings. The total energy consumption by the residential and commercial sectors includes end-use consumption and electrical system energy losses associated with retail electricity sales to the sectors. When electrical system energy losses are included, the residential and commercial sectors accounted for about 21% and 18%, respectively — 39% combined — of total U.S. energy consumption in 2021."

Also, per EIA, "… in 2021, renewable energy sources accounted for about 12.2% of total U.S. energy consumption and about 20.1% of electricity generation.'"

Back to TOC

This imbalance between the amount of renewable energy being generated in the U.S. and the total energy being used by residential and commercial building will continue to have a significant negative impact on the environment. It is important to note that a net zero building is not a building that uses no energy; a net zero building is a building that, on an annual basis, uses an energy amount that is less than or equal to the amount of renewable energy that it produces onsite.

Although design engineers and building owners strive to design and install energy-efficient HVAC equipment (i.e., chillers, heat pumps, etc.) and lighting fixtures, just by having this efficient equipment in a building it is not an indication that the building will be an energy-efficient building. Providing a building with energy-efficient equipment could be considered as a first step toward having an energy-efficient building; the building automation system plays a crucial role in the overall energy consumption levels of a building.

Up until the late 1980s and, on rare occasions, through the early 90s, the HVAC controls system in a commercial building was mostly pneumatic based. This type of pneumatic based control was, in its most simplistic form, an on/off type of a control system in which pumps and fans were left "riding their curves" based on the load. Variable frequency drives and implicitly, the concept of varying the speed of a pump moor or a fan motor based on the load was a relatively novel concept in the HVAC industry and one of the reasons behind this was the relatively high total cost of a VFD.

Similarly, the concept of having a building engineer receive alarms and notifications by the BAS was in its early stages. Looking back at these antiquated methods of controlling and operating building systems, one could assume that building systems could have performed better and use less energy.

Back to TOC

The advent of direct digital control systems in the mid-80s and the publication of the BACnet Standard for building automation and control system networks, ANSI/ASHRAE 135-1995 provided the building industry with the potential and tools for reducing the amount of energy that is being used by building systems.

BACnet, known as a building automation and control network, is a BAS communication protocol developed by ASHRAE. The standard is continuously maintained by the ASHRAE SSPC-135 committee.

It is common for building DDC systems to talk with the cloud and with myriad apps, each marketed with various promises to support the sustainability of the building, provide better control over the environment in the building and, for building engineers and commissioning professionals, to provide more information (i.e., alarms, trends, diagnostics, energy performance, etc.) about the operation of the building systems.

Smart buildings and building automation

Are smart buildings automatically energy-efficient buildings? What makes a building smart? A simple web search of this terminology shows as many definitions as there are web links in the results page.

For example, a provider of internet of things devices may define a smart building as "a building that uses IoT devices to monitor various building characteristics, analyze the data and generate insights around usage patterns and trends that can be used to optimize the building's environment and operations."

Similarly, a provider of information technology networks may define a smart building

Back to TOC

as a building that "converges various buildingwide systems — such as HVAC, lighting, alarms and security — into a single IT managed network infrastructure."

Adapting a widely used saying to the industry, we could infer that what makes a building smart is in the mind of the beholder. The same could be inferred when using the term energy-efficient building; to establish that a building is energy-efficient, we need to clarify what deficient baseline (i.e., reference) has been used to make the determination that a building is indeed energy-efficient.

Designing a smart building might be an effort that could start with a set of general requirements set by the building's owner, while recognizing that an energy-efficient or net zero building does not necessarily mean that the building needs to be a smart building. Similarly, designing a smart building does not mean that the building is an energy-efficient building.

A couple of examples of a type of broad performance requirements set by the building's owner regarding what constitutes a smart building could be as follows:

BAS shall use the BACnet communication protocol and shall use smart sensors and actuators. The BAS sequences of operation shall be based on ASHRAE Guideline 36: High-Performance Sequences of Operation for HVAC Systems.

BAS shall use the BACnet communication protocol, use edge control devices and be connected to the cloud. The BAS sequences of operation shall be based on the ASHRAE Guideline 36. The data from the building automation system shall be used by cloud-based applications such as analytics, anomaly detection and artificial intelligence algorithms for the control of building systems

The BAS shall be integrated with the building lighting control system such that information related to occupancy levels, occupancy detection and lighting levels is shared between the two systems. The BAS shall then monitor and control the HVAC system based on the actual occupant load and lighting levels in the building with the overall intent of reducing the energy consumption of the HVAC systems by minimum 25% when compared with the energy consumption levels of the same HVAC systems when the referenced information is not shared between the BAS and the building lighting controls system.

The overall intent behind the use of the BACnet Standard as a performance requirement is to provide the potential controls contractor(s) with a clear and concise set of requirements that must be met by any manufacturer of controls devices. It will not matter to an owner who makes the controls device for a lighting controls system and for an HVAC control system, as long as controls devices carry a BACnet listing, said devices will speak the same language.

How to design a building automation system

The BACnet Standard defines eight profiles for controls devices, as shown in Figure 1; the first three devices are typically used to access the entire BAS via a graphical user interface. Out of the first three device profiles, the BACnet advanced operator workstation is the most robust; a B-AWS provides the user with a complete engineering tool for the monitoring and configuration of the BAS and any systems (e.g., HVAC, lighting, etc.) controlled by it; consider the B-AWS as a computer provided with a relatively easy to use GUI.

Further, the B-AWS and its tools allows for future system changes under proper password protection including dynamic creation, deletion and modification of all config-

Back to TOC

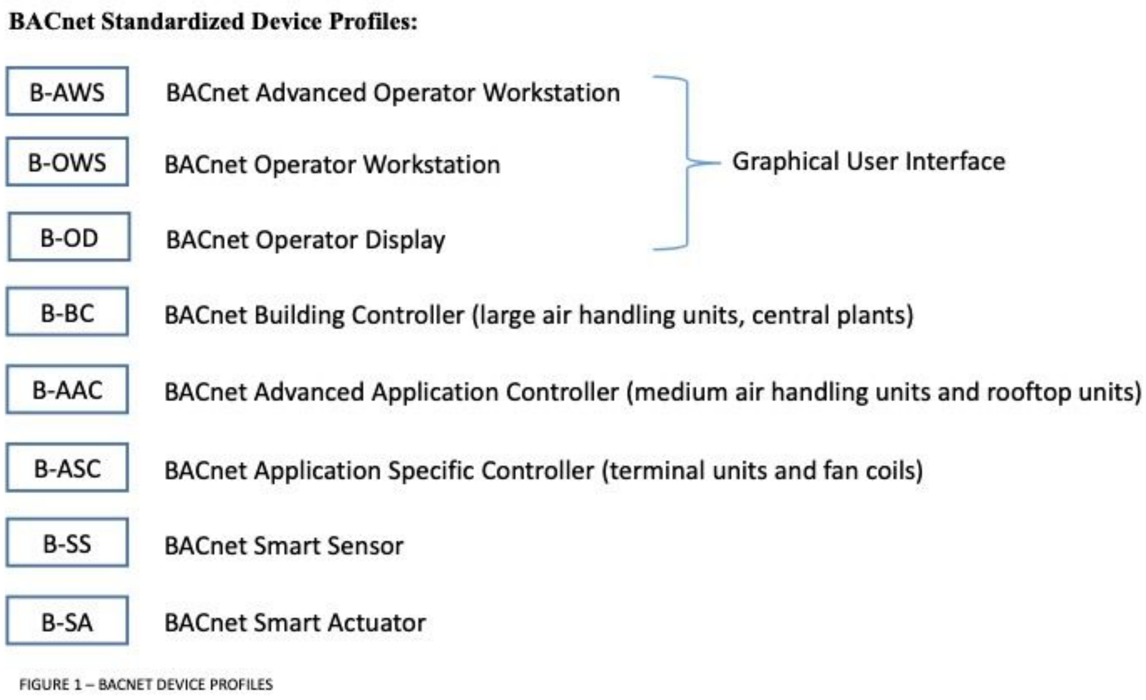


Figure 1: BACnet device profiles. Courtesy: SmithGroup

uration parameters, programs, graphics, trend logs, alarms, schedules and every BACnet object used in the installed system.

For each device profile, the ANSI/ASHRAE 135 standard defines a minimum set of requirements that the device must meet to be formally listed as a BACnet device. It is important to note the difference between BACnet "listed" control devices and BACnet "compatible" control devices. The fact that various manufacturers may claim that their product is BACnet compatible, it does not mean that said control device is also a BACnet listed device. At best, the claim may mean that the control devices can communicate with other BACnet devices.

Back to TOC

Back to TOC

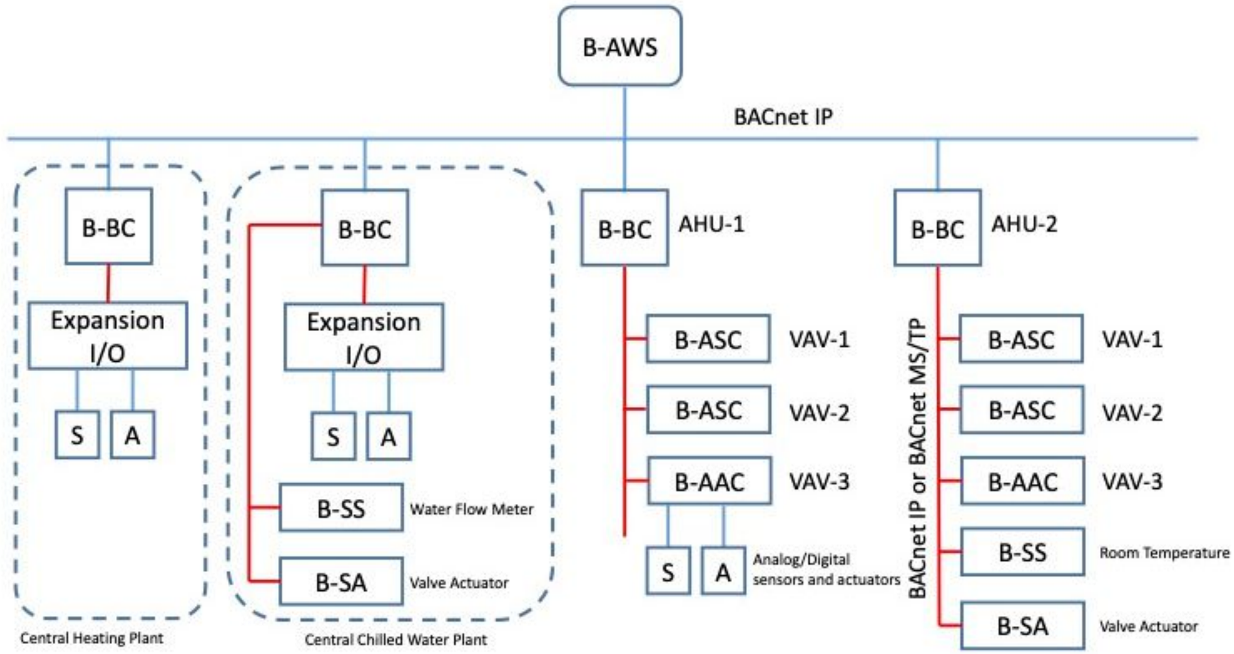


Figure 2: Sample BACnet network diagram. Courtesy: SmithGroup

For a control device to be BACnet listed, it must carry the BACnet Testing Laboratories stamp, which is an indication that the device has been tested by a BACnet certified laboratory and certified under the BTL Certification Program. The BTL website maintains a public list of all BACnet listed control devices.

