

## UV Photocatalytic Oxidation for Improvement of Indoor Environmental Quality

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### **Business Sponsors:**

#### **Primary Sponsor:**

Company Name: **Ingenuity IEQ, Inc.**  
Full Name: Mr. Michael T. Fox  
Title: President  
Address: 3600 Centennial Drive  
Midland, MI 48642  
Phone: T 989/496-2233, F 989/496-2695  
Email: [mfox@ingenuityieq.com](mailto:mfox@ingenuityieq.com)  
Webpage: [www.ingenuityieq.com](http://www.ingenuityieq.com)

Contact Person: Ingenuity IEQ, Inc.  
Full Name: Dr. Stacy L. Daniels  
Title: Director of Research  
Address: 3600 Centennial Drive  
Midland, MI 48642  
Phone: T 989/496-2233, F 989/496-2695  
Email: [sdaniels@ingenuityieq.com](mailto:sdaniels@ingenuityieq.com)  
Webpage: [www.ingenuityieq.com](http://www.ingenuityieq.com)

#### **Contributor:**

Company Name: **Genesis Air, Inc.**  
Full Name: Mr. Daniel Briggs  
Title: President  
Address: 5202 CR 7350 Suite D  
Lubbock, TX 79424  
Phone: T 806/745-7000, F 806/745-7079  
Email: [dbriggs@genesisair.com](mailto:dbriggs@genesisair.com)  
Webpage: [www.GenesisAir.com](http://www.GenesisAir.com)

Ingenuity IEQ, Inc. is the Primary Business Sponsor.

Genesis Air, Inc., is the Primary Contributor.

The two companies have established a mutual development and marketing agreement.

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### **Milestones.**

2007	Federal Interagency Committee on Indoor Air Quality (CIAQ) (GAP)
2007	Midland Tomorrow Award - Innovation Category (Ingenuity IEQ)
2007	Major Installation - VA Hospital, El Paso, TX (GAP)
2007	Review paper on photocatalytic ionization processes
2007	GSA marketing with Government Scientific Source (GSS) (GAP)
2006	Technology Testing at U.S. Army Dugway Proving Ground (GAP)
2006	Test chamber evaluation at University of Syracuse (GAP)
2005	Main St. USA Best Small Business Award (MI-SBTDC) (Ingenuity IEQ)
2004	Michigan 2004 Small Business of the Year (Ingenuity IEQ)
2004	Agreement (Ingenuity IEQ, Inc. and Genesis Air, Inc.)

Award Category: This technology is eligible for the Small Business Award.

Primary Focus Area: The Design of Greener Chemicals. This technology provides for chemical products that are "safer for the atmosphere", particularly to improve the IEQ of enclosed building spaces.

Secondary Focus Areas: (a) The Use of Greener Pathways. This technology involves both a novel catalyst and a novel catalyst support; and (b) The Use of Greener Reaction Conditions. This technology leads to significant improvements in energy efficiencies.

### **Abstract.**

UltraViolet Photocatalytic Oxidation (UVPCO) is an emerging technology applying principles of "green chemistry" to improve Indoor Environmental Quality (IEQ) by reducing levels of volatile, particulate, and biological contaminants in buildings. UVC light is used to activate nanoparticles of a titanium dioxide catalyst coated on a specially formulated support to initiate photocatalytic reactions. UVPCO modules are coupled with air filters and instrumented controls into integrated systems. Ingenuity IEQ, Inc., a small business in Midland, MI, provides extensive experience in the design/build/service of these engineered systems. Genesis Air, Inc., a small business in Lubbock, TX, develops UVPCO into generally applicable devices for engineered systems to treat diverse mixtures of airborne contaminants for a wide range of buildings. These two companies in collaboration have reached significant milestones in applying this technology to IEQ; Healthcare, Homeland Security; and LEED™ "green building" systems. It is generally applicable to a wide range of buildings, including homes; offices; laboratories; and institutional, commercial, governmental, and healthcare facilities. The GAP™ technology has been proven to be scientifically valid through extended evaluations in environmental chambers and field test sites at governmental and institutional facilities. The technology offers significant benefits to human health and the environment by treating building air contaminants by oxidation of VOCs and inactivation of bioaerosols (BAs). It is a practical, cost-effective solution to real-life IEQ problems and provides energy savings through reduced ventilation demands.

