6 Laboratory Applications Primer

6.1 Executive Summary

This primer addresses the issues that surround demand control ventilation in the laboratory environment. This includes a discussion of the basics of ventilation in a laboratory as it pertains to air change rates and how they are changing over time. Also included are guidelines in the design of the facility monitoring system including the required hardware, where the reference locations should be situated, and a review of optional hardware and their associated benefits. The topics include the following sections:

- **Section 6.1.1 – Lab Air Change Rate Dilemma** – Includes an explanation of the historical air change rates that have been used in laboratory spaces and why. Also discussed is how laboratory spaces are changing and why the air change rates for laboratories are changing.
- **Section 6.1.2 – OpiNet Sensing Technology Provides a Solution** – Includes an overview of how the OptiNet system would be applied to a labatory space and what the associated air change could be to offer an amount of safe ventilation while offering the greatest amount of savings.
- **Section 6.2 – Sequence of Operation for Laboratory Demand Control Ventilation (Lab-DCV)** - While generic in nature, this section serves as a guide for the engineer to use and to modify to create a project-specific sequence of operation for specification documents.
- **Section 6.3 – Equipment Required** – Includes a detailed list of what equipment is required and why. This includes an explanation of why some sensors (SENs) are required versus recommended.
    - o Required sensors for Laboratory DCV includes: SEN-TVC 1 and 2 and SEN-PAR.
    - o Recommended sensors would include SEN-CO2, SEN-DPT, SEN-COM. Beyond the sensors there are requirements for additional hardware to ensure the proper operation of this equipment such as the EXP2-EXA options for the ADRs. This hardware allows for flow feedback to be brought into the OptiNet system which enables it to upload to the Knowledge Center so that it may be used to validate the ventilation system's response to the DCV command.
- **Section 6.4 – System Configuration** – Includes a description of some of the requirements from hardware selection and layout considerations.
    - o Included are the requirements for flow feedback to validate the system performance, recommendations for other feedback that may be available such as power data, metered hot and chilled water flow, etc.
    - o Consideration of whether to use room sensors or duct probes and why duct probes are the preferred method of virtual sensing. Room sensors can be used conditionally. An explanation of what needs to be considered is also listed in this section.
    - o When using duct probes, issues discussed include the coverage area being limited to 1,000 square feet and the location of the duct probe in the duct work.
    - o The supply side reference location requirements are explained.
- **Section 6.5 - Solution Verification** - Addresses the methodologies used to verify the proper performance of the OptiNet system.
- **Section 6.6 - TVOC sensors Used by OptiNet – Lab DCV Applications** - Reviews the technologies used by the OptiNet system for sensing TVOCs. This includes a review of the Photoionization Detection (PID) approach and the Metal Oxide Sensing (MOS) approach. This section also addresses some of the benefits and shortcomings of both technologies and explains why both technologies are required for lab applications.

6.1.1 The Laboratory Air Change Rate Dilemma

Over the past 5 to 10 years, research facility design has been adapting to changing laboratory practices. Today's modern laboratory, especially in the life sciences, operates with fewer fume hoods due to the prevalence of microchemistry, or the use of minute quantities of chemicals and computational chemistry. Additionally, thermal loads in labs have dropped due to the reduced plug loads of more energy efficient equipment such as:

- LCD monitors instead of CRTs.
- More efficient freezers.
- Higher efficiency lighting.

As a result of these changes, the minimum air change rate is often the dominant or controlling factor for determining average, and in many cases, design values for supply and exhaust air flow volumes in laboratories. While acknowledging the increasing importance of this factor, there continues to be great debate over the correct value for the minimum air change rates (ACH) for laboratories. Air change rates are often set to a single value between 6 and 12 ACH for a laboratory with no hard guidelines or standards to rely on. There is no single correct rate of air changes for even a specific lab room. The dynamic nature of any individual lab space precludes that one "correct" value is appropriate at all times or for all conditions. The "correct" value varies based on the specific conditions of the lab at a given point in time. For example, if a spill of a solvent or volatile chemical occurs, or Chemists are working on a bench top that should be done in a hood, a higher room air change rate is desirable. In a spill situation, a rate far above 6 or 8 ACHs, such as 16 ACHs, can provide superior dilution performance during the incident and for a period time afterwards. When the situation calls for it, a higher air change rate is much more effective in reducing contaminant levels quickly. However, the majority of the time, under normal operating conditions, lab room air is typically clean and a minimum of 2 ACH would be "correct".

Diluting clean room air with clean supply air achieves no benefit and wastes significant amounts of energy. Consequently, the best theoretical approach regarding minimum air change rates for labs would be to determine the rate based on the real-time quality of the air in the laboratory. This would allow airflow in a lab to vary based on all the situational factors affecting lab airflow, as opposed to only the status of the hoods and the thermal load. Implementing a dynamic approach to controlling minimum air change rates requires measuring a unique set of indoor air parameters, such as total volatile organic compounds (TVOCs), particles, carbon dioxide and humidity and to integrate this information with the building management system (BMS).

