Air purification system assembly comprising five stages

Advanced Air Purification Systems

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The achievement of clean, comfortable indoor air is one of the challenges of the 21st century. Pollutants in outdoor and indoor air have increased in variety and concentration. Equally urgent is the need to control energy use, especially by HVAC. There is a dual urgency: to develop improved methods for air cleaning and to reduce HVAC energy consumption. Current methods achieve results, but they are constrained by their product's primary focus on cleaning air, the design resulting from that focus, and by industry requirements for ventilation. Energy use reduction becomes a secondary goal or the primary goal of a separate product. Advanced air purification technology takes a step forward in meeting the dual challenge with broad focus and capabilities. Its design flows from incorporating existing methods and adding advanced technologies to overcome limitations.

Two projects, a casino with heavy smoking and a new airport terminal, illustrate how an advanced air purification technology, designed to be integrated within the HVAC system, can provide superior IAQ safely, reliably, and energy-efficiently.

Scope of the Problem

Global building space will increase by 26% to 178 billion square meters by 2020. Of that, 4.92 billion will be green building certified. To address this rise in energy demand, Building Energy Management Systems (BEMS) investment will surpass 10 billion USD by 2016 in the US alone. Office and retail are the most energy intensive buildings typically accounting for over 50% of the total energy consumption for non-domestic buildings. In the USA, supermarkets, hospitals and restaurants have the highest intensity of use. HVAC is the main end use of 48- 55% energy consumed.

Ventilation: Effects on Indoor Air Quality and HVAC Energy Consumption

Ventilation with outside air to provide

About the Authors

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fresh air for occupants has been the underpinning of HVAC standards since 1836. It has thus driven HVAC design. The assumption has been that outside air is clean or cleaner than inside air. The reality is that both outside and inside air contain pollutants. Not since the late 1970's has the energy consumption by the HVAC system been widely considered. Now, methods like Demand Control Ventilation (DCV) are being applied to control use of outside air.

Achieving indoor air quality for comfort and safety has almost exclusively been limited to dilution with outside air. In the days of clean outside air and no air conditioning, opening a window was a straightforward solution. But buildings got taller, windows were sealed, and AC became the norm year round. Energy use and cost significantly increased. Today, we are striving for Net Zero, sustainable buildings. However, lightening the energy burden caused by high levels of ventilation and high air conditioning loads still leaves the indoor air quality issue to be solved.

In ventilation theory, outside air mixes with recirculated air to continuously dilute pollutants, thus assuring there will always be pollution, just less concentrated. This leads to over ventilation.

In 2005, the US Department of Energy (DoE) funded Lawrence Berkeley National Labs (LBNL) to conduct research on air purification methods that would also reduce energy use in buildings[1]. This study found some disadvantages of increased ventilation:

1. Indoor concentrations of some outdoor pollutants increase.
2. Outdoor air is a major source of ozone indoors increasing with higher ventilation.
3. Outdoor respirable particles increase indoors with increased ventilation, unless properly filtered.
4. Indoor humidity will increase with ventilation rate when outdoor air is more humid than indoor air.
5. Higher indoor humidity can lead to more dust mites and greater risk of mold growth.

LBNL's 2005 paper studied ultraviolet light (UV) and photo catalytic oxidation (PCO) as means to remove volatile organic compounds (VOCs), the main pollutant class of gases including many carcinogens. Their tests showed that UV and PCO do destroy VOCs, but destruction is not complete due to limited residence time and partial conversions. Harmful intermediates are formed, such as formaldehyde and acetaldehyde. These and other intermediates must, in turn, be eliminated.

In 2007 LBNL repeated the test and energy study with UV/PCO followed by permanganate on alumina[2]. This combination yielded a vastly better solution:

"In summary, the use of a multi-panel, folded scrubber filled with $NaMnO_4.H_2O$ (sodium permanganate monohydrate) chemisorbant media downstream of the prototype UV/PCO air cleaner effectively counteracted the generation of formaldehyde and acetaldehyde due to incomplete oxidation of VOCs in the UV/PCO reactor. Thus, this combined UV/PCO air cleaner and chemisorbant system appears to have sufficient VOC removal efficiency to enable a 50% reduction in ventilation rate without increasing indoor aldehyde concentrations."[3]

Uses & Limitations of Existing Air Cleaning Methods

Gas Phase Media Filters:

Activated carbon, an adsorbent, along with chemisorbant media such as potassium permanganate ($KMnO_4$) on alumina, effectively removes odors and VOCs. Various types of filters or modules hold carbon, $KMnO_4$ on alumina, or a blend of both. These solutions by media are available from multiple vendors and are safe to use. Control of pathogens with gas phase filtration is very limited. Gas phase filtration costs can mount up with 1-2 changes per year.