Each BACnet listed device is required to be provided with protocol implementation conformance statement, which is a document that describes the options specified by BACnet that are implemented in the device.

A sample network architecture of a BAS based on the BACnet communication protocol is shown in Figure 2.

Back to TOC

The BACnet master slave/token passing (MS/TP) communication protocol is a peer-to-peer, multiple-master protocol that shares data by passing a token, or permission to “speak”’ across the network, between control devices (masters) that authorizes the holder device to initiate communication on the MS/TP network; master devices send requests and slave devices submit responses.

Further, master devices can only request services from slave devices if they have an available token; if master device does not have a token, it must wait for a token to be passed on to it. This is one of the main reasons for an MS/TP network to become slow, in particular when there is a high number of devices (more than 50) on the same bus. The control devices on an MS/TP network are connected in series via shielded twisted pair cable and the communication speed across the network is typically limited to 0.1 MB per second.

Unlike the devices on an MS/TP network, the devices on a BACnet internet protocol network are connected via Ethernet cable and the network speed is typically greater than 100 MB per second.

A standard analog sensor (e.g., air temperature, chilled water temperature, etc.) can send an analog signal (typically resistance or volts) only to a BACnet control device. The control device then uses the analog signal for control of the HVAC equipment or shares (via BACnet communication protocol) the associated values from the sensor with the other BACnet devices. The same principle applies to standard actuators; they are typically controlled by a BACnet control device via a 0- to 10-volt signal or 4 to 20 milliampere signal.

Figure 3 shows a sample PICS for a BACnet smart sensor. The main difference between a BACnet smart actuator and B-SS and a standard analog or digital sensor or actuator is that the B-SAs and B-SSs are provided with a control board that allows them to be connected to a BACnet network and communicate with other BACnet devices on the network.

Lastly, but not less important, BACnet listed smart sensors and actuators are significantly more expensive than standard sensors and actuators, typically by an order of three or more.

PICS
B-SS

BACnet Protocol Revision: 1.12

Product Description:
Sensor device with BACnet MS/TP RS485 Interface

BACnet Standard Device Profile: BACnet Smart sensor (B-SS)

BACnet Interoperability Building Blocks supported:
Data sharing - ReadProperty-B (DS-RP-B)
Data sharing - ReadPropertyMultiple-B (DS-RPM-B)
Data sharing - WriteProperty-B (DS-WP-B)
Data sharing – COV Unsubscribed-B (DS-COVU-B)
Device Management - DynamicDeviceBinding-B (DM-DDB-B)
Device Management - DynamicObjectBinding-B (DM-DOB-B)
Device Management - DeviceCommunicationControl-B (DM-DCC-B)

BACnet Standard Application Services Supported:
ReadProperty
ReadPropertyMultiple
WriteProperty
DeviceCommunicationControl
WhoHas
WhoIs

Segmentation Capability: No

Data Link Layer Options: MS/TP Master,
Baud rates 9'600, 19'200, 38'400, 76'800
Max. 32 nodes (without repeater)

Device Address Binding: No static device binding supported

Networking Options: None

Character Sets Supported: UTF-8

Figure 3: Sample for protocol implementation conformance statement for a BACnet smart sensor. Courtesy: SmithGroup

Figure 4 shows two controls diagram for the same variable air volume box. In the diagram on the left of the figure, the control and monitoring of the VAV box and associated zone is done via standard analog and digital sensors and actuators while in the diagram on the right side of the figure, the control and monitoring of the VAV box and associated zone is done using a combination of standard analog and digital sensors and actuators and B-SS and B-SA.

ASHRAE Guideline 36

ASHRAE Guideline 36 is a repository of sequences of operation applicable to HVAC systems that are typically installed in most buildings, except residential buildings.

Back to TOC

Back to TOC

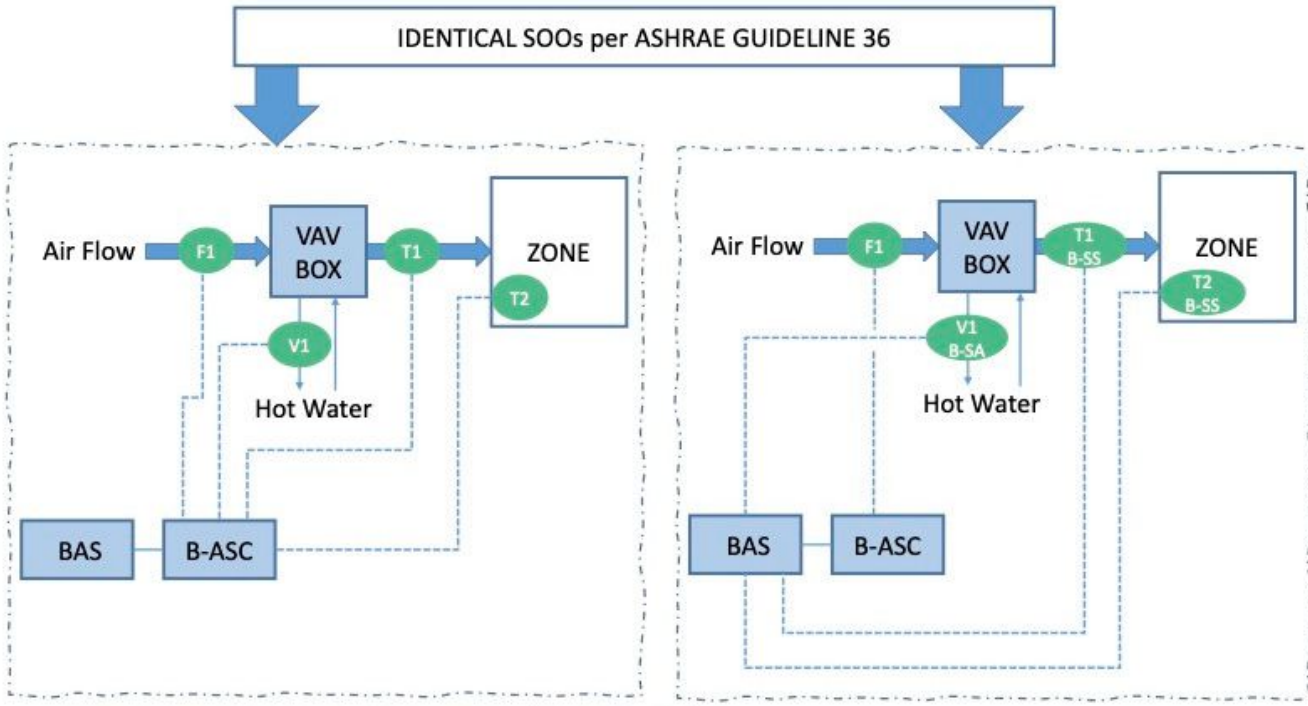


Figure 4: Sample control diagrams using standard sensors/actuators and BACnet smart actuator/BACnet smart sensor. Courtesy: SmithGroup

The intent of this guideline is to encourage engineers, contractors and building owners to use standardized sequences of operation that have been proven over time to be reliable and to operate systems in an energy-efficient manner. These proposed control sequences are sensor and actuator agnostic. In the context of this example, being sensor and actuator agnostic means that it does not matter if a building automation system is provided with standard sensors and actuators or with B-SAs and B-SSs; the outcome (i.e., the energy consumption of the building systems) will most likely be the same.

Referring back to the first example of broad requirements set by the building's owner regarding what constitutes a smart building and assuming that the building HVAC

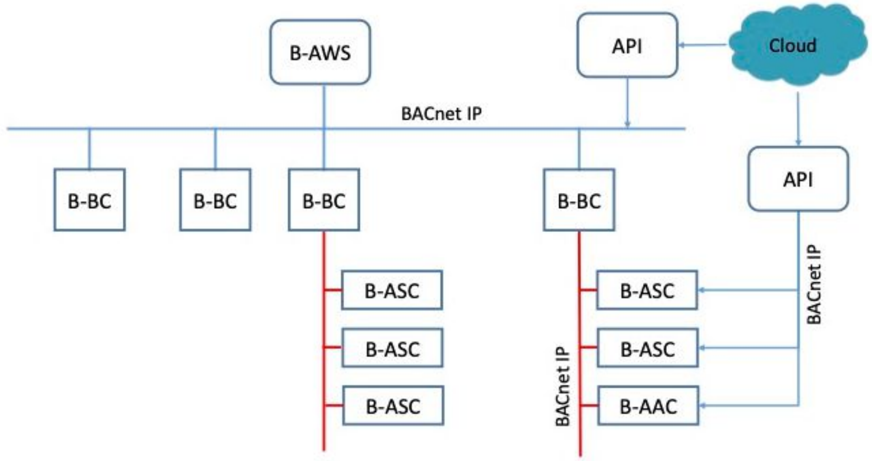


Figure 5: Sample BACnet network diagram with edge control devices. Courtesy: SmithGroup

systems are programmed to operate based on the sequences of operation defined in ASHRAE Guideline 36, what value will the owner get if the energy efficiency of the building will be the same, regardless of what type of sensors are being used? It may be that an owner may find the marketing aspect of using smart sensors as extremely valuable, in addition to the value of having an energy-efficient building. One could reasonably infer that the building by itself did not become smarter due to the use of BACnet listed B-SSs and B-SAs. Engineers and design professionals should inform the owners about any potential risks and benefits before recommending the use of B-SSs and B-SAs.

Figure 5 shows a sample BAS network architecture connected to the cloud. In this scenario, the local controllers, typically the BACnet application specific controllers are connected to the BAS network and also to the cloud. What makes these controllers edge controllers is the fact that they are located at the edge (periphery) of the BACnet network. These types of controllers are provided with significantly more capabilities (i.e., memory, processing speed, storage capacity, etc.) than typical B-ASC controllers; this is because they must be able to execute the standard proportional-integral-derivative loops required to control the associated HVAC equipment and, in the same

Back to TOC

Back to TOC

time, must be able to respond to the requests (i.e., sending data) from the cloud-based applications.