Until now, such an approach was not feasible or cost effective primarily due to the quality and quantity of sensors necessary to safely implement this approach. In addition, the associated calibration and maintenance costs rendered it impractical to populate a large number of sensors throughout a facility.

6.1.2 OptiNet Sensing Technology Provides a Solution

OptiNet has been developed to support the implementation of the dynamic control of laboratory room air change rates in a practical, reliable and cost effective manner. This approach changes the age old paradigm of sensing and minimizes calibration and maintenance expenses. Instead of placing multiple sensors in each sensed space or area of a building, the networked system routes packets or samples of air sequentially in a multiplexed fashion to a shared set of sensors. Every 30 to 40 seconds a sample of air from a different area is routed on a common air sampling backbone to the same set of sensors, known as a sensor suite, for measurement. These sequential measurements are then "demultiplexed" for each sampled area to create distinct sensor signals used for traditional monitoring and control. Typically 20 to 30 areas can be sampled, with one set of sensors, approximately every 15 minutes depending on the requirements for those spaces. Calibration and maintenance expense is minimized due to the limited number of sensors and their centralized grouping in one location. The calibration process is easily accomplished through an exchange program whereby a set of factory calibrated sensors from the manufacturer periodically replaces the onsite sensors, such as every 6 months. The system is therefore assured to operate at peak performance with minimal, or no disruption to the facility's operation.

This multiplexed sensing approach, Figure 6-1, can measure almost any air parameter of interest. For laboratories, the use of a PID or photoionization detector type of TVOC sensor is very beneficial for accurately detecting literally hundreds of commonly used laboratory chemicals that can volatize and become a safety concern. In addition, the PID is combined with a Metal Oxide Semiconductor (MOS) sensor, which provides additional capabilities to detect a number of parameters which the PID is less sensitive to; such as methanol and methylene chloride, for example. Further, combining these sensors with a laser-based particle counter to identify aerosol vapors, affords detection of the majority of airborne chemicals of concern. In this dilution ventilation control concept, when an increase in contaminants in a space is detected, the airflow in the room is increased as appropriate up to a maximum level such as 16 ACHs or the design capability of the room's airflow control devices. The lower value of the dynamic range when the air in the lab is "clean" can be set to 4 ACH (Occupational Safety and Health Administration or OSHA guidelines recommend 4 to 12 ACH). For additional savings, a nighttime or unoccupied level of 2 ACH can also be implemented. For less critical labs or support rooms, 2 ACHs could be used as the minimum level for all times. Although a value such as 2 ACHs at first glance might seem low, analyzed further, it is more than three times the typical office outside air ventilation level. It is important to note that no set of sensors will detect every possible compound that can be used in a laboratory. However, with the sensors previously described, the vast majority (90 to 95%) of the chemicals of any concern will be detected allowing the air change rate to be appropriately increased. As a result, for the vast majority of spills or chemical releases it is preferable for safety reasons to increase a lab's airflow rate from 6 or 8 ACH to 16 ACH. The remaining 5 to 10% of the time, when a chemical release is not detectable, the lab will still operate at the OSHA minimum guideline of 4 ACH. Varying air change rates as the situation demands thus provides a better overall approach compared to operating at 6 or 8 ACH *all* the time, regardless of whether a spill or accidental release of chemicals occurs in the lab.