## **UV Photocatalytic Oxidation for Improvement of Indoor Environmental Quality**

### **Executive Summary.**

Ingenuity IEQ, Inc.<sup>1</sup>, a small business in Midland, MI, integrates customized engineered systems to promote more energy efficient, greener, cleaner, and healthier buildings in the commercial, institutional, and governmental sectors. Four key aspects of indoor environmental quality (IEQ): (1) airflow, (2) air quality, (3) surfaces, and (4) measurement, are implemented by several technologies: design of critical airflow systems; remediation of IEQ using UVPCO technology, protection of surfaces using an antimicrobial technology; and monitoring, reporting, and control of IEQ.

Genesis Air, Inc.<sup>2</sup>, a small business in Lubbock, TX, has developed a treatment technology for air contaminants incorporated into engineered devices as parts of HVAC systems in new and existing buildings. UltraViolet Photocatalytic Oxidation (UVPCO), an emerging technology in the HVAC industry, significantly improves IEQ by oxidation of volatile organic compounds (VOCs) and inactivation of bioaerosols (BAs). UVPCO can also reduce ventilation demands to save significant energy over classical designs.

Ingenuity IEQ, Inc., is collaborating with Genesis Air, Inc. to commercialize the GAP™ technology, an innovative application of "green chemistry" principles to improve IEQ through source reduction, the subject of this nomination. Two patents pending for the GAP™ technology<sup>3</sup> relate to devices for purifying and sterilizing air using a photocatalytic scrim formed by coating a fibrous substance with titanium dioxide (TiO<sub>2</sub>).

The products and services of Ingenuity IEQ, Inc. are incorporated into HVAC and IEQ systems to control: potential releases of chemical/biological agents to insure Homeland Security/Defense, accidental releases of commercial products to provide Building Safety, undesirable occurrences of normal air contaminants to improve IEQ, and demands for excessive cooling and heating to increase Energy Efficiency.

Ingenuity IEQ, Inc. is recognized for leadership, technical and engineering expertise, and commitment to products and services with proven performance. Its focus includes commercial, industrial, institutional, and governmental facilities. Clients include: the University of Michigan, Michigan State University, the University of Cincinnati, Pfizer, the Dow Chemical, Children's Hospital Columbus, the Ohio State University, Wright State University, Battelle Memorial Institute, U.S. EPA, and FAA. Ingenuity IEQ, Inc. has excellent relationships as a leading manufacturing representative. Phoenix Controls Corp. (PCC) designs and manufactures precision airflow control systems. Strobic Air Corporation manufactures exhaust fans. Aircuity, Inc. is a leading manufacturer of IEQ monitoring and reporting systems.

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<sup>1</sup> Ingenuity IEQ, Inc., [www.ingenuityieq.com](http://www.ingenuityieq.com).

<sup>2</sup> Genesis Air, Inc., [www.genesis.com](http://www.genesis.com).