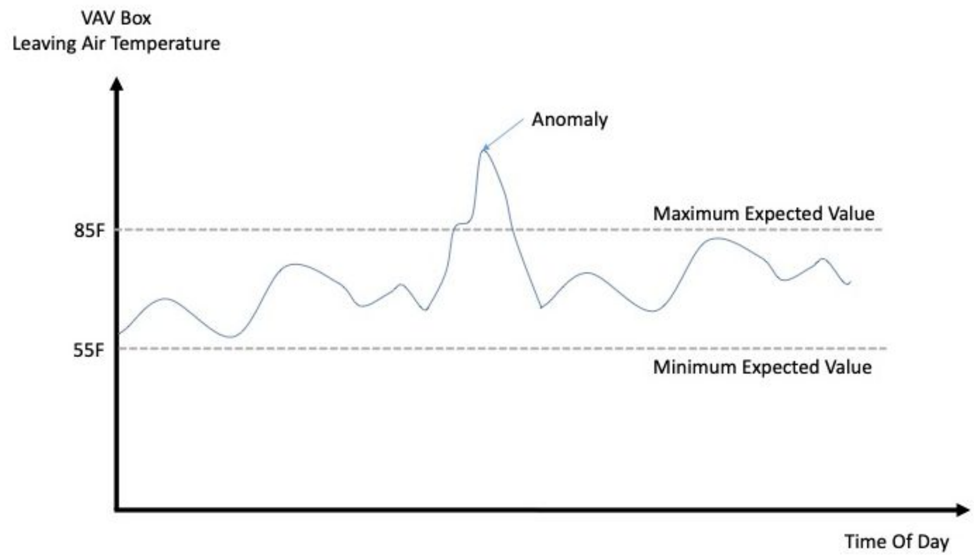


Figure 6: Example of a simple anomaly in building automation system trends. Courtesy: SmithGroup

An application programming interface is typically needed to facilitate the communication between the cloud-based applications and the edge controllers. An API can be viewed as a collection of software applications required to collect and prepare the data before sending it to the cloud-based applications. Although building automation systems are provided with the capability to store, trend data and provide alarms with the operator, anomaly detection applications are typically cloud-based. This is because they typically require more computational power (to execute various algorithms) that cannot be supported by typical BACnet building controllers.

Defining fault detection

Fault detection and diagnosis is the process of identifying or detecting deviations from normal or expected operation (faults) and resolving (diagnosing) the type of problem or its location.

Back to TOC

Figure 6 shows an example of an anomaly in the operation of the VAV box shown in Figure 4. At a certain time during the day, the VAV box leaving air temperature has exceed an expected maximum value of 85°F. It is important note that the BAS also could issue an alarm once it detects this condition; however, in the case of a more complex scenario (as shown in Figure 7) the BAS may not be able to detect the anomaly.

In this scenario, even though the VAV box reheat control valve is almost fully open, the actual VAV box leaving air temperature is below an expected range. This may be an indication that either more airflow is going through the box than expected (even though damper is not as open) or the temperature of the water entering the coil is not as warm as expected, which, in turn, has caused a reduction in the heating capacity of the VAV box. The output from an anomaly detection software application may be a series of actions for the user to implement; the intent of said actions is to help the user determine the actual cause of the anomaly.

Anomaly detection applications can play a significant role in the operation of building HVAC systems; anomalies that go undetected can result in systems using more energy than expected. For example, an owner may use the output from a predictive energy model as a reference to predict future operating costs; anomalies (e.g., chiller plant uses 20% more energy than predicted) may negatively impact an owner's cash flow models. Undetected anomalies can also affect the preventive maintenance efforts of the facilities team by reducing the useful life of equipment; this, in turn, may also negatively impact an owner's cash flow models associated with the operation of the building.

An overview of the application of AI-based algorithms for the control of building systems is available in the article "Using artificial intelligence to control building systems." Referring back to the second example of broad requirements set by the building's

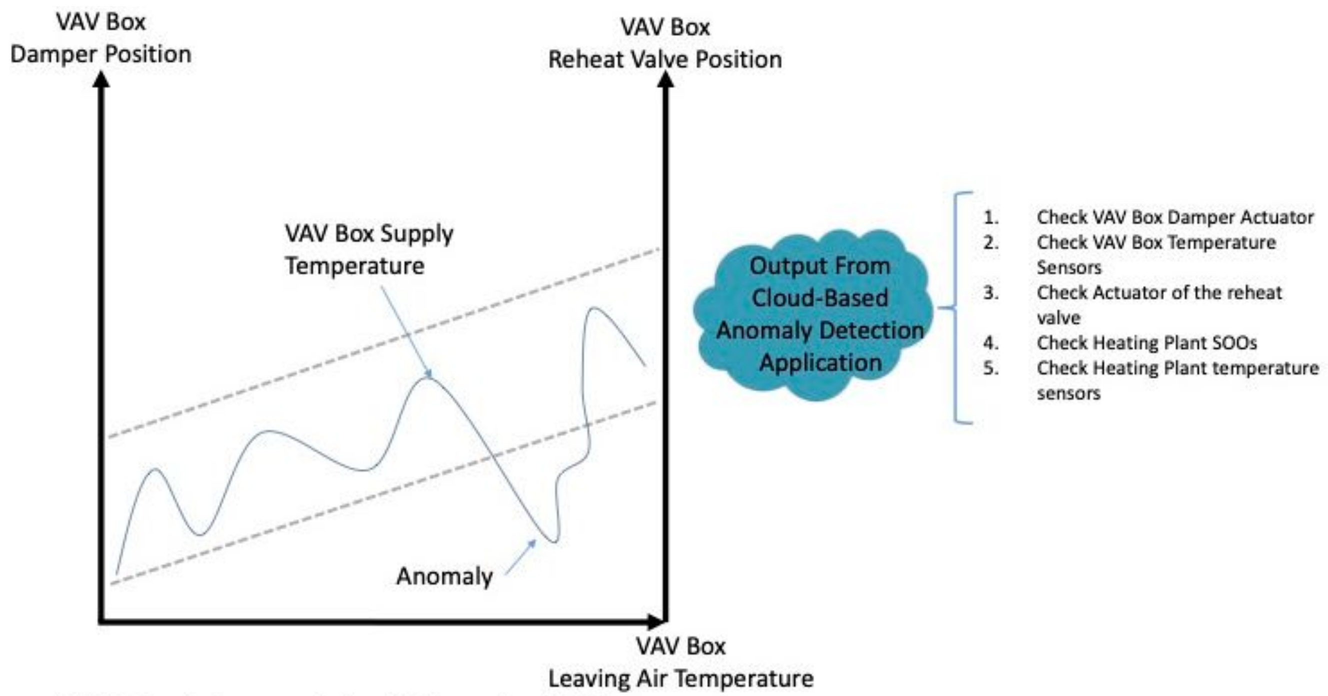


Figure 7: Example of a more complex anomaly in the operation of a variable air volume box. Courtesy: SmithGroup

owner regarding what constitutes a smart building, are analytics, anomaly detection and AI based applications enough to classify a building as being a smart building or a green building?

For this example, neither the BAS nor the other three types of applications (analytics, anomaly detection and AI-based algorithms) can help in identifying what caused an anomaly. Giving a building automation system user a series of actions to execute to find the cause of the anomaly is helpful, however implementing the actions takes time and, when the facilities teams is short-staffed, finding the cause of the anomaly and then fixing the issue may not prevent the building as a whole from running in an energy-inefficient manner for prolonged periods of time.

Back to TOC

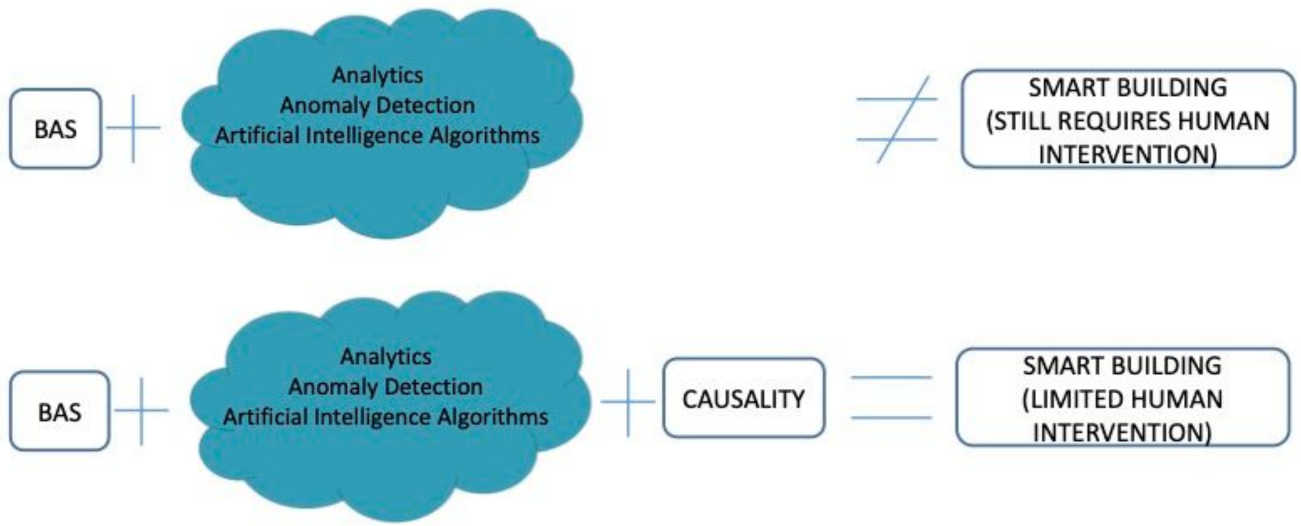


Figure 8: Limitations of standard applications. Courtesy: SmithGroup

Identifying the cause behind an anomaly will most likely require the implementation of causal algorithms in addition to the three types of applications previously mentioned. AI Algorithms by themselves are not enough to make a building smart. Causal algorithms are not AI algorithms. AI algorithms take data input at face value; said algorithms assume that the input is correct (I.e., garbage in, garbage out). AI algorithms cannot determine if a portion of the training data is incorrect or if it includes anomalies. Causal algorithms are used to find the cause behind an anomaly, with minimal to no human intervention. Causal algorithms are extremely difficult to program at scale and the industry is just not there; my overall message with this article is that AI algorithms to control building systems are simply not enough to make a building smart and to minimize the impact on the environment. The industry needs to keep pushing for more advanced algorithms, i.e., causal algorithms.

Back to TOC

Example building automation success

Causal algorithms are typically used in biomedical research to discover causal relationships from biomedical data. Causal models can be build using prior data or, in the case of building systems, data stored by the BAS. A sample process for causal inference is shown in Figure 9.

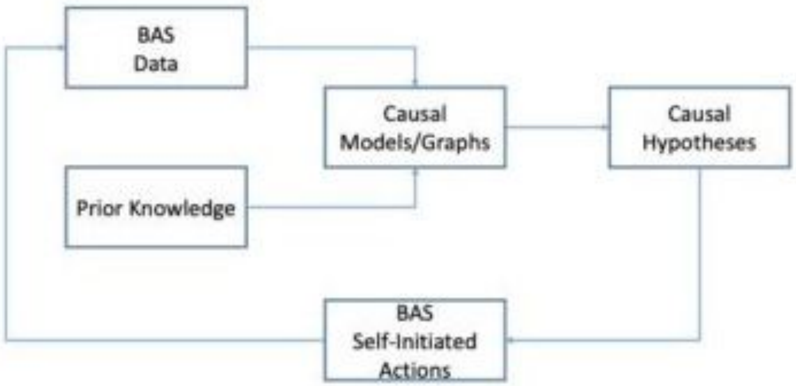


Figure 9: Causal discovery workflow. Courtesy: SmithGroup

A causal model is typically build using a direct acyclic graph, aka DAG, which is a graph between a set of variables connected by arrows. A path in a directed graph is a nonrepeating sequence of arrows that have endpoints in common; in a DAG a variable cannot have a path toward itself.

Figure 10 shows a sample causal model for the VAV box shown in Figure 4; each variable in the DAG represents all historical values available at the BAS and filtered by a desired timeframe (i.e., the time interval starting with one hour before the anomaly as occurred and up to two hours, for a total of three hours). The purpose of the graph is to identify what may have caused the VAV box supply temperature to go outside of its expected range (the cause behind the anomaly). An arrow from one variable to another variable — from F1 to T1 — represents that F1 is a direct cause for T1.

