DOAS Optimization With Connected Commissioning

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From classrooms to cubicles, maintaining a high standard of indoor environmental quality in varying buildings and climates is often a challenge for building designers. One solution to achieve higher levels of IEQ involves using dedicated outdoor air systems (DOAS), designed to handle cooling and heating loads associated with treating a large percentage of outdoor air. A universal challenge is verifying that these units are continuously working efficiently and implementing the intended control strategy.

This article describes how this can be achieved through a "connected commissioning" process by:

- Integrating sensors with system controls;
- Developing a scalable data collection network through an integrated cellular gateway;
- Analyzing results of the data with engineering staff; and
- Implementing a competent, nationwide equipment service network.

The data set described was gathered from more than 500 DOAS units and 400 job sites in the U.S. over a period of approximately two years.

DOAS Design and Sensor Integration

Utility and first costs for conditioning high percentages of outdoor air are often significant. DOAS heating and cooling systems must be sized to a larger capacity per unit of airflow relative to traditional rooftop equipment because of the high latent and sensible loads associated with outdoor air. Thus, it is critical to optimize DOAS performance by using the least amount of energy required to maintain comfortable indoor conditions.

Similar to a vehicle's engine and transmission, an important feature of DOAS units is their ability to adjust capacity instantaneously to match continuously changing loads. Having dynamic control over major components such as a variable speed scroll compressor, modulating indirect-fired furnace, energy recovery wheel, and/or ECM supply fan, allows a unit to provide demand capacity and minimize power consumption. This modulation comes with many challenges. For example, variable speed scroll compressors require extra attention to oil levels within the crankcase at low speeds; modulating indirect-fired furnaces lose efficiency at low capacities if not implemented correctly; energy recovery

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wheel effectiveness declines as it ages; and ECM supply fans risk reducing airflow to the point of freezing a coil or negatively affecting building pressures. All these side effects are well-known to manufacturers when designing variable capacity DOAS equipment.

What is not as common is confirming that DOAS units perform as intended on every building, independent of application. To help achieve this, an array of digital and analog sensors can be used throughout the unit, collecting and transmitting data to a master control facility. For example, in a supply airstream, temperature and relative humidity sensors are frequently paired to allow for dew point calculations throughout each section of the unit. *Figure 1* represents common DOAS sensor positions located in the outdoor, return, mixed, and supply airstreams. (Note: DOAS units are generally used for 100% outdoor air applications. However, some control sequences may require high recirculation rates during unoccupied times, which warrant the usage of return sensors.)

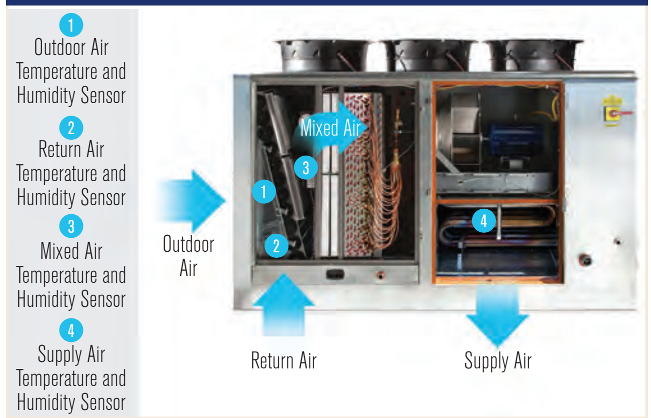
Dew-point calculations in a DOAS are essential data points when cooling and dehumidifying a space. If too high, moisture from the outdoors is introduced to the space, accelerating mold and bacteria growth. If too low, unnecessary energy is wasted in overtreating the airstream. Therefore, the ability to calculate the outdoor dew point and determine whether it is lower than the target space dew point allows the system to provide either "free dehumidification" with minimal power consumption or activate cooling until the desired dew point is achieved, similar to an enthalpy economizer, but without the risk of negatively impacting building pressure balance.

Frequently, advanced controls such as this work well during development and testing but fail when implemented at a macro scale after all variables associated with climate, construction and installation are considered. In addition, the sensors required to implement DOAS controls strategies increase the number of potential failure points of these systems. For such complex systems to achieve the desired results, one solution is to connect these units to a centralized platform that surpasses traditional BMS data gathering and alarm reporting capabilities by directly incorporating manufacturer support teams.