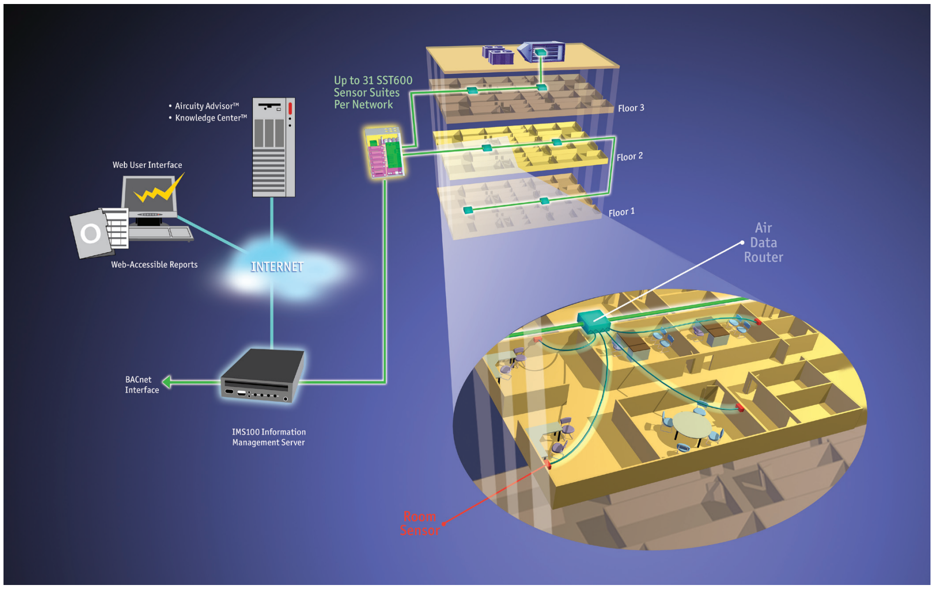

Figure 6-1. Facility-Wide Sensing Architecture

Figure 6-2 illustrates the significant benefits of operating at higher ACH rates during a spill. Figure 6-2 also illustrates what happens during a National Institutes of Health (NIH) handbook dilution ventilation test of spilling a 1.5 liter container of acetone on the floor of a single 250 sq ft lab module.

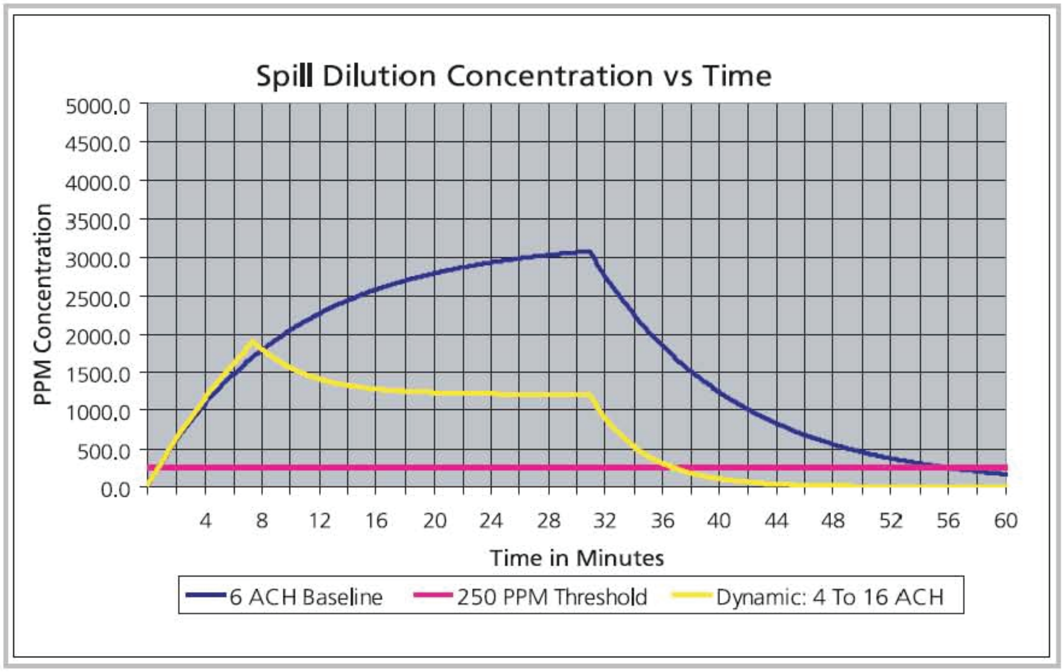

Figure 6-2. Comparison of Dilution Rates of Acetone as a Function of Air Change Rates

The figure of merit evaluated by NIH is the length of time it takes to reduce the contaminant to a safe level, shown in the above figure as 250 PPM or 1/3 of the threshold limit value (TLV). After approximately 7.5 minutes from the point of occurrence, the dynamic control system senses a spill and increases the air change rate from 4 ACH to 16 ACH, which reduces the peak concentration reached versus the 6 ACH baseline ventilation case. Additionally, after 31 minutes, the solvent has evaporated and the dynamic system takes only 5 minutes to reach the 250 PPM threshold, whereas the 6 ACH baseline takes 5 times longer or 25 minutes to reach this same level. Even more interesting, is that after one hour the dynamic dilution control system reduces the background level of acetone vapors to 0.53 PPM whereas the 6 ACH baseline is still at 169.0 PPM or 320 times greater. Regarding animal facilities, this approach is an excellent means to both safely vary and oftentimes reduce air changes, while providing real time monitoring and documentation of the quality of the room environment in which the animals are housed. Air quality problems that could affect research results can be quickly detected and remedied before the animals are substantially impacted. The ability to reduce an animal room's air changes from perhaps 10 or 15 ACH to 6 or 8 ACH is not only now practical but allowed. The Institute for Laboratory Animal Research (ILAR) guide used by the Association for Assessment and Accreditation of Lab Animal Care (AAALAC) for vivarium accreditation permits lower air change rates as long as good or specifically non-harmful levels of room air quality are maintained.