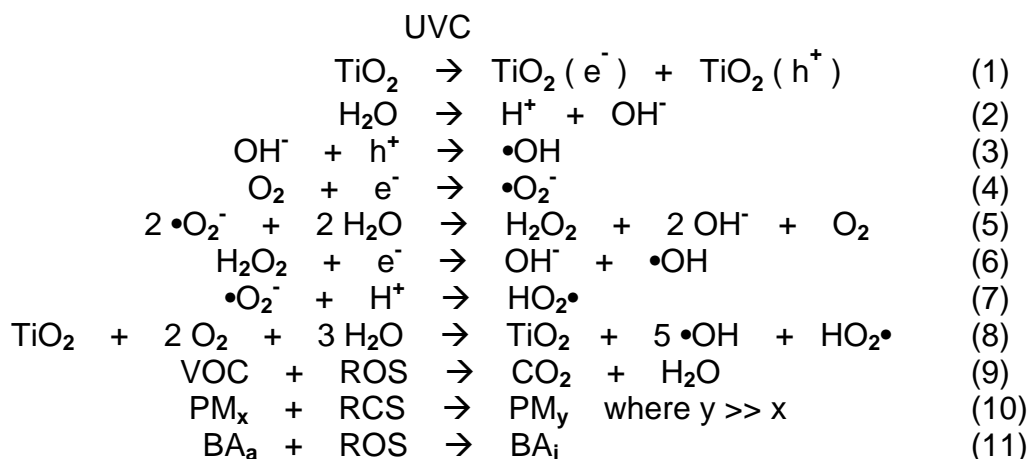
<sup>3</sup> Genesis Air Products, Photocatalytic Air Purifier, Appl. No. 60/424270 (April 2, 2004); Photocatalytic Air Purifier, Appl. No. 60/706895 (Aug.10, 2005).

## Description of Nominated Technology.

### Science and Innovation.

The GAP™ technology involves irradiation of titanium dioxide (TiO<sub>2</sub>), a semiconductor photocatalyst, with UltraViolet (UV) light at a wavelength of <385 nm causing its band gap energy of 3.2 eV to be exceeded and promoting electrons from the valence band to the conduction band. The resultant electron-hole pairs have sufficient lifetimes in the space-charge region to allow them to participate in chemical/physical reactions. Hydroxyl (•OH), hydroperoxy (HO<sub>2</sub>•), and superoxide (•O<sub>2</sub><sup>-</sup>) radicals are highly reactive oxygen species (ROS) that react with contaminants on the catalytic surface or in the air volume (heterogeneous photocatalysis). Photoionization also creates Reactive Charged Species (RCS) that agglomerate Particulate Matter (PM<sub>x</sub>) and BioAerosols (BAs).

### Photocatalytic Oxidation/Agglomeration/Inactivation Reactions<sup>4</sup> (\*)



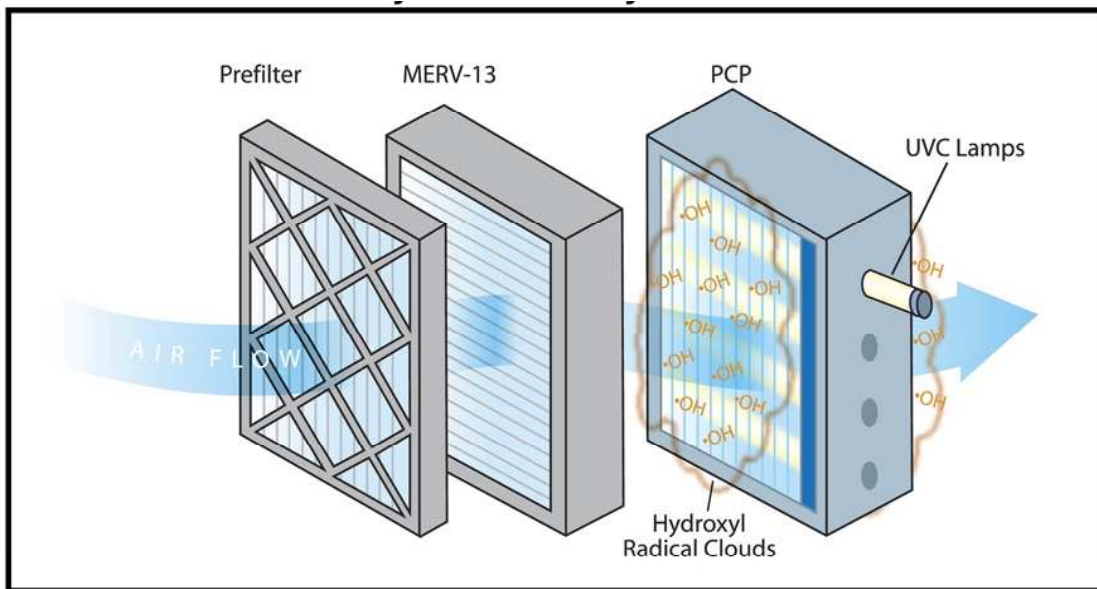
(\*) Abbreviations: electron (e<sup>-</sup>); hole (h<sup>+</sup>); Hydrogen cation (H<sup>+</sup>); Hydroxide anion (OH<sup>-</sup>); Hydroxyl (•OH); hydroperoxy (HO<sub>2</sub>•); and superoxide anion radical (•O<sub>2</sub><sup>-</sup>); Particulate Matter (PM<sub>x</sub>), subscripts x, y signify different mean particle diameters; Volatile Organic Compound (VOC); BA (Biological Aerosols), subscripts a, i signify "active" and "inactive" species; Reactive Oxygen Species (ROS); Reactive Charged Species (RCS).