For example, if the reheat valve doesn't continue to open, an increase in airflow of

Back to TOC

the VAV box has a direct effect on the VAV box supply air temperature. The causal model also includes the air handling unit supply air temperature (variable T2), which has a direct effect on T1 and an indirect effect on T1 (via variable V1). The outcome from this causal model may be that the AHU supply temperature has changed unexpectedly. The causal algorithm will then create a new causal model of the AHU as whole to identify what may have caused the AHU supply air temperature to drop.

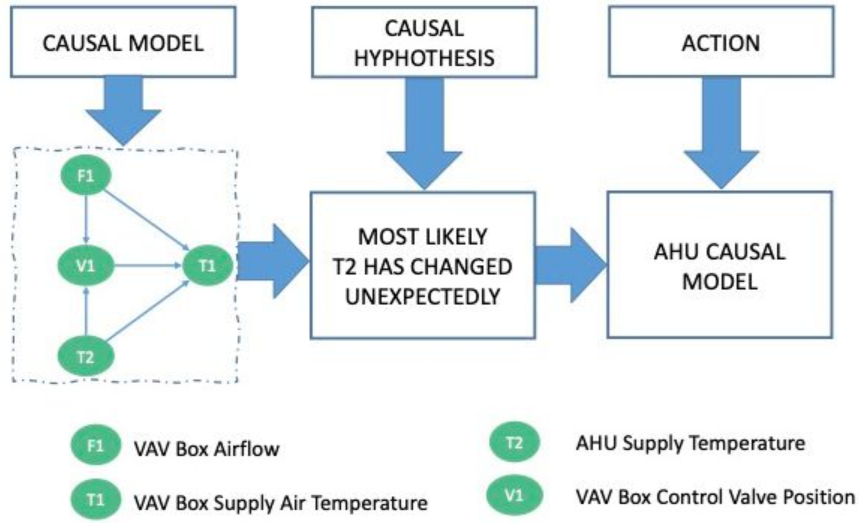


Figure 10: Variable air volume box causal model. Courtesy: SmithGroup

Causal models used with high-performing building automation systems (including analytics, anomaly detection and AI algorithms) have the potential to help facility operators better maintain the building systems and operate them in the most energy-efficient way possible and/or meet owner's requirements.

Ionel Petrus, PE, CEM, LEED AP BD+C, SmithGroup, Washington, D.C.
Ionel Petrus *is principal and mechanical discipline leader of the Washington, D.C., office of SmithGroup.*

ELECTRIC TANKLESS WATER HEATERS

THE RIGHT TEMPERATURE. AT THE RIGHT TIME.

Bradley's Electric Tankless Water Heaters ***POWERED BY KELTECH*** are the industry's most precise, durable and reliable products for emergency safety and other tankless heating applications. These tankless water heaters have the industry's longest warranty and are the only ones with an ASME HLW stamp and to be recognized by the National Board of Boiler and Pressure Vessel Inspectors. Bradley Tankless Water Heaters deliver performance, precision and safety. **Tankless Water Heating Solutions. Brought to Life.**

For easy-to-use sizing calculator visit bradleycorp.com/water-heater-sizing

bradleycorp.com/tankless-water-heaters

Four Reasons Engineers are Going Tankless to Heat Water

Today's specifiers and plumbing engineers are feeling greater pressure to cut energy consumption and costs while improving performance in their operations So, when it comes to heating water for applications, such as emergency safety showers and eye/face washes, many are seeing the benefits of "going tankless."

Using tankless electric water heaters make operations more efficient and functional because they provide:

1) Reliable, on-demand hot water

2) Dependable, consistent water temperature

3) High energy efficiency

4) Easy installation

Bradley's Electric Tankless Water Heaters, powered by Keltech™, deliver on-demand ANSI/ISEA-required tepid water to emergency safety showers and eye/face washes and other tankless heating operations. Drawing energy only when needed, these tankless water heaters are efficient and precise in consistently supplying tepid water, saving energy and utility costs. The **ANSI/ISEA Z358.1–2014 American National Standard for Emergency Eyewash and Shower Equipment** recommends that tepid water for plumbed

Back to TOC

emergency equipment be between 60-100° F or 16-38° C. Tankless water heaters ensure that the water temperature is heated within this temperature range at all times.

Compared with traditional water heaters that require energy to maintain tepid water at all times – continuously having to heat and reheat water – Bradley's tankless water heaters use energy only when the safety units are activated, resulting in significant cost savings.

Since tankless water heaters heat water on-demand, eliminating the need to store hot water in a tank, there is reduced risk of bacterial growth in stagnant water. Plus, in emergency situations, having clean, on-demand heated water readily available can make all the differences in preventing bodily exposure, injuries or harm.

Bradley Tankless Water Heaters deliver performance, precision and safety

Designed to meet the needs of today's complex operations, Bradley's Electric Tankless Water Heaters are the industry's most precise, durable and reliable products for

Back to TOC


Back to TOC

emergency safety and other tankless heating applications. These tankless water heaters have the industry's longest warranty and are the only ones with an ASME HLW stamp and to be recognized by the National Board of Boiler and Pressure Vessel Inspectors. Bradley's Tankless Water Heaters deliver performance, precision and safety.

"Designed for long-lasting performance, all Bradley models are precision-engineered with durable materials, such as copper tubing and robust brass castings, exceeding the standards of any application and setting the bar for other technologies in the tankless category," says Tony Clouse, Industrial Business Development Specialist, Bradley Corp.

Using state-of-the-art technology, Bradley's tankless CLE and SNA models feature the lowest pressure drops in the industry, providing greater reliability and performance than competitive models.

Installation of these units is easy since only one electrical connection and a cold water line are needed, saving labor time and additional costs. Bradley's tankless water heaters also have a smaller footprint than large commercial tank water heaters, making them easier to retrofit existing eyewash stations and emergency showers.

Another advanced feature of Bradley's water heaters is TepidGuard™, which is an anti-scald feature, standard on all SNA-Series Safety Shower Heaters. "This overshoot purge will automatically open and purge excess temperature water, and actively monitors temperature within the heater while operational," Clouse said. "It also passively monitors water temperature while the heater is inactive. This is beneficial for outdoor installations where sun and weather can cause water temperature to exceed ANSI standards."

Not only are the heaters ideal for instantaneously providing ANSI/ISEA-required tepid water to emergency safety showers and eye/face washes, they also deliver heated water for a wide variety of industries and applications that require an immediate, on-demand and unlimited supply of water at a specific temperature.

"Operations don't want to have to constantly heat 500 to 1,000 gallons of water when they may not need constant access to heated water," Clouse explained. "Our customers have responded very positively to the fact that Bradley's electric tankless water heaters provide measurable cost savings due to their efficient operation, and can also achieve sustainability goals for the facility."

Learn more at **https://www.bradleycorp.com/tankless-water-heaters**

Health care building design model shifts how HVAC is handled

As hospitals and health care facilities evolve, the HVAC systems within them must update to meet air quality and HVAC needs

Tanner Burke, PE, Senior Fire Protection Engineer, ACS Group, Austin, Texas; Derek Cornell, Senior Associate, Certus Consulting Engineers, Dallas, Texas; Beth Gorney, PE, Assistant Project Manager, Dewberry, Raleigh, North Carolina; Sierra Spitulski, PE, LEED AP BD+C, Associate Principal/Studio Leader/Mechanical Engineer/Project Manager, P2S Inc., Long Beach, California; Kristie Tiller, PE, LEED AP, Associate, Team Leader, Lockwood Andrews & Newnam Inc. (LAN), Dallas, Texas.

Back to TOC

Back to TOC

How have you and your team addressed the unique air requirements of COVID-19?

Derek Cornell: In hospitals, the approach to HVAC systems in response to COVID-19 has evolved through stages of the pandemic. The additional exhaust and outside air required poses obvious challenges in existing facilities. The more difficult challenge has been designing for flexibility to help ensure prescriptive health care code compliance, maintain environmental conditions and minimize additional energy consumption outside of pandemic surges and state/federal disaster declarations.

For example, in smaller hospitals with existing systems limited in the ability to handle additional outside air load, strategies such as HEPA fan-filter units ducted back into the return system help to minimize the need for major system upgrades and also provide flexibility in returning to normal pressure relationships outside of a pandemic.

Kristie Tiller: We've had a lot of discussion regarding air cleaning products being installed at the suggestion of the manufacturers. UV lights and Ionizing filters, for example. Some building owners are arbitrarily increasing the amount of outside air in their buildings. The guidelines from the various agencies are still in flux and it's difficult to know which modifications can be made that are both sound investments for health and safety and capital expenditures.

Sierra Spitulski: For one recent project, we were asked to create a pandemic ready pod within the emergency department for highly contagious patients. To protect the staff and nurses working around patients, computational fluid dynamic modeling of air distribution was performed on a typical emergency department scenario. This allowed

us to design the HVAC distribution in a way that optimized infection control which can help reduce spread of disease and illness.

How have you worked with HVAC system or equipment design to increase a building's energy efficiency?

Sierra Spitulski: We work with health care providers, builders and designers to create reliable, energy-efficient facilities that safeguard their patient's health and comfort while simultaneously reducing operating costs. Lately, we've been leveraging current code exemptions to decrease airflows in specific areas of the hospital during unoccupied hours through strategic zone level controls, finding creative ways to decarbonize such as rejecting boiler fuel heat to raise the temperatures of the domestic hot and heating hot water systems, in addition to more obvious decarbonization efforts such as heat recovery chillers and electric boilers. Specifically designing the air handlers to be dual duct and dual mixing box has also shown an incredible amount of energy savings in a system.

What is the most challenging thing when designing HVAC systems in such buildings?

Kristie Tiller: The most challenging HVAC design in health care tends to be renovations in active facilities. Renovations are never simple, especially in older buildings, due to existing structure, utilities and equipment location. In an active health care facility, it is especially important to maintain proper conditions while phasing from the old equipment to the new. As engineers, we must work hand in hand with the contractors to ensure that we maintain the health and safety of the patients while renovating

Back to TOC

Back to TOC

Mechanical HVAC equipment in a major hospital in Dallas Fort Worth. Courtesy: LAN

existing systems. This includes proper selection of equipment type and location, the right temporary equipment and careful phasing of construction.

Sierra Spitulski: Challenges are abundant when planning HVAC for hospitals. Equipment that is seismically certified in California comes from a much smaller pool of resources and is not always readily available. Long lead times for this specialty equipment impacts construction schedules, cost and facility cashflow. Infection control protocols and limitations to shut down times require detailed construction procedures. Then, when the new equipment is being installed in a live 24/7 acute care hospital, it's often necessary to have an engineer in the field with the contractors to assist with troubleshooting as the room for error is small–and this is likely happening in the middle of the night.

What systems are you putting in place to combat hospital acquired infections (HAI)?

Derek Cornell: In the aftermath of the pandemic, a cleaner environment for patients and staff is ever-increasing and with that, we have seen a trend in UV technology. The use of UVGI (ultraviolet germicidal irradiation) lamps in air streams, while not new technology, are gaining popularity. UVGI lamps in air streams has been pretty popular over the past couple of decades, however, newer technology using UV-C LED lamps is now becoming prevalent in light of recent years. These are replacing the older mercury UV lamps. We are also seeing them applied for more effectiveness using higher watts/square foot irradiation intensity.