In particular, the ILAR Guide to the Care and Use of Laboratory Animals is a performance-based standard that specifically states that fixed air change rate guidelines such as 10 to 15 ACH although being generally accepted, "*…might pose a problem by over ventilating a secondary [room] enclosure that contains few animals and thereby wasting energy or by under ventilating a secondary enclosure that contains many animals and thereby allowing heat and odor accumulation.*"

Additionally, the ILAR Guide states that lower room ventilation rates can be appropriate, *"… provided that they do not result in harmful or unacceptable concentrations of toxic gases, odors, or particles in the primary [animal cage] enclosure."* By directly measuring and controlling room particle levels, as well as odors/TVOCs and ammonia, good room air quality levels can be maintained energy efficiently.

6.2 Sequence of Operation - Laboratory Demand Control Ventilation (Lab-DCV)

6.2.1 Overview

The Laboratory Airflow Control System (LACS) will control the airflow control valves in response to the greatest of three demands: 1) temperature control, 2) fume hood demand and 3) Lab-DCV. The temperature controls and fume hood controls will operate independent of the Facility Monitoring System (FMS) and shall override the Lab-DCV when required to maintain comfort and well being.

The FMS will provide analog proportional Lab-DCV signals that correspond to the contaminant levels (TVOC, particles, CO2, etc.) sensed within the General Exhaust (GEX) duct for each lab.

The OptiNet system shall provide a Lab-MpDCV signal that corresponds to an Air Change per Hour (ACH) ventilation rate that is defined by the contaminant levels (TVOC, Particles, CO2, etc.) sensed within the Laboratory. These sensed parameters shall be measured against a supply air reference point that shares the same sensor set and is representative of the air being supplied to the space, typically at the Air Handling Unit, to provide a space-specific differential measurement. This differential measurement shall be converted to a Lab-MpDCV signal in ACH based on a prescribed control range for each contaminant type and sent to the LACS.

6.2.2 Reduction in Minimum Ventilation Setpoint, Air Changes per Hour (ACH)

When the GEX air contains a contaminant (e.g. TVOC, particles, CO2, etc) concentration, as sensed by the FMS, that is below minimum setpoint (configured within the LACS) the minimum airflow setpoint within the LACS shall be reset to 4 ACH during occupied hours (8 am to 10 pm) and 2 ACH during unoccupied hours (10 pm to 8 am). The actual lab ACH shall be dynamic and equal to the higher of the temperature control demand, the fume hood exhaust demand and the Lab-DCV demand. Note: there may be other control demand criteria not covered by the AN (e.g. occupancy sensors). See Table 6-1. Example: Minimum Ventilation Lab Setpoints:

Lab Number	Room Volume (cu. Ft.)	CFM @ Max ACH	CFM @ Min Occ ACH	CFM @ Unocc ACH
101	5760	758	384	192
102	8640	1152	576	288

Table 6-1. Example: Minimum Ventilation Lab Setpoints

6.2.3 Increase in Air Changes per Hour (ACH)

When the GEX air contains a contaminant concentration, as sensed by the FMS that is above high setpoint (configured within the LACS) the minimum airflow setpoint within the LACS shall be reset to maximum airflow of the installed system during both occupied and unoccupied hours. See Table 6-1.

For GEX contaminant concentration levels that are between the low and high setpoints, the LACS shall correspondingly and proportionally increase the minimum airflow during both occupied and unoccupied hours.

Once the GEX air contains a contaminant concentration, as sensed by the FMS that is below setpoint (configured within the LACS) the minimum airflow setpoint within the LACS shall be reset as described above.

6.3 Equipment Required

The system will require a fully functional OptiNet system whose components are listed in Table 6-2.

Equipment	Quantity (from Equip Sched)
ADR504-EXP2-EXA	1
DPB201-RTD	3
DPB202-RTD	1
HFP100-LC	1
IMS100-BAC	1
OSC105-N-P	1
OSC-C11	1
SEN-CO2-2A*	1
SEN-TVC-1&2	1
SEN-COM-1	1
SEN-PAR-1	1
SEN-PWR	1
SensorWorks	1
SST700	1
XFM124	2

**Carbon dioxide and in some cases dewpoint will additionally be specified*

Table 6-2. Equipment list from the OptiNet Estimating and ordering Spreadsheet (ONE)

In addition to the equipment listed in Table 6-2 shall be a Laboratory Airflow Control System and a means of interfacing with that system, either BACNet or hardwired directly to the local controllers responsible for regulating the airflow control in the affected labs. Both the BACNet interface and a hardwired solution are covered in the equipment list in Table 6-2. The BACNet solution is accomplished by means of providing a "-BAC" option to the IMS. The hardwired solution is accomplished by providing for local UOs that are on the "-EXA" board

As a part of the "Solution Verification" detailed below there needs to be a means to provide an input to the OptiNet system to allow for the upload of the lab's supply flow feedback to the Aircuity Knowledge Center. This is what necessitates the need for the "-EXP2" option on the ADR504. The equipment from Table 6-2 is shown in Figure 6-3.