Connected Commissioning

The process of connected commissioning involves three main activities: data acquisition (DAQ), data aggregation and interpretation and the execution of support strategies. When all three are combined with active and passive reviews using advanced analytics, automated faults and remote diagnosis, data trends and patterns begin to develop that would have been difficult to identify in a lab environment. Sensitive DOAS applications that require precise control of supply and space conditions cannot rely on a single system commissioning during start-up. When compared to a single commissioning approach, connected commissioning can increase the likelihood that long term performance is maintained throughout the system's lifetime by continuously linking manufacturer technical support teams to relevant equipment operating data. The manufacturer support teams referenced in this article applied 2,888 remote adjustments to setpoints, factory settings and schedules throughout the past year to the 500-plus DOAS units to continuously optimize their performance.

FIGURE 1 Typical DOAS temperature and relative humidity sensor locations.



Data Acquisition. DAQ has been gaining traction in recent years due to advancements in the Internet of Things (IoT) field. For example, it is common for household devices such as thermostats, light switches and wall outlets to be equipped with Wi-Fi capabilities, allowing these devices to report data and be controlled through the Internet. This type of integrated remote monitoring and control technology has been generally seen as cost prohibitive for more complex equipment, particularly in light- to medium-scale commercial buildings, due to the need for expensive building management system (BMS) hardware and specialty controls contractors for proper implementation. Additionally, companies that provide these services often charge high monthly fees for the collection and analysis of data. However, just like the manufacturers of typical household gadgets have taken advantage of IoT, some manufacturers of critical building equipment such as DOAS have begun integrating built-in IoT capabilities into their products. This has provided DOAS manufacturers, users and service personnel with invaluable operating data at a much lower cost.

The process of DAQ for DOAS units must be done methodically for it to provide the desired capabilities. Optimal integration of the multiple components and functionalities requires a comprehensive analysis of data from each subsystem. Furthermore, data gathered from over 500 DOAS units has proven that effective troubleshooting does not solely rely on sensor readings. It is equally important to keep track of changes to setpoints, which can sometimes impact system performance negatively. Therefore, it is important for the DAQ process to include all relevant unit settings and provide remote control capabilities for setting adjustments when necessary.

Figure 2 shows the impact that a "maximum heating discharge setpoint" of a unit can have on its ability to maintain a target space setpoint. Trended data acquired from the unit's sensors showed that it had been operating at the maximum allowed discharge temperature, which is in place to prevent undesired space temperature variance. However, the space setpoint was not being reached, hence the support team decided to progressively increase the maximum allowed discharge temperature by a few degrees to improve the unit's performance without negatively impacting the space.

Similarly, real-time refrigeration circuit data can be extremely useful when troubleshooting alarms and warnings remotely. *Figure 3* shows pressure transducer readings over time, which can be used to assess the potential causes for high or low refrigerant pressure alarms—typical if a unit has a leaking or clogged coil.

Data Aggregation and Interpretation. Throughout the data aggregation process, it is important to apply algorithms that can sort the information for optimizing goals. In addition, the data must be filtered and organized in a manner that simplifies the process of identifying inefficiencies and alarms.

Real-time data may provide important performance information, but an integral part of the connected commissioning of DOAS units is the analysis of trends and aggregated data that may reveal otherwise hidden information. For example, a high refrigeration pressure fault might initially indicate a failed condensing fan or dirty condensing coil. However, if the system modulates condensing airflow to maintain a floating head pressure, a failed outdoor air temperature sensor can cause similar effects. By cross-referencing data points over time and diagnosing the root cause of a fault prior to a service visit, the user saves valuable time and money.

Aggregation provides a broader perspective by condensing gathered data across a particular time frame

FIGURE 2 The response of space conditions to changes in the heating modulation band.