Several attributes of UVPCO make it a strong candidate for IEQ applications. VOCs are preferentially adsorbed on the surface and oxidized to (primarily) water and carbon dioxide (CO<sub>2</sub>), and BAs are inactivated. Rather than simply changing phase and concentrating contaminants for disposal, the levels of contaminants in treated air released within the building environment are reduced.

<sup>4</sup> As modified from Daniels, Stacy L., On the Qualities of the Air as Affected by Radiant Energies (Photocatalytic Ionization Processes for Remediation of Indoor Environments, J. Environ. Eng. Sci. 6(3), 329-42 (May 2007). <http://article.pubs.nrc-cnrc.gc.ca/ppv/RPViewDoc?handler=HandleInitialGet&journal=jees&volume=6&calyLang=eng&articleFile=s06-072.pdf>

Advanced technologies, such as the GAP™ technology, offer competitive advantages in being more generally applicable and more efficient at lower contaminant levels than conventional systems. The heart of the GAP™ technology is a uniquely fabricated nanoparticulate titanium oxide (TiO<sub>2</sub>) catalyst that is coated on a pleated flexible mesh. This material is stable, durable, and cost-effective. The physical configuration is modular with banks of UVC lamps illuminating impregnated catalytic media within a populated charge panel (PCP) that generate hydroxyl radical clouds. The technology is used in association with a prefilter and Minimum Efficiency Reporting Value (MERV-13) filter. Systems are then customized in engineered systems for new/existing buildings.

### Schematic of the GAP™ technology.



The technology is scalable and can be deployed as small stand-alone appliances for treating limited spaces, or as large in-duct installations supplementing conventional HVAC systems of very large buildings. Specific systems can be configured to treat small to large airflows, and to respond to low and high contaminant concentrations.

The efficacy of the GAP™ technology for treating mold and bacteria has been tested by the U.S. Army, Dugway Proving Ground, UT. Its efficacy for oxidizing VOCs has been tested by GD Air Testing. Installations include: the Federal Law Enforcement Training Center, DHS, Artesia, NM; three facilities for the USAF, San Angelo, TX; a Forensic Pathology Lab at Texas Tech University Health Science Center, Lubbock, TX; a Pathology Laboratory for CDD, San Antonio, TX; and a VA Hospital in El Paso, TX. Ingenuity IEQ, Inc., with its unique experience in the design of sophisticated engineered systems, is positioning the GAP™ technology into new and existing systems to ensure proper residence time and effectiveness for optimized air purification. Ingenuity IEQ's support technologies include: computer-aided-design (CAD), real-time monitoring of IEQ parameters, and online reporting of IEQ evaluations.

## Human Health and Environmental Benefits.

There are increasing concerns in the vulnerability of buildings to chemical, biological, and radiological (CBR) threats. Intentionally or accidentally dispersion of CBR agents represent direct threats to Homeland Security and Building Safety. Exposures to nontoxic levels of regulated air pollutants, e.g. those listed in various environmental laws (TSCA, FIFRA, CAA, CWA, RCRA), can also affect human health and productivity. In 2002, the U.S. Office of Homeland Security (OHS) formed the Interagency Workgroup on Building Air Protection "to produce guidance to building owners and managers that would contain a set of recommendations they could implement now to better protect the indoor environments of their buildings from terrorist threats", including effective automated chemical biological detection systems, medical diagnostics, and countermeasures. In tandem, the IEQ focus areas of the U.S. EPA National Homeland Security Research Center (NHSRC) and the Indoor Environments Division (IED) include<sup>5</sup>: diagnostics for air monitoring; assessments of air contaminant exposures; decontamination of buildings; and evaluation of Homeland Security technologies. Recent concerns for hospital-acquired illnesses (HAI) have been voiced by hospitals, community healthcare facilities, and the Centers for Disease Control<sup>6</sup>.