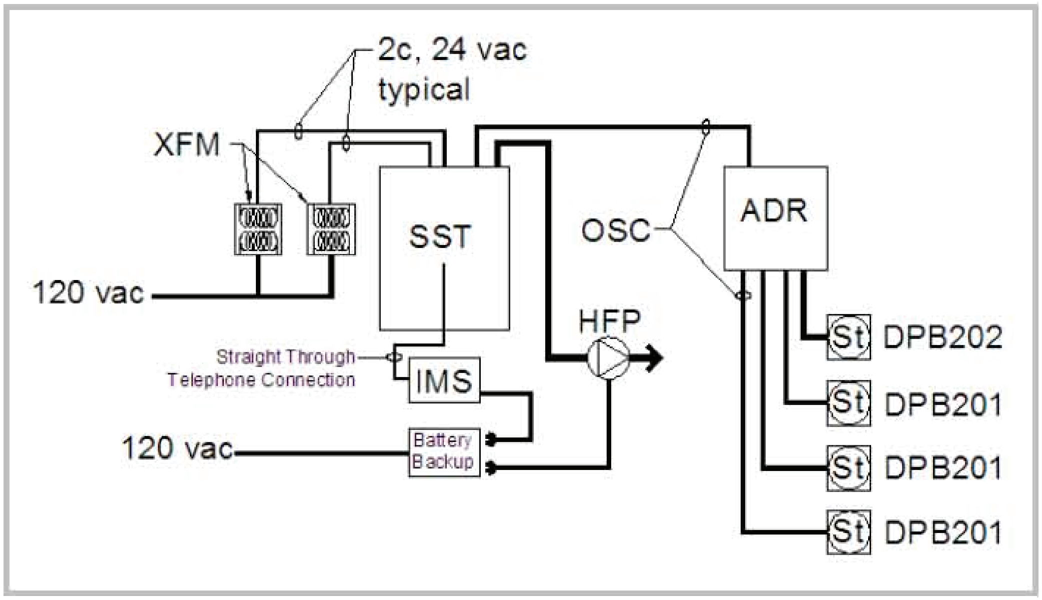

Figure 6-3. Typical System Configuration

6.4 System Configuration

For laboratory/vivarium Multiple-parameter Demand Control Ventilation (MpDCV) applications with 100% outside air, there must be a supply air probe as a test area on each SST. Supply air must be sensed versus outside air due to the need for a differential measurement of particles in the lab rooms with a particle reference location after the supply air handler filters. If a sensor suite is covering rooms or areas that are fed by different supply air handlers, then the supply air flows from each of these different air handlers must be sensed as well to get accurate differential measurements.

It is recommended (particularly for larger projects), but not required to provide one outside air reference location for the building (not per sensor suite), located away from the air handler inlets and also away from potential contamination from air handler or building exhaust sources. This is used for building diagnostic purposes only to get an indication of the true outdoor conditions unaffected by potential re-entrained air pulled into the air handlers.

For each controlled lab zone where energy savings are to be achieved, it is required that the following inputs be provided to the OptiNet system:

- Supply flow feedback
- General Exhaust flow feedback

For each AHU where energy savings are to be achieved, it is recommended that the following inputs be provided to the OptiNet system:

- Power data from the variable speed drives on the supply fans, particularly due to the nonlinear relationship between flow and fan power.
- Metering of chilled water and steam/hot water
- Metering of the hot water for VAV reheats

6.4.1 Additional Details

Some specific system configuration concerns unique to this lab application are as follows:

6.4.2 Duct Probe versus Room Sensors

When sampling the air from a lab room, a duct probe(s) offers better sampling performance than a wall mounted room sensor due to the centralized location in which a probe is typically mounted (usually within the general exhaust air stream). Room sensors on the other hand are generally less appropriate for these applications as they can often be located too close to a lab bench or other location where the concentration of parameters from an experiment or other activity can be out of proportion to the actual ambient levels within the lab space. This is similar to why a CO2 sensor used for DCV control should not be located next to a desk and a person's breathing zone. Supply diffusers can also provide a clean air wash over the wall mounted room sensor preventing the sampling of any room air at all. Duct probes will take a sampling of the air from the entire room including any area that has experienced an incident making them a better choice for lab room air sampling.

Figure 6-4 shows the effect of Supply Air diffusers providing a clean air wash over the wall mounted room sensors.