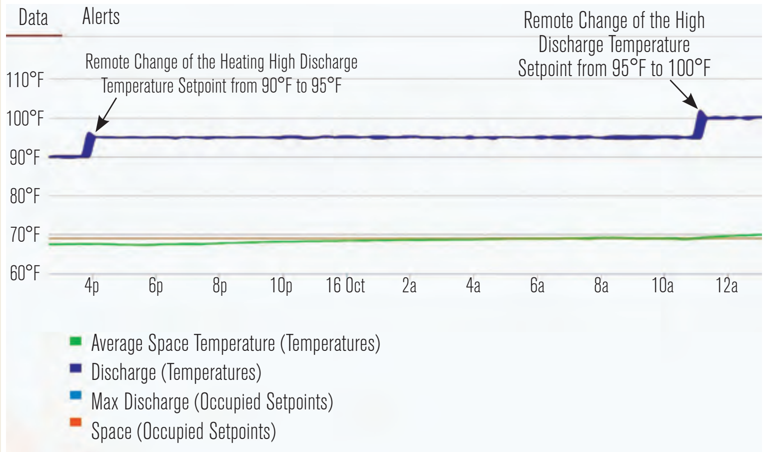
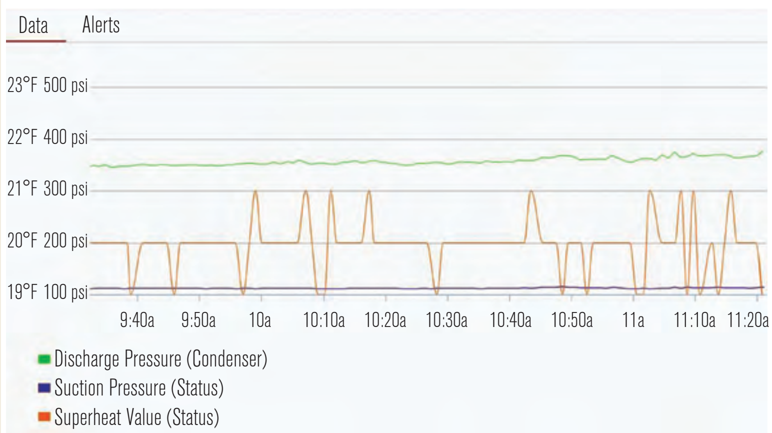


FIGURE 3 Real-time feedback of a system's refrigeration pressures and superheat temperatures.



and/or while a unit is performing a specific function. *Figure 4* shows the one-month distribution of the average discharge temperature at varying outdoor air temperatures while a unit is cooling or in blower-only mode. Reviewing this plot of aggregated data gives the support team an idea of how well a unit has been able to maintain the target discharge setpoint when cooling (in this case 64°F [18°C]). Likewise, it exposes outliers that may need to be investigated.

Execution of Support Strategies. With the interpretation of real-time or aggregated DOAS data, there may be a need to implement some form of corrective action. Support teams can assess whether a system is delivering the expected results in an efficient manner and determine if any actions need to be taken to produce the desired outcomes.

When implemented as part of a comprehensive connected commissioning program, support teams may involve one or more of the following:

- Factory-certified local service technicians;
- Local technical sales engineers involved in the design; and
- Remote engineering support teams.

All these teams should have access to the centralized data. Events or inefficiencies that can be handled by adjusting either unit setpoints or factory settings can be addressed remotely. *Figure 5* shows a computer display of a U.S. map from the centralized facility where DOAS data is collected. Green light signal alerts can be viewed by remote support teams, which can quickly identify units that may require attention.

FIGURE 4 Empirical data showing average outdoor temperature vs. average discharge temperature for a DOAS over the course of a month.

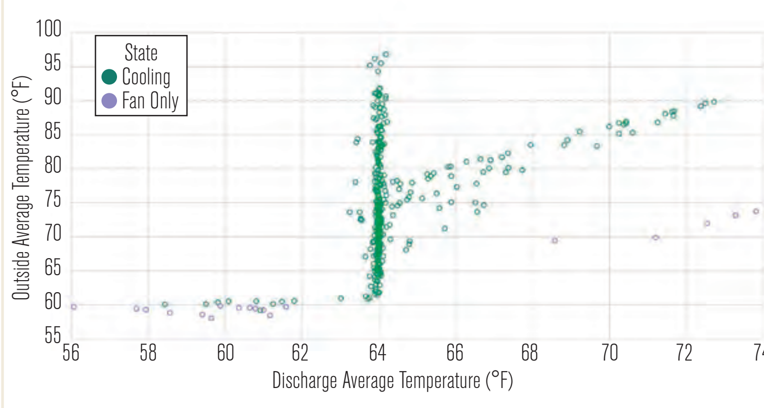


FIGURE 5 U.S. map reporting DOAS sites with active alerts in real time.