Sierra Spitulski: State and federal code regulations and recommendations for hospitals already contain elements aimed at improving air quality and removing airborne pathogens: low-level air exhaust near a patient's head in infection-control spaces to remove exhaled particulates from the airstream, multistage filtration at the air handling unit, negatively pressurized and exhausted dirty spaces and positively pressurized and HEPA-filtered protective spaces for the most vulnerable and immunocompromised pa-

Back to TOC

Back to TOC

tients. Hospitals can opt-in to additional levels of HVAC cleanliness through the use of UV lights in the air handling system to further eradicate airborne pathogens, increased levels of MERV filtration and regular maintenance and cleaning. There are also lots of conversations and constantly evolving research around recommended airflows over and around patients in an operating room environment.

What type of specialty piping, plumbing or other systems have you specified recently?

Sierra Spitulski: Our team is on the cutting edge of today's medical advancements. This includes codes, standards, new technologies and California Department of Health Care Access and Information (previously OSHPD) requirements. There's a new requirement in California that's hitting all hospitals in 2030 that will require all acute care facilities to provide on-site storage for 72-hours or more for domestic water, waste water and emergency generator fuel oil. These requirements are aimed at enabling hospitals to maintain functionality in the event of a disaster that renders the city services inoperable for a period of time. This is a massive undertaking, as this means anywhere from 10,000 to 100,000 gallons worth of storage for these resources, which can be an even bigger challenge in landlocked hospitals.

Medical gases are vital for hospitals and medical campuses. Define the project, its goals, the challenges and the design solutions.

Tanner Burke: We provided consulting on the code challenges for medical gas upgrades to a Level 3 imaging room at a medical facility in Northern Nevada medical facility. This involved review of the 2018 Facility Guidelines Institute and NFPA 99: Health

Back to TOC

Care Facilities Code requirements to determine the required quantity and location of medical gas outlets, as well as the provisions associated with the medical gas zone valve box nurse alarm systems.

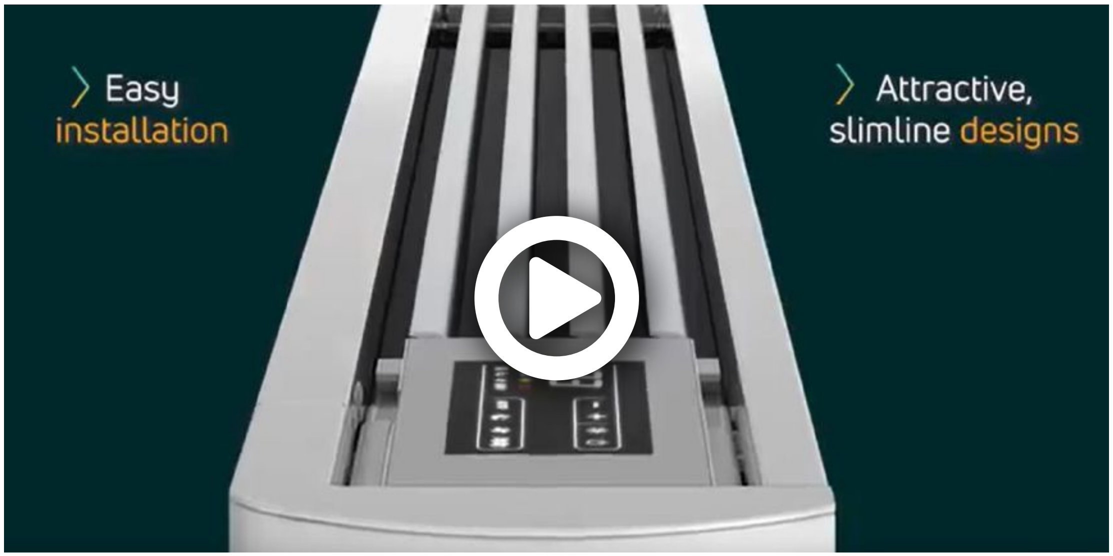
Derek Cornell: The need to design medical gas systems for increased ventilator quantities is here to stay. We are currently working on a full evaluation and design of upgrades to a large campus oxygen (O_2) system. At this facility, one of the largest COVID surges occurred simultaneously with extreme winter conditions for the region, resulting in adverse road conditions making increased frequency of deliveries difficult. In the extremely cold weather and very high demand, icing of the vaporizer was also an issue. The proposed design includes a complete replacement of the bulk O_2 system in a new location while keeping the existing hospital operation via connection to multiple emergency oxygen connections.

Consulting-Specifying Engineer


The new iVECTOR S2
Heating and cooling with low temperature systems
Optimum room climate

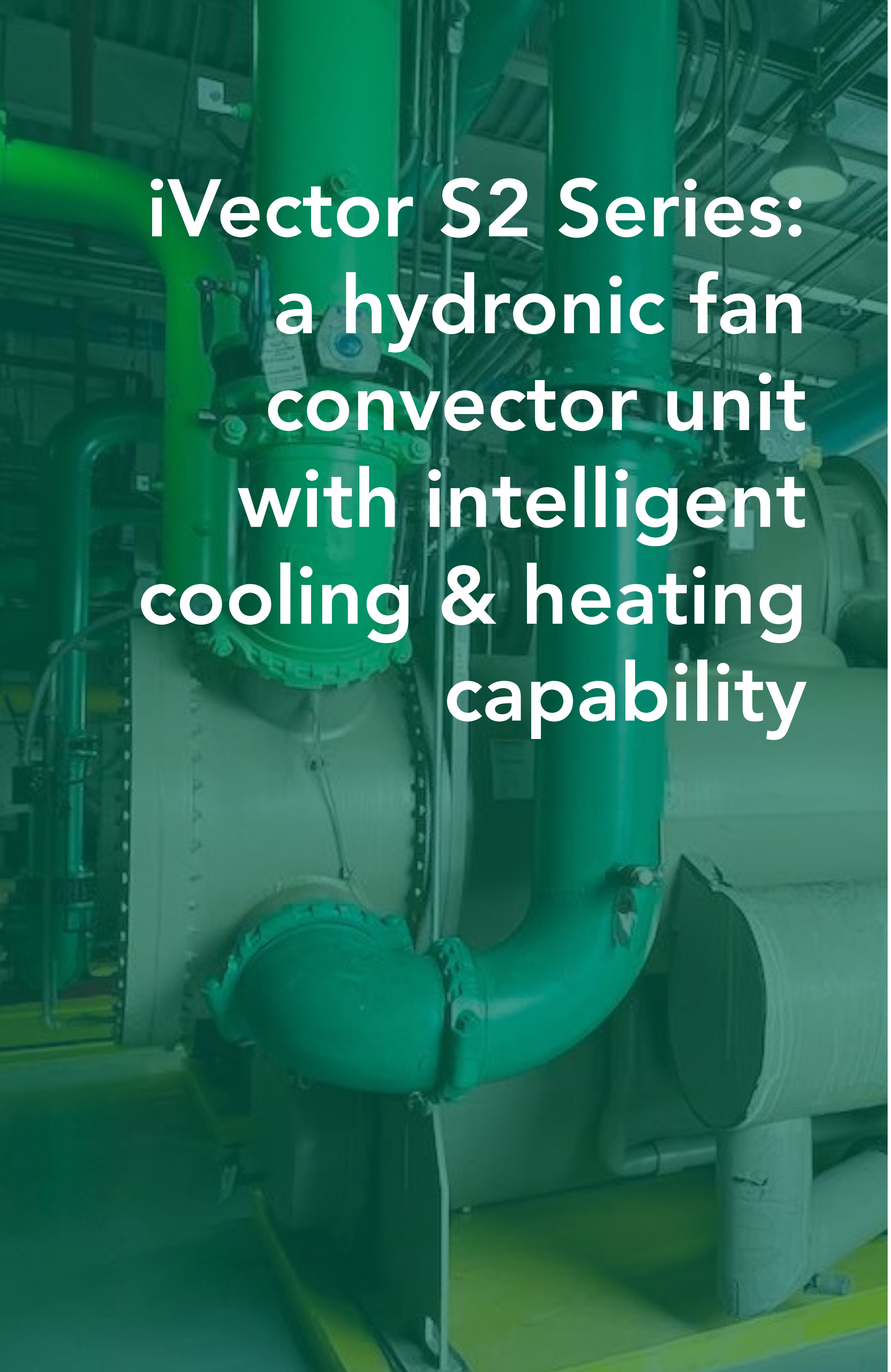
Back to TOC

MYSON



iVECTOR S2

A new generation of hydronic fan convectors for heating & cooling



iVector S2 Series: a hydronic fan convector unit with intelligent cooling & heating capability

A smart way to improve indoor climate

Today, both renovation and new building projects have strict standards that raise the bar for overall efficiencies. At the same time, there is a demand to reduce dependence on finite energy sources, cut emissions and lower overall costs. Modern hydronic heating systems are designed to work at significantly lower temperatures to help improve system efficiency, achieve meaningful energy savings and improve indoor climate comfort.

Meet the newest generation of fan convectors

Advanced European technology adapted for the North American market. The iVECTOR S2 is the newest energy efficient fan convector from MYSON, designed specifically to address emerging demands for comfort and energy efficiency. Boasting an attractive, compact design the iVECTOR S2 can provide high heating performance even when operating at low temperatures and with low water content. This provides efficient energy use without sacrificing outputs. When combined with a reversible heat pump or a separate cooling source, the iVECTOR S2 can offer both heating and cooling functions, making it a perfect solution for both commercial, multifamily and single family residential use.

Back to TOC

Built with flexibility in mind

With iVector S2 it's all about design flexibility. Installation options include both surface mounting as well as built-in options (walls or ceiling). Controls are available in either onboard or remote options, along with solutions for fully autonomous control, 0-10V control for BMS systems or fixed fan speed control. With a choice of either 2-pipe or 4-pipe heat exchangers, iVector S2 is available in 5 different sizes so specifiers won't have a problem finding an iVector S2 model to meet their project's needs.

Combining iVector S2 with other low temperature systems, for example hydronic panel radiators or a radiant system, provides an ideal combination for optimum in-door climate comfort all year long. The iVECTOR S2 is also the perfect solution for rooms not in regular use such as guest rooms or hobby rooms thanks to rapid heat-up and cool-down times.

Modern/Slimline Design

With inspiration from leading Italian designers, the aesthetically pleasing iVector S2's slimline design allows for discreet positioning without compromising performance. Whether it be wall or ceiling mounted, or a recessed/built-in installation, iVector S2 will blend into its environment seamlessly. For maximum design flexibility, all casings and grilles can be produced in virtually any RAL color (standard is RAL 9003).

Controls with a high IQ for smart buildings

The heart of the iVector S2 is its ingenious and highly accurate controls with PID logic and specially designed algorithms that intelligently drive optimal performance all year long. Combined with a high efficiency DC fan motor, the result is ideal comfort and energy efficiency.

User interface flexibility

Whether selecting the intuitive onboard SmartTouch user interface or the remote wall mounted SmartTouch user interface, specifiers have choices when specifying iVector S2. The onboard control is capable of controlling a single unit while the remote SmartTouch can control up to 30 similarly equipped iVector S2 units. If these solutions aren't optimal, then iVector S2 can be fitted (field or factory) with the available 0-10V control board for use with suitable 3-party thermostats or BMS systems.