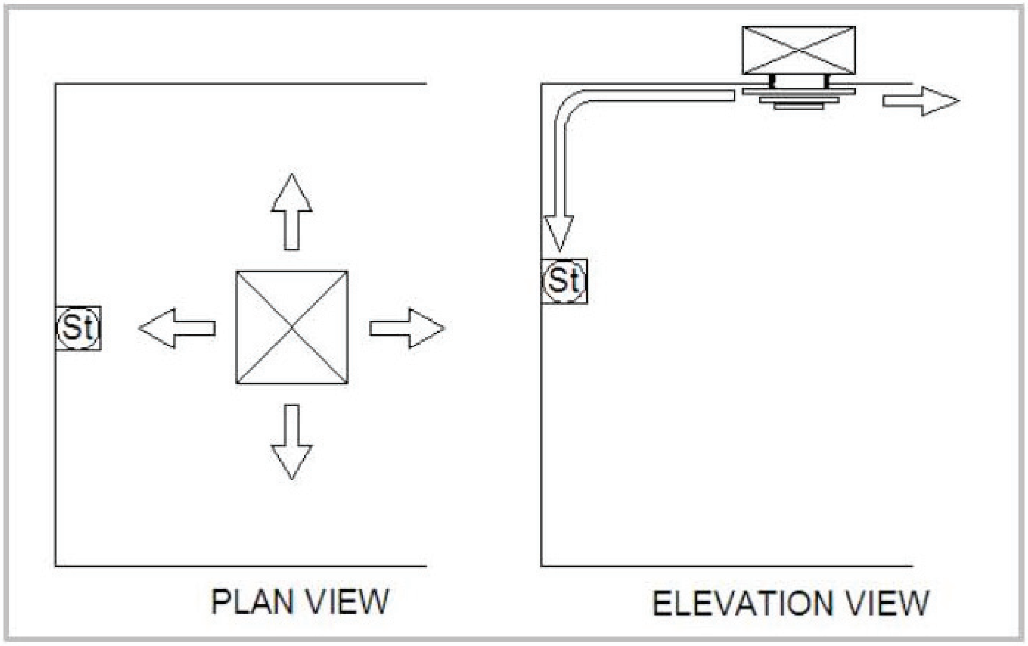

Figure 6-4. Supply Air Washing Over Room Sensors in Lab Applications

6.4.3 Duct Probe Quantity and Location

The goal of the duct probe is to take a sampling of the entire lab's air.

For larger labs that exceed 1,000 to 1,200 square feet and have multiple exhaust points and/or are covered by one temperature or pressurization control zone it is not recommended to use a single duct probe located in a common trunk duct due to the high dilution that will occur. A highly diluted air sample will result in a limited response and under ventilation of the lab space. Therefore, use multiple duct probes. See Figure 6-5.

Note: A guideline of (1) duct probe for every 1,000 to 1,200 square feet will cover most lab configurations.

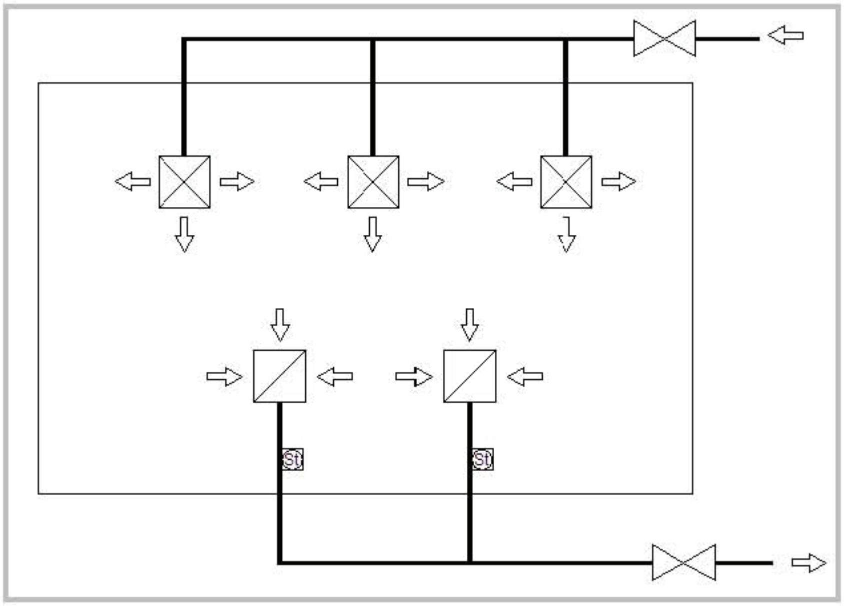

Figure 6-5. For Large Labs, use Multiple Duct Probes to Avoid Dilution of Air Samples

For areas with approximately 1,000 sq. ft or less per airflow control zone, a single probe can be located within a trunk that serves one or more general exhaust points. See Figure 6-6.