With continuing emphasis on Homeland Security defense against chemical and biological attack, and desires to improve both air quality and energy efficiency in home and work environments, the IEQ market is expected to grow substantially. The overall U.S. IEQ market was \$5.6 B in 2003 and is expected to rise at an average growth rate of 11% to \$9.4 B by 2008 (Business Communications Co., Inc., 2004). The commercial and residential cleaning services are projected to advance 5.5 % per annum through 2009 to over \$60 billion. Of this the air cleaner market has grown 34% to \$395 million with growth estimated to \$515 million by 2008 (Freedonia Group, 2005).

The GAP<sup>TM</sup> technology was recently presented to the Federal Interagency Committee on Indoor Air Quality (CIAQ) that coordinates the IAQ activities of 23 Federal entities<sup>7</sup>. The National Center for Energy Management and Building Technology (NCEMBT) has a significant research program in air cleaning with several universities<sup>8</sup>. Efficacy testing has been done in environmental chambers and in-duct systems. The GAP<sup>TM</sup> technology is included in General Services Administration (GSA) listings by Government Scientific Source (GSS) for governmental facilities in the U.S. and overseas.

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<sup>5</sup> The Inside Story: A Guide to Indoor Air Quality, U.S. EPA/OAR and CPSC, EPA 402-K-93-007, <http://www.epa.gov/iaq/pubs/insidest.html> .

<sup>6</sup> Klevens, R. Monina, et al., for the Active Bacterial Core surveillance (ABCs) MRSA Investigators, Invasive Methicillin-Resistant *Staphylococcus aureus* Infections in the United States, JAMA 298, 1763-1771, 2007.

<sup>7</sup> Briggs, Dan, Genesis Air, Inc., GAP<sup>TM</sup> Technology, Cost Effective Removal of Chemical & Biological Airborne Contaminants, presented to the Federal Interagency Committee on Indoor Air Quality (CIAQ), October 17, 2007.

<sup>8</sup> Novocel, David, NCEMBT, Reduced Energy Use through Reduced Indoor Contamination in Residential Buildings, CIAQ, Washington, DC, July 7, 2006.

## Applicability.

Over the past 200 years, the paradigms for Indoor Environmental Quality have shifted<sup>9</sup> from simply assumptions that building occupants were the exclusive sources of indoor pollution. Demands for more than just dilution by ventilation with "fresh" outdoor air caused a shift toward "comfort" and "air conditioning". The present paradigm shift addresses whole buildings by focusing on pollution prevention by source reduction of contaminants and treating specific contaminants from diverse sources at differing times and concentrations that challenge health and productivity of building occupants, and degrade values of buildings and manufactured products.

Architects, consultants, building managers, and health/environmental professionals must make informed choices, therefore, between prevention and remediation technologies to insure IEQ for all purposes. Conventional technologies do not provide adequate levels of treatment. Innovative "green" technologies with broad applicability must be integrated into engineered systems. UVPCO technologies have received much recent attention by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)<sup>10</sup>. The, categorized in ANSI/ASHRAE Standard 62.1 as an IEQ procedure, allows the design professional an opportunity to select an alternative to the prescriptive Ventilation Rate Procedure method.