Ultraviolet Germicidal Irradiation (UVGI):

UVGI is becoming more widely applied in hospitals and buildings to control some bacteria and viruses. It helps prevent growth of algae and legionella in the AHU drain pan and cooling coil. UVGI can be effective against microbes; however, the kill rate is dependent on extended exposure and contact or residence time. In-duct installations are unable to treat the entire airstream as it goes by, so bypass is assured. In addition, certain bacteria and viruses (such as TB bacilli, Legionella pneumophilia, C-DIFF, MRSA and H1N1) may need multiple UV doses to ensure eradication, thus requiring additional stages of UV lamps.

Advanced Air Purification - Safe, Sustainable, Clean Indoor Air

An advanced air purification system (APS) harnesses the oxidative power of UV/PCO and embeds it in a five stage sequence of air filtration, air purification, controls, sensors and safeguards.

The five stage process eliminates viruses and bacteria, in addition to VOCs, odors, SOx, NOx and particulates. Any intermediates formed along with newly created oxidation radicals are destroyed within the system. Purified air then passes downstream. The process of advanced air purification does not create hazardous waste or byproducts, is a safe process to maintain, and offers ease of operation.

The advanced APS is scalable and can be integrated into existing HVAC. Placed in front of the AHU, it should treat both outside and recirculated air. By purifying all the air each time it passes through the AHU, pollutant existence is shortened to a few minutes. With pollutant levels reduced, the need for ventilation to dilute indoor air is significantly reduced.

Advanced Air Purification System Stages

Stage 1: Prefiltration

Prefiltration uses conventional HVAC filters, but must be capable of 95% efficiency to 1µ (micron). This protects the next stage, which is UVPCO.

Stage 2: Ultraviolet light and photocatalytic oxidation (see *Figure 1*).

This is the most effective use of UV light, increasing its germicidal power dramatically by partnering it with a catalyst.

Full potential of UV light spectrum is utilized which goes beyond UVGI to create hydroxyl radicals with the oxidative equivalent of 2.5 times chlorine.

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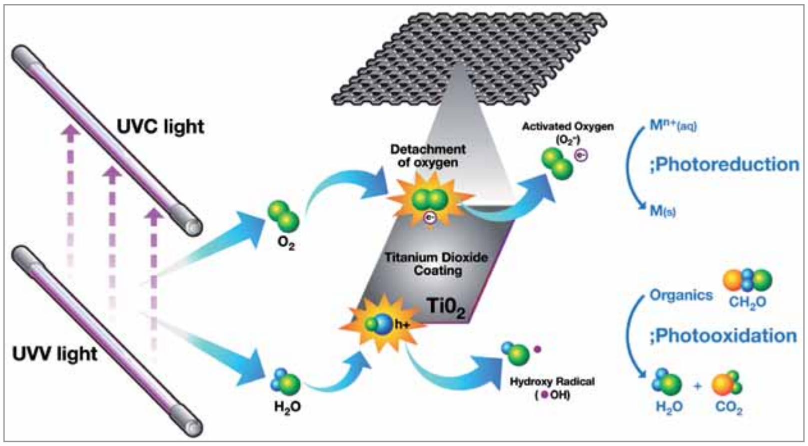


Figure 1: Ultraviolet light and photocatalytic oxidation

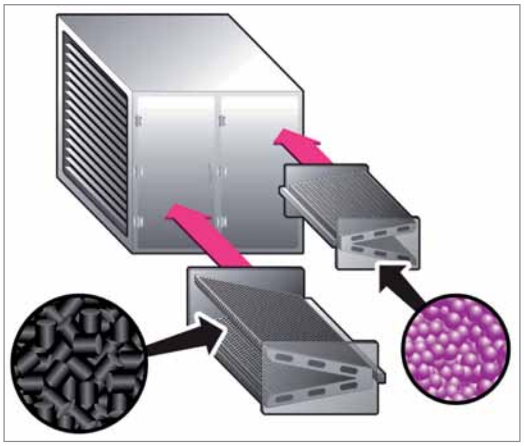


Figure 2: Media in modules

This powerful chemistry is generated dynamically from water molecules. These active molecules oxidize organics, such as VOCs and pathogens.

Stage 3: Media in Modules (see *Figure 2*).

The carbon and $KMnO_4$ on alumina remove both odors and VOCs. Intermediate products of Stage 2 oxidation are captured by carbon and converted to carbon dioxide and water by ozone from Stage 2. In the Stage 3 process, the ozone is broken down and the carbon is regenerated in situ, retaining its active life, often for years.

The V-shaped media-holding modules are an advanced design that offers reduced air resistance, increased media bed depth, and longer residence time.

Stage 4: Controls and Sensors (see *Figure 3*).

UV safeguards sensors when section doors are being opened and automatically turn off UV lights to prevent accidental exposure.