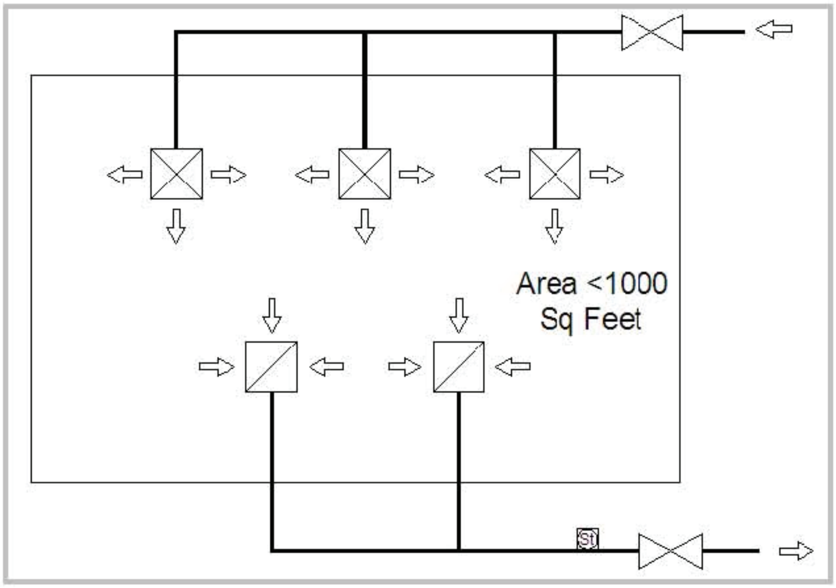

Figure 6-6. For Small Labs use Multiple GEX Diffusers, use One Duct Probe at a Central Location

It is important that this trunk is not affected by other lab/room exhausts and that it is exclusive to the lab being sensed. It is also important that the duct probe not be in a trunk that shares hood exhaust due to the high corrosives that may affect the sensors. See Figure 6-7. The required multiple duct probe installation will be similar to that shown in Figure 6-8.

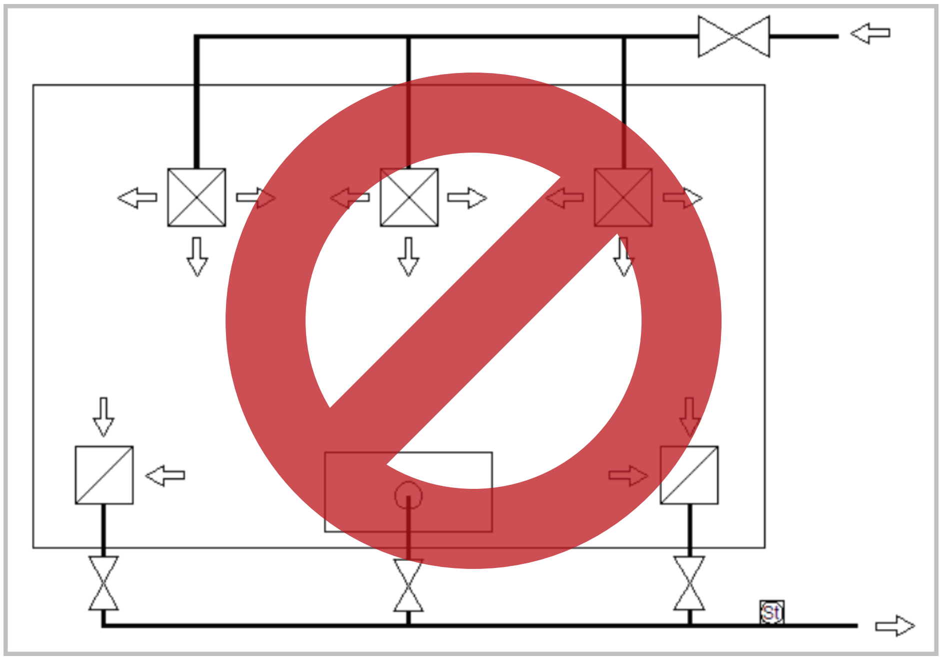

Figure 6-7. GEX Location Cannot Contain Hoods or other Labs GEX Flows

6.4.4 Labs without General Exhaust Ducts

Some labs are ventilated entirely through fume hoods and are not served by general exhaust ducts. In this case, duct probes may not be used to draw air samples from the space, making room sensors necessary. Although they are not typically recommended for the reasons outlined above, they can be used effectively if certain design considerations are followed.

- Avoid locating room sensors close to lab benches where chemicals may be used. The intent is to modulate the ventilation rate based on contaminant levels throughout the room, not a specific area where contaminants are generated.
- The room sensors should draw air samples that are representative of the overall space conditions. For this reason, two room sensors can be connected with a Dual Sample Coupler on one ADR test area, providing an “average” air sample between the two sensor locations. Use only factory-provided Couplers. As this is a special order, please consult Aircuity for this application.
- Do not locate room sensors in the air flow of a supply air diffuser.

6.4.5 Reference Location

Labs are typically supplied with 100% outside air that is often filtered after the air handling unit. As a result the supply air must be sensed at a duct location after the filters to provide a reference location for this application as shown in Figure 6-8

The reason for measuring downstream from filtration is for purposes of providing an adequate reference for particles and other measurements made within the lab. Here the lab room’s condition is measured against the source of supply air to that room. Since the particle levels of interest are those generated in the lab room, not those coming from outside, it is important to make a differential measurement of the room level particles vs.

the background level in the room that is being created by the supply airflow's contaminant levels. In this case, if room measurements were made with respect to outside air, the system could be ineffective at responding to even significant particle events that might take place within the lab, given the very small differential signal that would result due to often high ambient outdoor particle levels.