Performance versatility

iVector S2 is available in either a 2-pipe or 4-pipe version with standard connections on the left side of the unit (field or factory changeable to right side). Depending upon unit size, heating outputs range from 7,541 btuh to 32,552 btuh at 176/167/68oF (2.21 kW – 9.54 kW at 80/75/20oC). Total sensible cooling ranges from 3,106 btuh to 12,659 btuh at 45/54/81oF (0.91kW – 3.71kW at 7/12/27oC). All values at high fan speed.

Consider iVector S2 for your next project and enjoy all of these benefits;

- **High heat outputs at low system temperatures**
  The iVECTOR S2 provides high outputs in low-temperature heating systems. Ideal in combination with heat pumps!

- **Fast, responsive heat-up times**
  The iVECTOR S2 has considerably less water content than conventional panel radiators. Its low thermal mass ensures fast heat-up times and efficient operation.

Back to TOC

Back to TOC

- **Cooling**
  Cooling is possible with the iVECTOR S2 when connected to a reversible heat pump or a separate chilled water source.

- **Intelligent control**
  The iVECTOR S2 is equipped with an intelligent control system. It allows easy operation and integration with other building management systems

- **Whisper quiet operation**
  The latest in modulating fan technology offers the best heat output with the lowest imaginable noise level.

- **Space-saving installation**
  Thanks to its compact dimensions the iVECTOR S2 provides high heating and cooling performance with minimal size.

MYSON is a brand of Purmo Group (www.purmogroup.com) and is one of the oldest and most respected names in the HVAC industry. We have been manufacturing fan convectors for over 50 years. With a reputation for maximizing the role of innovation and technology in our operations, we are committed to helping reduce CO_2 emissions by developing energy efficient heating and cooling products that are capable of operating effectively at low flow temperatures.

Contact us today to for complete information about iVector S2 including model specifications, submittals, iVector S2 performance metrics and more.

Your questions answered: Pairing VRF with applied HVAC solutions

Back to TOC

In this Q&A, learn how Linear Expansion Valve (LEV) Kits help pair VRF with applied HVAC solutions for more flexibility to meet a building's specific load, airflow, and application requirements.

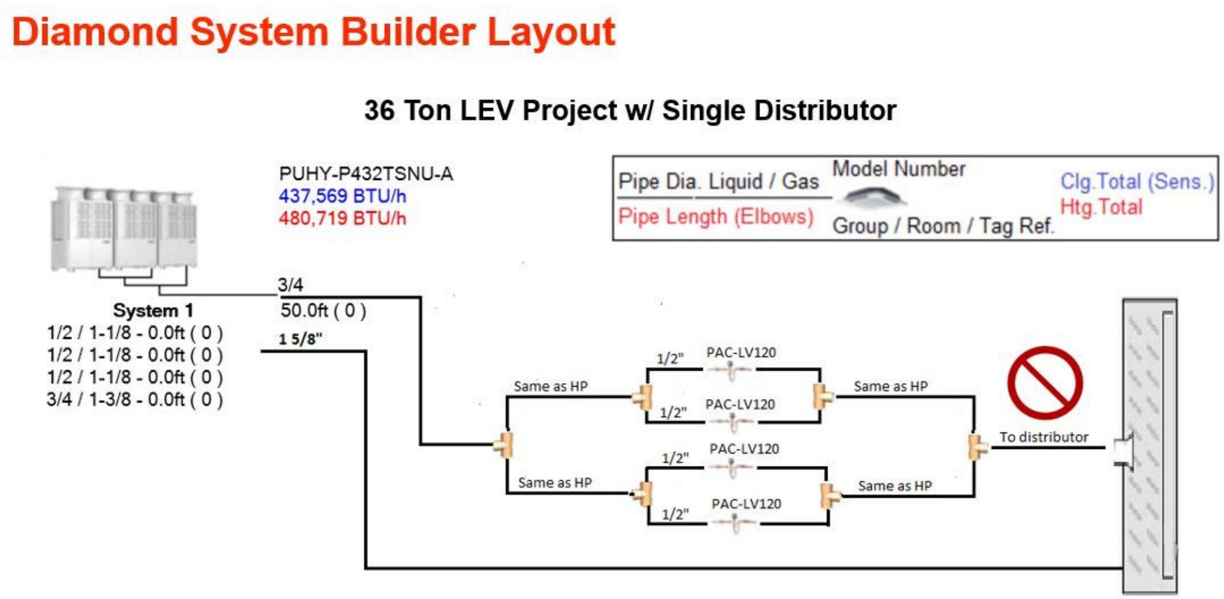
A variable refrigerant flow (VRF) system is an increasingly popular choice as it provides industry-leading comfort, flexibility, high efficiency, and all-electric heating and cooling. Traditionally, VRF systems can be limited in their type and size of indoor equipment, but by using a Linear Expansion Valve (LEV) or Air Handler Expansion kit, air handler options can be expanded and provide engineers more flexibility to meet a building's specific load, air flow, and application requirements.

LEV kits enable the advantages of the VRF outdoor system to be paired with applied equipment to get the benefits of inverter technology resulting in higher efficiency. Additionally, LEV kits can provide higher static pressure, larger capacity, customized products, and dedicated outdoor air system configurations.

Several questions were left unanswered during the July 27, 2022, webcast: Pairing VRF with applied HVAC solutions Learn more from these experts in this Q&A:

- Aaron Askew, VRF and Ductless Technical Specialist (DTS) for Indiana and central Illinois, Trane

- Evan Eitemiller, VRF and Ductless Sales Specialist for the Pacific Northwest/Rocky Mountain Region, Trane



What outdoor temperatures are the DSB blue and red heating and cooling capacities based on?

You can set the outdoor conditions specific to your design manually or you can use the ASHRAE standards for the City/State you are designing in.

Any plans for larger capacities above 20 tons?

You can now go greater than 20 Tons as long as you have multiple distributers. You would need to have multiple controllers to go larger than that 20 Tons.

You have to have a variable speed compressor?

Yes. All VRF ODUs have variable speed compressors.

Back to TOC

Can a vrf outdoor be connected with Trane residential indoor units?

Yes, within LEV Kit design guide limits. LEV Kits are not compatible with single phase (i.e., Smart Multi, NV or P-series) ODUs. Typically, LEV kits are not approved for use with residential furnaces.

Can we combine typical VRF evaporators with LEV, non-VRF AHU's?

Yes, within LEV Kit design guide limits.

A failed 4 pipe system have new ahu's, can we retrofit VRF LEV kits to these units?

Yes, within LEV Kit design guide limits.

Is it possible to use LEV kits paired with a commercial AHU to become a split DOAS on a single system?

Yes, within LEV Kit design guide limits.

Recommendations for VAV applications with coil turndown? use dampers?

Yes, using bypass dampers is one potential design solution when working with minimum VAV turndown limits.

Will the controller allow control of a multi speed motor?

Back to TOC

Back to TOC

Yes, there are 3 discrete fan speed signals (H/M/L) that can be sent to the AHU fan controller.

When you say "distributor" does that apply to a single heating/cooling coil?

Yes, some single coils may have multiple distributors.

Having the refrigerant piping being installed correctly and as designed is critical to the performance of VRF systems. Are the piping installation tolerances as critical with LEV systems?

Yes, even more critical.

Can you list actual examples of projects that LEV kit installation?

Yes, contact your local Trane account manager.

For load conditions, can 2 smaller outdoor units be used in lieu of 1 larger one (e.g., two 10-ton vs one 20 ton?

Yes, but the DX coil is still subject to minimum airflow turndown limitations.

Can this be retrofitted into Blower coil units?

Yes, but may need a new DX coil.

Back to TOC

Are these LEV kits compatible with both water-cooled and air-cooled outdoor units?

Yes, but LEV Kits are only compatible with 3ph ODUs. They are not compatible with Smart Multi, nor NV, P-series.

Can LEV kits be used in Multizone VAV air handlers?

Yes, as long as the coil and AHU design fit within all required specifications per the app guide (i.e., minimum fan turndown limits, etc.)

Can an LEV AHU be part of a multi-unit VRF system?

Yes, with both the Heat recovery and standard VRF heat pumps the LEV kits can be used in combination with other VRF indoor units. There are limitations such as nothing bigger than 8 tons on a Heat Recovery system due to Port Max size on the branch controller.

Cold climate, 100% OA ERU, do we need electric reheat coil downstream of the VRF coil for when the ODU goes into defrost? Assuming we cannot shut the fan off due to code reasons when the VRF coil is in defrost.

Yes, that would be best practice for when the system goes into defrost or error to prevent huge fluctuations in temperatures.

Can you provide some insight on using cassettes with a VRF and bringing in outside air to accommodate required air changes?

Yes, outside air can be brought into any of the cassettes, they all have a max value depending on size. The air cannot be raw fresh air, minimum return is 59 degrees. The Fresh air has to be forced into the cassette by another piece of equipment (DOAS, ERV, etc..) there is not enough negative pressure to draw in the air.

Can the LEV kit be controlled based on discharge air temperature? Or only space temperature?

Yes, both options are standard with the LEV kits. For discharge Air Control the minimum is a 3 Ton kit for guaranteed outputs.

Does the LEV kit require power connection?

Yes 208/230 Single Phase voltage to each LEV controller.

Will the LEV control to a heating LAT setpoint at all?

Yes.

Does the “linear” component of the title refer to capacity control of the refrigerant?

Yes.

It seems there are lot of Trane-provided tools available for engineers to do very detailed designs with these refrigerant systems. In the past other VRF suppliers

Back to TOC

Back to TOC

have offered to do the heavy lifting with solutions for designers providing detailed selections, piping diagrams, and performance data that is unique to the project, etc. While Trane offers access these tools to designers, do Trane reps offer similar levels of support with these systems as other manufacturers?

Yes.

Is this system planned to be used with A2L refrigerants in the future?

Yes.

How do you control the system using a wireless thermostat system?

Wireless control options are N/A at this time.

Can you discuss the benefits of using VRF condensing units with LEV over traditional condensing units (like the Trane RAUJ/RAUC) in cooling only applications?

When using VRF condensing units you have the full range of the invertor compressor for better part load control, long line length applications with no additional refrigerant specialties needed. With the Y-series VRF used in cooling only you can cool down to -10 degrees ambient with the use of a low ambient cool kit.

When designing a VRF system that is going to serve an area that contains a shell space (not built out), how do we prepare the piping system handle fan coil units in the future? Valve and cap branch selector unit piping?

Using heat recovery VRF is the best way to effectively do a build out. Yes, you would valve and cap unused ports on the branch controller. The limitations to look out for are the 8-ton limit for the LEV kit on heat recovery and also that 50% of the total system capacity will need to be connected to startup the system.

I assume that the LEV kit is compatible with a retrofit of DX cooling. Would a coil for district chilled water be compatible?

Typically, LEV Kits used in retrofit applications require installation of a new DX coil as well as new piping so that contaminants from the old system do not cause premature failure of the new VRF system.

Before use of LEV Kits, how was refrigerant flow to evaporator controlled?

Traditional VRF IDUs have factory installed LEVs to meter refrigerant flow. Before LEV Kits connection to non-VRF AHUs was not allowed.