Benefits of Connected Commissioning

DAQ, either through a BMS or by a manufacturer, is common; however, aggregation of data and coordinated execution of support strategies based on this information is relatively uncommon. When executed properly, connected commissioning of DOAS units can result in consistent, long-lasting benefits for the major stakeholders: end users, service and support groups and manufacturers. Building occupants and owners can rely on connected commissioning to ensure that the spaces served by DOAS units are as comfortable as possible and can continue to rely on them to maintain that comfort over the long term.

DOAS are designed to maintain a high level of indoor environmental quality. Real-time remote monitoring and data logging of IEQ allows multiple support teams to track unit performance at any given time. *Figures 6* and *7* show examples of temperature and relative humidity data gathered from DOAS that serve different types of buildings. By linking acquired data and alarms directly to manufacturer support teams, connected commissioning can rely on their expertise to continuously monitor equipment operation.

Indoor environmental quality is one of the most important aspects that connected commissioning seeks to address. Another benefit that end users receive from this process is optimizing equipment operating efficiencies, which directly impacts building owners' operating costs. A few examples of how this is achieved are:

Scheduling

- Are systems running only when needed?
- Are setback periods being implemented properly?

Equipment Integration

- Are units interlocked with each other per the required sequence of operations in order to maintain adequate IEQ and building balance?
- Are units serving the same space operating in such a way that prevents them from simultaneously heating and cooling?

Remote Support

- Can required system changes be implemented remotely in order to eliminate service visit costs?

Optimization of Standard Designs

- Are units selected for prototypical designs oversized or undersized based on their historical performance?
- Are energy recovery devices and associated equipment capacities sized appropriately?
- Can standard building designs that use traditional RTUs benefit from switching to DOAS?

Part-Load Performance

- Are modulating units saving energy at part-load conditions?

Figure 8 shows the performance of a DOAS unit during a three-month seasonal transition period (late February to early May). The unit displayed a relatively low average compressor speed, which is an indicator of the unit's ability to reduce energy consumption at part load conditions. Likewise, space conditions were within the setpoints the majority of the time. A high average compressor speed during off-peak seasons or poor space conditions could be indicators of system inefficiencies or HVAC design problems.

FIGURE 6 Space dry-bulb and dew-point temperatures over a period of approximately 18 hours.

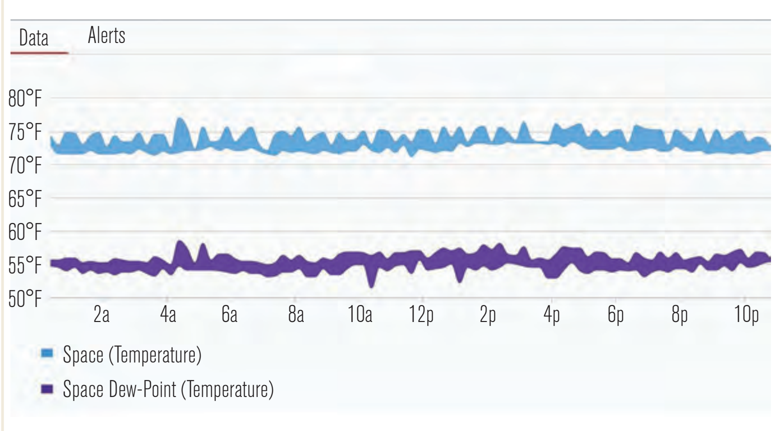
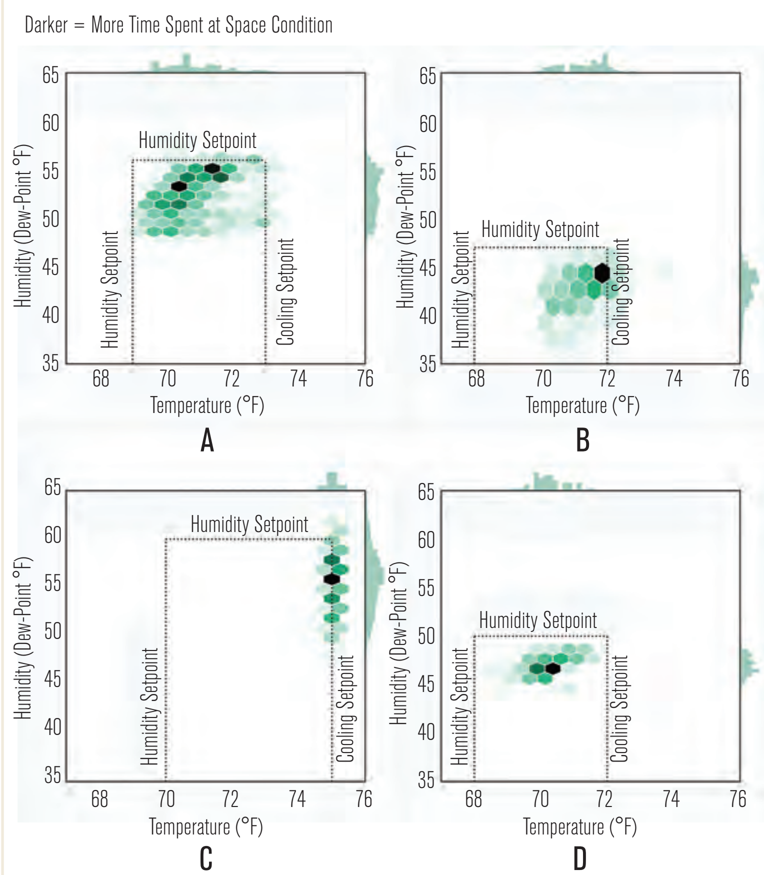