Sensors monitor temperature, humidity, ozone, and TVOCs in real time to provide IAQ data. Monitoring for additional target contaminants can be added.

BMS – Building Management System interface is provided allowing integration with HVAC systems based on sensor data.

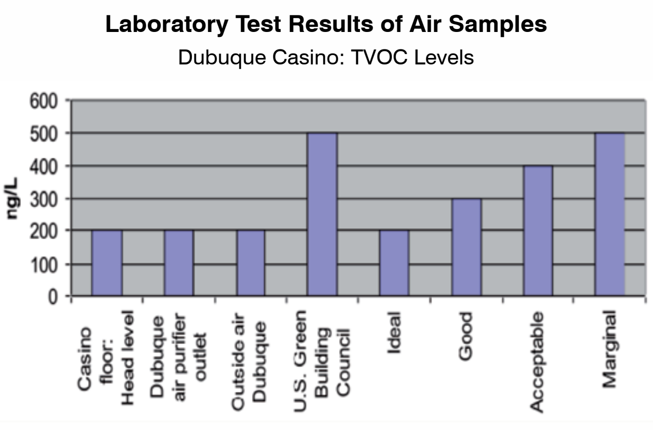
Pressure guages are provided to monitor when particulate filters need replacing. This is also available to the BMS.

Stage 5: Final Filter/Catalyst (see *Figure 4*).

This stage serves as the final stop-gap for any media dust that may get through from Stage 3 or 4. Standard filters are with 30% efficiency. For critical applications, HEPA filters can be added.

Casino Case Study

Casino Project: New construction addition



Courtesy of Prism Analytical Technologies, Inc.

Figure 5: TVOC levels in a casino

Figure 3: Controls and sensors

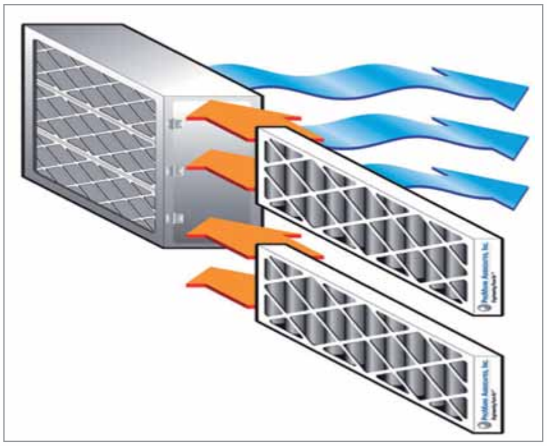


Figure 4: Final filter/ catalyst

Challenges:

- 60-70% smokers
- 30,000 sq. ft. with 20 ft. ceilings
- High odor complaint volume experienced in previous facility

Solution:

- 30% fresh air, 70% recirculated air
- APS consisting of three prefilters, UV/PCO, carbon media modules, potassium permanganate on alumina media modules, final filter and controls
- Three 33,000 cfm APS units installed ahead of respective AHU
- 100% of all returning air sent to APS first

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Results:

- In operation since May 2005
- Original activated carbon still in use as of May 2011
- UV lamps and $KMnO_4$ media only replaced twice
- Maintaining TVOCs at 200-300 nanograms/liter, making the air on the casino floor (first bar in *Figure 5*) cleaner than USGBC minimal requirements

Airport Terminal Design Case Study

IGI Airport Terminal 3, which uses 120 advanced air purification systems for TFA AHUs handling 5,00,000 CFM of treated fresh air

In 2007, an advanced solution for IAQ was sought for New Delhi's IGI Terminal 3 new construction. The proposal was based on the casino design taking into account the difference in the outdoor environment. The outside air in this airport is very hot, humid, dusty, and full of both car and plane engine fumes. Neither ventilation alone, nor ventilation combined with gas phase filtration, can eliminate odors and pollutants economically. Singular energy reduction solutions such as desiccant wheels would do little to improve IAQ. DCV is the same dilution solution, just more energy sensitive.

The final airflow volume is around 5 million CFM. The PPP that is holding the building for 30 years has a long-term vision embracing operating savings estimated at $162 M from installation of the APS.

Conclusion

The direction is clear: advanced air purification technology, integrated into new or existing HVAC systems, utilizes the capabilities and helps surmount the limitations of current air cleaning methods. The whole is larger than the sum of its parts. An advanced air purification system can successfully tackle the dual challenge of eliminating harmful pollutants and reducing HVAC energy consumption. Lesser the ventilation needed to dilute indoor air to acceptable levels, lesser the air which must be heated or cooled. Use of energy recovery or control methods can further enhance energy savings. A strong case can be made for adding an advanced air purification system to new or existing buildings. It is a sustainable solution to 21st century air quality and energy use challenges. Most importantly, advanced air purification provides clear benefits for people and for the environment.

References

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