When incorporating a non-VRF air handler into as system design – how do we define the applicable characteristics of the coiling coil in DSB [like coil volume]? Or can that be done?

This cannot be done in DSB, which is why it's recommended to use a third party coil selection software.

AHRI treats small VRF systems as mini-spits. How can I explain why a smaller VRF system can be treated as a VRF for purposes of calculating energy savings?

Back to TOC

Back to TOC

This all depends on the condenser capacity. For systems > 60,000 BTU/h they are tested by AHRI 1230. For systems < 60,000 BTU/h they are tested by AHRI 210/240.

One of the biggest concerns we and the building owners have is the refrigerant leaks. Do you monitor the leaks? What happens if there is a leak. Can we have redundant circuits in order not to lose the entire cooling/heating systems.

There are extensive pressure testing requirements for all VRF installations so there should not be any leaks after startup. The VRF system does not monitor for leaks. If a leak occurs, it must be found and repaired ASAP via soapy water solution applied to piping connections or with a refrigerant detector. You would need to provide redundant VRF systems in order to keep a system online in the event the other system has a leak.

How far LEV can be from VRF outdoor unit?

There are different piping limitations for if the LEV is being connected to a Heat Pump or a Heat Recovery VRF system and would be specific to the manufacture but as for Trane Mitsubishi on a Heat Pump system furthest actual is 541 actual feet and 623 equivalent feet. For a Heat recovery system single branch controller max length from the Outdoor unit to the branch controller is 360 equivalent feet and from the branch controller to the LEV would be 197 equivalent feet. Always run estimated lengths through the VRF selection software to check for rules and restrictions.

Is it possible to have both a third-party thermostat interface and an MA controller connected to the same LEV kit? It is my understanding that the MA

controller is needed for some programming of the LEV kit, and I don't always have a DDC system and need the thermostat interface for some systems.

The MA controller is used and required for initial setup and configurations. It may also be used for standard space temp control. However, you cannot have both the MA controller and a third party t-stat controlling the unit in normal operation. It's one or the other.

What is the advantage of LEV units compared to VRF units?

The LEV kit allows connection of a non-VRF AHU. Any feature that is required that is not available in a standard VRF IDU (i.e., heat wheel, higher than 1.0 ESP requirement, etc.) could be an advantageous application of an LEV Kit.

What is the advantage of installing LEV units in a typical HVAC unit?

The LEV kit allows connection of a non-VRF AHU. Any feature that is required that is not available in a standard VRF IDU (i.e., heat wheel, higher than 1.0 ESP requirement, etc.) could be an advantageous application of an LEV Kit.

Did we see that a special TEE is not recommended to twin LEV kits? It appears the twinned factory LEV kits (6,8,10T) uses a special TEE NOT a standard bull head TEE

Standard Ts are recommended. Do not use special Y-fittings, Refnet fittings, etc.

Back to TOC

Back to TOC

What is the most common application you are seeing LEV kits being used on?

Split DOAS applications.

How is auto mode changeover handled in a DAT application? What control inputs are needed to accomplish the change between heating and cooling?

See p. 50 of LEV Kit app guide.

We have been told minimum airflow at the VAV AHU is 80% of maximum. Why is this? This can create problems with VAV systems. Can airflows be lower but staging the LEV valves using the BAS?

See p. 47 of LEV Kit app guide.

Can the LAD be located in ceiling space below the Rooftop unit and piped up to the unit?

Probably not. The LEV valve and temp sensors have a max 16 ft wire length that cannot be extended.

Can refrigerant press connection copper fittings be used to install the LEV kits (i.e., NIBCO PressACR)?

Press fittings are allowed but not recommended. See this app guide for more detail.

Back to TOC

Can a conventional DX AHU with a LEV be used with a VRF to use as a chilled water VAV unit would be used?

Potentially, but with more limited applications. For example, the LEV Kit may not be able to achieve as low of a LAT setpoint as with CHW. The turndown of the VAV fan may be more limited as well.

Are the details in CAD only or are they available for Revit?

Only REVIT is available.

Mitsubishi / Trane provides air handlers up to 8 tons. Why use an LEV kit for the smaller air handlers?

Only if you needed some feature not available with standard VRF IDUs – i.e., heat wheel, ESP requirement > 1.0 inch etc.

I have a customer who wants a 60-80k high efficiency residential Trane furnace with a 2.5-ton Mitsubishi condenser. Would this be a good application for an LEV kit or is there a guide somewhere to help put this together?

No. LEV Kits are limited to Y and R2-series systems, which start at 6 tons and larger.

Can existing DX coils be reused in a retrofit application? (i.e., RTU with DX cooling and gas heating retrofitted with LEV kit to operate as a heat pump?)

Back to TOC

No. A new coil would need to be used. Other systems use different oil types which could potentially contaminate the refrigerant and cause premature failure.

Can you clean the strainers?

No, the strainers are built into the LEV kit.

Can LEV kit pre-packaged in factory?

No.

What are some best practice solutions for VRF systems to comply with ASHRAE-15 if requested by client?

Limit the total system charge to be less than 26 lbs. R-410a / 1000 cu ft of occupied space. Use permanent opening between adjacent spaces to increase dilution volume of small zones.

Sorry can you clarify that the reheat coil size is maxed at 8tons or the entire lev kit?

LEV Kit applications are limited to 8 tons on a heat recovery application due to capacity limitations of the Branch Controller.

Do I need one wired controller per each LEV control box?

Back to TOC

If using Mitsubishi wired remotes, you can group multiple LEV controllers to one Mitsubishi wired controller, similar to grouping of standard VRF IDUs. However, if using third party t-stats or BAS control, you would need one control signal per LEV control board.

On face split do you not get stratification?

Face split coils can be used for better part load capacity and dehumidification control, but could still be subject to stratification, similar to traditional face split applications.

Are LEV kits applicable to warm/hot environments CA, AZ, NV?

EAT limits for LEV Kit DX coils is 59-75 F WB in cooling and 0-59F DB in heating. The ODU is subject to the same temperature limitations as with standard VRF applications.

Any NEMA rated cabinet options for outdoor AHUs to place controller into? Or do people install inside AHU?

Dimensions of the controller are shown in the submittal. As long as it fits inside, any weather-proof enclosure would work. The controller may be able to be mounted inside the AHU as long as there is available space where it doesn't interfere with other AHU operations. In most cases the controller gets mounted outside of the AHU.

Do you have a ballpark percentage for sensible to latent capacities in the coil?

Depends on the EAT conditions.

Back to TOC

Can the LEV kits really go up to 80 ton? It looks like the largest condenser grouping is 40 ton. So, would that be controlled by 2 condenser groups?

Correct, it would be split between 2 condensing systems most likely 4 distributers and 4 20 Ton LEV kits.

Do they require any special service clearance?

36 inches NEC clearance to high voltage connection on controller.

What is the equivalent length of a typical LEV and is the total refrigerant line length measurement include both the liquid and line piping?

16-24 inches. The pipe length input to DSB includes both pipes.

Is there any way to provide heat below 0°F ambient with these kits?

0°F is minimum EAT to LEV DX coil. Below that temp, pre-heat is required. ODUs are subject to normal temp limits.

Aaron Askew and Evan Eitemiller

***Aaron Askew, VRF** and Ductless Technical Specialist (DTS) for Indiana and central Illinois, Trane. **Evan Eitemiller, VRF** and Ductless Sales Specialist for the Pacific Northwest/Rocky Mountain Region, Trane*

A2L and New Refrigerant Strategies Take Holistic View of Environmental Impacts

Across nearly every industry worldwide, there has been a continued push for fuel and energy efficiency – along with a reduction in global warming impacts. The heating, ventilation and air conditioning industry has been a focal point of that trend.

The U.S. Energy Information Administration estimates that the energy used to cool residential and commercial buildings accounted for a full 10 percent of total electricity consumption. The latest push in the industry to help reduce electricity use and greenhouse gas emissions is the shift to A2L HVAC systems featuring new refrigerant types designed to be both energy efficient as well as less impactful toward global warming.

The use of advanced A2L refrigerants – and their widespread use – will help drive a continued reduction in greenhouse gas emissions and continue a push for a healthier world.

Push for A2L - Regulatory and Historical Background

The processes which set the stage for the development of A2L refrigerants go back to the late 1970s and early to mid-1980s, when scientists studying the thinning of the ozone layer in Earth's atmosphere discovered the impact

Back to TOC

man-made chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) were having on the planet.

Those discoveries ultimately led the way to the creation of the Montreal Protocol through the United Nations, which was adopted in September of 1987. To this day, it is the only treaty which that has been ratified every country on Earth - all 198 UN Member States.

That treaty created a phase-down schedule for almost 100 man-made chemicals designated as ozone depleting substances – many of which had been traditionally used in refrigeration and air conditioning contexts. Under that schedule, developed countries completed phased out HCFCs by 2020, and developing countries operating under a timeline of 2030.

Introduced to replace those ozone-depleting chemicals in many cases were another group of substances - hydrofluorocarbons (HFCs). While they did not have the same negative impact on the ozone layer, these chemicals did still have elevated global warming potential (GWP), creating an outsized effect on global warming.

Back to TOC

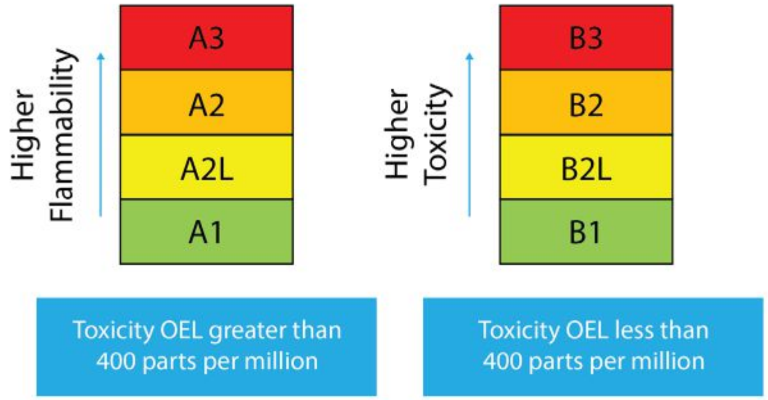
To address that aspect of the dynamic, the United Nations developed the Kigali Amendment in 2016, which would look to phase out HFCs over time, reducing their use by 80 to 85 percent by the late 2040s in developed countries. Many European countries have taken independent actions, and the United States ratified the agreement in September 2022.

Overall, the trend in refrigerant technology and approach over the past 40+ years has been the continued movement toward systems with a reduced GWP and overall lower environmental impact.

Breaking Down Environmental Impact of Refrigerants

The environmental impact of refrigerants – and why the A2L category is coming into focus – comes back to the holistic impact those chemicals have on the environment.

In this context, chemicals are generally classified in terms of both flammability and toxicity according to ISO 817.



Chemicals in category A3 are considered less toxic, but highly flammable – such as propane. While chemicals at B1 may not be flammable, they are toxic. A2L chemicals are slightly flammable but are less toxic.

The third factor to consider is how efficient and effective a chemical is for a given purpose. After all – most of the environmental impact of HVAC equipment – about 70 percent – is in their power consumption (and the energy generation processes used to provide it).