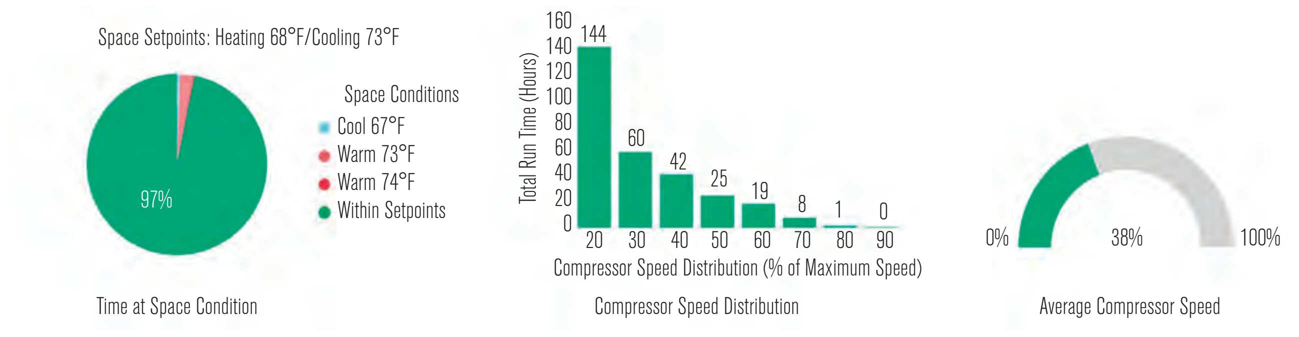
FIGURE 7 Humidity and space temperature distribution for various applications. (A) restaurant dining area; (B) laboratory; (C) hotel corridor; and (D) elementary school.



Service and Support Group Benefits

Service and support groups benefit greatly from connected commissioning. Having remote access to systems' operating data greatly simplifies the troubleshooting process. For example, a qualified service technician or engineer can remotely view the operating data of units and determine if unit settings are optimally set to provide the desired performance. In addition, these settings can be adjusted remotely, and the support team can view instant feedback of the results. This flow of

FIGURE 8 One of the major features of DOAS is their ability to modulate energy usage at part load conditions.



information and feedback loop ends up expediting or eliminating the typical trial-and-error approach taken in so many HVAC applications today. Access to real-time and historical operating data with the ability to remotely adjust settings results in lower diagnostic costs and improved troubleshooting accuracy.

Manufacturer Benefits

Even though connected commissioning typically provides the greatest benefit to customers, end users and support teams, equipment manufacturers can also see substantial benefits as well. HVAC equipment manufacturers tend to have somewhat limited performance data when it comes to the development of their products.