"The application of this technology (UVPCO) can provide protection against most airborne health and environmental hazards. These materials are now being incorporated and tested by Genesis Air, Inc. in systems designed for "smart" buildings."<sup>11</sup> The holistic approach to taken by Ingenuity IEQ, Inc. in the design/build/service of "smart" and "green" buildings includes: quantification (Optima™ monitor, by Aircuity, Inc.); design (CAD/CAM); installation (Phoenix Accel® II Airflow Control Systems, and Strobic Air Tri-Stack™ Fume Exhaust Systems); treatment (GAP™ technology by Genesis Air, Inc.); monitoring (OptiNet™ Facility Monitoring System, by Aircuity, Inc.); and performance (LEED® Green Building Rating System)<sup>12</sup>. Ingenuity IEQ, Inc. has been active with the U.S. Green Building Council and the Small Business Association of Michigan, and as members/chairs of national science advisory committees and editorial review boards to promote these technologies

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<sup>9</sup> Daniels, Stacy L., Interactions of Volatile Organic Compounds and Particulates - Speciation of Copollutants in Indoor and Outdoor Air Environments for Risk Assessment, Paper 5-3, Proceedings of the Odors and VOC Emissions 2000 Conference, Water Environment Federation, Cincinnati, OH, April 16-19, 2000.

<sup>10</sup> Tompkins, D.T., et al., Evaluation of Photocatalysis for Gas-Phase Air Cleaning – Part 1, ASHRAE Trans. 111(2), 2005a; Ibid., Part 2, ASHRAE Trans. 111(2), 2005b.

<sup>11</sup> Dr. Alan Gotcher, President and CEO, Altair Nanotechnologies, testimony before the U.S. Senate Committee on Commerce, Science, and Technology, Feb. 15, 2006. (SMART – Specific, Measurable, Attainable, Realistic, Tangible.)

<sup>12</sup> LEED - Leadership in Energy and Environmental Design. Green Building Rating System® is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings.

Ingenuity IEQ, Inc. has identified a large IEQ market for engineered systems that is receptive to development and adaptation of new technologies. Conventional technologies for treating conventional airborne contaminants, such as porous media filtration and gas-phase filtration, are not designed to protect against unusual contaminants and catastrophic events. The market is open to the introduction of innovative systems that can provide effective treatment at low cost. The potential for new technologies for governmental markets, evident since the events of 9/11, has positively affected Ingenuity IEQ's existing core market in the governmental sector.

The competitive landscape comprised of conventional solid- and gas-phase filtration technologies has had limited success in Homeland Security applications. The GAP™ technology offers features that conventional technologies can not provide. The strength of the GAP™ technology is simple and direct installation allowing considerable flexibility in incorporating custom designed and engineered systems into most HVAC systems in both new and existing buildings. Ease of maintainability, low life-cycle costs, and superior treatment efficiency are major features of the GAP™ technology.

"Green chemistry, also known as sustainable chemistry, refers to environmentally friendly chemicals and processes that result in: reduced waste, eliminating costly end-of-the-pipe treatments; safer products; and reduced use of energy and resources—all improving the competitiveness of chemical manufacturers and their customers."<sup>13</sup>

The GAP™ technology responds to the "green chemistry" challenge. It has the following advantages over competing technologies:

- Unique patent (pending) technology.
- Environmentally friendly catalyst and catalyst support.
- Effective in reducing volatiles, particulates, and bioaerosols.
- Effective for treating diverse classes of contaminants.
- Responsive at both low and high concentrations of contaminants.
- Reduced use of energy in indoor building environments.
- Applicable to both new and existing buildings.
- Deployable as stand-alone appliances for treating small spaces.
- Deployable as in-duct installations for very large buildings.
- Scalable design to match small to large airflows.
- Customized engineered systems to meet facility demands.
- Cost-effective design, fabrication, installation, and operation.
- No solid waste generated requiring disposal.

Ingenuity IEQ, Inc. integrates the GAP™ technology, with its unique capability for immediate remediation of a variety of potential airborne contaminants in diverse indoor building environments, into customized engineered systems that are both "smart" and "green" by achieving energy conservation through reduced ventilation demand, and by improving overall IEQ through contaminant treatment.

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<sup>13</sup> Definition of "Green Chemistry", From <http://www.epa.gov/gcc/>