Holistically, the goal is to find the balance between a chemical's global warming potential (GWP) and its efficiency in use in an HVAC environment while also considering flammability, toxicity, or other issues.

While legacy hydrofluorocarbons did provide strong efficiency in HVAC systems for their time, they carried extremely high GWP rates, in addition to the ozone depletion issues discussed prior. Many A2L refrigerants developed in the years since deliver stronger HVAC performance without those ozone-depleting or greenhouse gas side effects.

Other chemicals – such as propane, CO_2, or ammonia - have also been used in this application, but each of them has issues which stand as barriers to truly widespread use. CO_2 systems operate at 5 to 10 times higher pressure than other systems and may not be permitted in some context, propane is extremely flammable, and ammonia has the potential to be highly toxic.

That concept of finding the right balance between GWP, safety, and cooling efficiency is the genesis behind the A2L category, and its use within the HVAC context.

Back to TOC

	R12 Freon (Banned CFC)	HFC-134a	HFC-152a	CO2 (R-744)	Propane (R290)	Ammonia
Ozone Depletion Potential (ODP)	1	0	0	0	0	0
Global Warming Potential (GWP)	10,200	1,430	124	1	3	0
Flammability/Tox-icity	A1	A2L	A2L	A1	A3	B2L
Operating Pressure Range	2.1 - 11.7 bar	0.6 - 6.7 bar	0.6 - 6.7 bar	10 -150 bar	10 - 50 bar	2.9 -13.5 bar

Codifying A2L HVAC Systems in Buildings

A2Ls have been used in the European Union, Japan, India, Australia, and the auto industry for some time. But as the advantages of using A2L systems became more clear, regulatory bodies made adjustments to account for their use in commercial and residential HVAC systems, such as ASHRAE 15-2019 and UL 60335-2-40.

In order to burn, A2L gases would need to leak, reaching concentrations above the chemical's lower flammability limit, and then be exposed to an open flame or other ignition source. To prevent this, much of the regulatory focus has been on the preventing and detection of leaks within a given system.

Systems designed to operate with A2L refrigerants must be designed so they cannot operate if leak detection systems are bypassed. Those same leak detection systems must withstand very challenging environmental conditions – high in condensation with significant temperature extremes - without needing additional maintenance or calibration over a planned 15-year equipment life. In addition, many chemicals used in servicing HVAC equipment may use oils or other chemicals which may foul some detection systems.

Back to TOC

Those factors put the pressure on HVAC OEMs and their partners to develop solutions for this next generation of equipment.

Looking Forward with Refrigerant Technology

Stretching back more than 40 years, the continuing arc of HVAC technologies has been the continued push toward more environmentally friendly technologies and refrigerants – a trend which will likely continue to take shape in the coming decades.

Actions taken under the Kigali Amendment to reduce and eliminate the use of HFCs is expected to prevent more than 100 million tons of carbon dioxide equivalent of greenhouse gases from the atmosphere. By 2100, that effort will have hopefully helped to avoid up to 0.5 degree Celsius of global temperature rise.

Looking ahead, further enhancements in HVAC system design throughout the coming years and decades will continue to take shape, governed by that ongoing focus on safety, environmental impact, and energy efficiency worldwide.

Simulating HVAC defense against COVID-19 infection

Back to TOC

In fall 2020, The University of Alabama at Birmingham Healthcare (UAB) was faced with an increasing influx of COVID-19 patients and the question of how to best maintain medical staff safety as a top priority was at the forefront of UAB's concerns.

Changes in operation of heating, ventilation and air conditioning (HVAC) systems' configuration to increase the effectiveness against the spread of COVID-19 was given careful consideration. Specifically, three questions were asked of the team on HVAC defense. Does an air change rate of six provide the quickest and most orderly removal of particles from the patient room? Does maintaining a room differential pressure relationship of -0.01 inches water column relative to the adjacent corridor achieve near 100% particle containment? Does the addition of a high-efficiency particulate absorbing (HEPA) air scrubber have a positive effect on the time to remove particles from the room and does the location of the HEPA air scrubber play a vital role in containment of the particles?

In order to better answer these questions, UAB organized a small team of healthcare engineers, an environmental health and safety manager, and the support of the hospitals C-Level stakeholders. At the inception of the efforts, UAB had just opened a new bone marrow transplant unit which provided the team with the unique opportunity of having an empty bone marrow transplant unit to utilize as a test site before the unit was to be transformed into a dedicated COVID-19 unit. And so began the task of creating the framework for a field-testing lab to serve as the epicenter of the experiments.

The approach to achieving valid answers was to utilize one of the bone marrow transplant patient rooms with a high-supply, low-return diffuser configuration (referred to as patient room "A") as one of the two test sites. Specifically, the configuration consisted of two perforated supply diffusers with an integrated HEPA filter, one floor-mounted return grille, and a typical ceiling exhaust in the adjacent dedicated restroom. The second test configuration (referred to as patient room "B") consisted of a modified diffuser layout with high-supply high-return layout. Specifically, the configuration consisted of two smaller perforated supply diffusers without an integrated HEPA filter, one ceiling mounted return grille, and a typical ceiling exhaust in the adjacent dedicated restroom. The furniture layout was kept consistent and simple with a patient bed, an adjustable over-the-bed table and a chair in the corner of the room.

The method used to create measurable results started with procuring two BS 5295 rated fog generating machines that utilize pharmaceutical grade fog fluid producing the

Back to TOC

same Atomic Energy Authority (AEA) certified 0.2-micron particle sized fog. The size of the particles being generated was important because the particles should be in the same range of typical aerosolized COVID-19 particles (0.06-1.4 micron). A high output machine, capable of 6,356 CFM, was chosen to be used in a "saturated" room test where the amount of time to completely fill the room with fog was precisely calculated. The smaller machine, capable of 100 CFM, was chose to be used in testing meant to simulate the amount of aerosolized COVID-19 particles generated from a typical infected adult male patient. To measure the effectiveness of the HVAC system to remove the fog from the room, a light intensity meter and ionization smoke detector were utilized. The time was recorded for the smoke to visually clear, for the smoke detector to clear and for the light level to return to the same level as measured at the start of each test. In addition, other important parameters were monitored and recorded for each test such as the room pressure, the use or lack of an air scrubber, the air scrubber CFM and equivalent air change rate (fixed at 6 ACH) and the supply and return airflow (measured by the Building Automation System).

The team faced many challenges and barriers from the onset to the end of the endeavor. The first obstacle was developing a means to measure the effectiveness of the tests. The team reviewed plausible methods and ultimately settled on utilizing the ionization smoke detector and light meter combo to gauge the effectiveness of the HVAC system. The second major obstacle was selecting a fog machine(s) suitable for the testing. The team identified the machines must be pharmaceutical grade and generate particles between 0.06- and 1.4 micron. After much research and debate, the team decided on two machines, one which had to be shipped from the United Kingdom, which presented the looming concerns of international shipping delays, which were rampant at the time and still linger today. Another obstacle was the testing site had a non-typ-

Back to TOC

Back to TOC

ical HVAC distribution layout with HEPA filters in the supply diffusers and a low return grille. The team decided to modify the HVAC distribution layout to better match the typical patient room with two supply diffusers and one high return grille. Furthermore, the inlet conditions to one of the terminal units was modified to obtain accurate airflow control. Perhaps the biggest obstacle was time itself. The same team that was dedicated to the experimentation was also being tasked with converting numerous patient floors into "COVID-19 wings" and the location of the testing site was a prime location to convert into a COVID-19 wing. As soon as the testing was completed, the HVAC system was slated to be retro-commissioned and turned over for immediate use.

The results of the study showed that six air changes provided subjectively better results (27.5 Minutes) when compared to CDC Guidelines (46 minutes at 99% efficiency) for Environmental Infection Control in Health-Care Facilities (2003). Typical COVID-19 patient particle generation testing shows that the infectious risk posed by a patient infected with COVID-19 is relatively low because of the low viral load typical in infected patients unless that viral load is increased by severe acute coughing. For this scenario, with a neutral room pressure, a patient who is infected and is coughing 10 times per minute poses the least risk to medical staff with an air change rate of 6 air changes per hour with a HEPA scrubber in the room close to the patient bed between the supply and return grilles in the room. The chance of medical staff inhaling the viral particles is decreased the further the distance from the patient. Increasing the air change rate decreases the time to remove the virus particles from the room, but with increased air-change rate turbulence is created which causes the airborne particles to be distributed around the room. This phenomenon at eight and ten air changes increases the probability of the virus infecting medical staff compared to the tests conducted at air change rates of six. No visual difference was witnessed, related to undesired spread of aero-

Back to TOC

solized smoke, between four and six air changes per hour. However, at four air changes per hour, the time it took for the aerosolized smoke to clear was much greater than at six air changes per hour.

The smoke saturation room testing answered three important questions:

- The testing showed six air changes per hour provided comparable particle removal times compared to higher air changes rates of eight and ten air changes which are not feasible in most patient rooms due to existing HVAC infrastructure limitations.

- Scrubbing the air in the room with a HEPA scrubber significantly improves the particulate removal times.

- Orienting the scrubber so that the intake is at the door can better protect staff in the corridor areas by capturing the particles before they can exfiltrate the room.

Ideally, the scrubber would be pointed at a low return, so the majority of particles are quickly removed from the room. In addition, the testing proved that operating a room at negative 0.01 inches protects the staff in the corridor by not allowing the particles to escape the room. However, it is impractical to configure the majority of patient care spaces in such a manner due to the limitations of the existing HVAC infrastructure. In such cases, where a patient exhibits severe coughing, it is advisable to configure a room to be at six supply air changes, ten return air changes and to install a HEPA scrubber at the door with the discharge directed at a return grille or restroom door with exhaust of ten air changes per hour.

Based on the data collected from the testing, UAB made strategic decisions to set all patient room air changes to six air changes and to include HEPA scrubbers in each COVID-19 patient room. At the height of the COVID pandemic, UAB Healthcare had 300 COVID-19 patients admitted to the hospital. Despite the high COVID-19 patient census rates, UAB medical staff contraction rates were relatively low. Based on these promising results it is recommended healthcare institutions implement self-deployed air change compliancy verifications and when pandemic risks are great, implement additional filtration and air changes in the form of HEPA air scrubbers. If feasible, operate the patient room at a negative pressure equal to negative 0.01 in. w.c.

Craig Phillips

Craig Phillips *has 16 years of industry experience and is the Director of Commissioning at Bernhard. He has extensive experience commissioning healthcare facilities and campus expansions around the country. He helped to build Bernhard's commissioning services group, providing project management and commissioning services for projects including a 1-million-square-foot healthcare campus expansion, new data centers, commercial facility renovations, and more. Craig is a registered Professional Engineer, Certified Commissioning Authority, Certified Energy Manager, Healthcare Facility Design Professional, a NEBB Building Systems Commissioning Certified Professional, and LEED AP BD+C. Craig was the co-author of the US Military Health Care Commissioning Guidelines and co-author of Ascension Health's Commissioning Guidelines. He holds a Bachelor of Science degree in Mechanical Engineering from Arkansas Tech University.*

Back to TOC

Content Archive

HVAC/R

Thank you for visiting the HVAC/R eBook!

If you have any questions or feedback about the contents in this eBook, please contact CFE Media at *customerservice@cfemedia.com*

We would love to hear from you!