Typically, manufacturers' data comes from computer simulations, lab testing and a limited number of test sites. However, through a large-scale

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connected commissioning program such as the 500-plus DOAS sites described here, manufacturers can use operating data from a much larger and diverse sample of units to determine potential areas of improvement.

For instance, aggregated data from the connected commissioning of 500-plus DOAS units was used by the manufacturer to develop a more robust algorithm to control the dew point of a space. The same data allowed for the optimization of night setback periods for humidity control in larger buildings such as schools. In some cases, these improvements can also be applied remotely as part of the connected commissioning initiative itself. Other areas in which a centralized database can be used by manufacturers involve:

Identification of Performance Outliers

- Are there systems that serve very similar applications while exhibiting much different performance metrics? Why?

TABLE 1 Average, maximum observed and maximum recommended compressor activations and unit runtime (hours) for over 500 DOAS over the course of a year.

METRIC	AVERAGE	UPPER BOUND	MAX REC.
Activations	1,260	3,966	10,000
Runtime	3,440	6,340	6,667

Product Warranties

- Based on the operating data, what is the likelihood that a unit or component will last its expected lifetime? *Table 1* shows data of runtime and unit cycling that could be used to assess the probability of system component failures. The maximum recommended activations and runtime are typically listed by compressor manufacturers when referencing their expected lifetime.

Operational Enhancements

- Are there specific scenarios that cause inefficiencies in logic?
- Can software be used to identify hardware failures?

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- Can certain system functions be handled effectively through software without adding hardware components? (For example, data collected from the connected commissioning process proved that proper oil management logic can eliminate the need for an oil separator.)

Conclusions

DOAS units can be used in a wide array of applications. In addition, they are expected to deliver consistent results year-round, independent of season. Even if a unit is fine-tuned at the time of project delivery, it is unreasonable to expect consistent results without periodic performance assessments and seasonal setting adjustments. Likewise, system warnings and alerts must be dealt with in a timely manner. The optimal way to deliver consistent performance is through manufacturer-based connected commissioning with the following features:

- Remote parameter adjustment capabilities;
- Reduced alarm response time;
- Expertise in diagnostics and implementation of solutions; and
- Cost effectiveness when compared to traditional BMS.

One of the most important lessons learned from the connected commissioning process is that the identification of problems and response times are greatly reduced when there is a network of factory certified, local technicians working in conjunction with remote engineering support teams. The combination of engineering expertise, availability of data through a centralized platform and local technicians with HVAC experience ensures that potential system faults can be dealt with from several angles in a streamlined fashion.

The availability of centralized data for many units is also what sets apart the use of manufacturer-based connected commissioning tools when compared to typical BMS. A BMS operator may know how to control a unit and apply setpoints, but he or she may not be able to identify units that are underperforming based on benchmarks established by the data from similar applications.

In addition, while a traditional BMS can control the relevant unit setpoints and monitor system faults, generally the knowledge of BMS operators regarding the units that they monitor is no match for the expertise of the manufacturer's support teams. Manufacturers also have a vested interest in extending the lifetime of their units, particularly when those units have long warranty periods.

Such focus results in increased accuracy and speed of alarm responsiveness through the connected commissioning process when compared to a standard BMS.

This does not mean that a manufacturer-based connected commissioning program can completely replace a BMS. Some sites, particularly larger buildings with many complex systems, have much to gain from a traditional BMS. BMS monitoring and manufacturer connected commissioning do not have to be mutually exclusive. However, the cost associated with a BMS sometimes makes it financially impractical, particularly for smaller commercial buildings.

For the connected commissioning process offered by the manufacturer described in this article, monitoring was achieved through low-cost cellular gateways included as a standard option with each unit, regardless of size or application. Cellular connectivity in most cases ensures that units can be connected to the Internet without additional coordination with the job site, such as additional field wiring and access to an internal network.

Due to the savings associated with remote troubleshooting and settings changes for energy optimization, given that the manufacturer referenced will adjust setpoints and diagnose alarms remotely free of charge as part of standard technical support, the inclusion of connected commissioning products is an economically promising approach with a rapid return on investment.

DOAS products have the potential to provide significant savings and improved IEQ when compared to traditional rooftop units. However, connected commissioning as part of a preventative maintenance program can help fully realize the value proposition of DOAS.

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