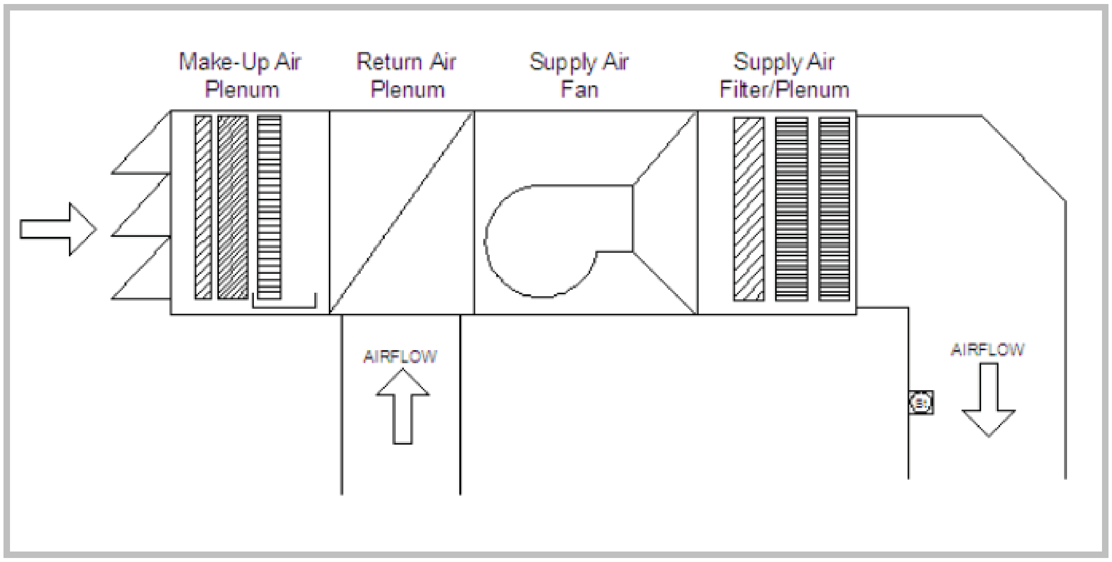

Figure 6-8. Supply Air Sensing after the Final Filters

The reason for this location is that to use particles as a sensed parameter it is required that you use supply air after the filter on the AHU as the reference location. Here you are comparing the lab room's condition against the source of supply air to that room. Since the particle levels of interest are those generated in the lab room, not those coming from outside, it is important to make a differential measurement of the room level particles vs. the background level in the room that is being created by the supply airflow's contaminant levels. If instead OA was used as the referenced location, then you would be measuring the lab's particle count to outside air before it has been filtered by the AHU. This means the OA particle count will almost always be higher than the lab's particle count eliminating the effectiveness of this sensed parameter. See Figure 6-9.

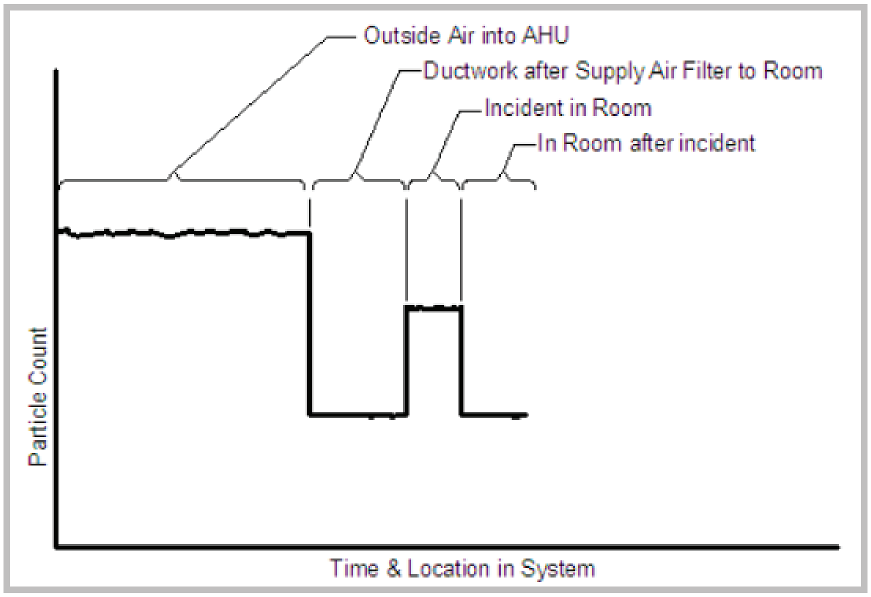

Figure 6-9. Example: Particle Counts Versus Time and Location in the System

6.4.6 Contaminant Levels versus Air Change Rate

The DCV signal, Figure 6-10 modulates between zero and the maximum ventilation rate, based on a corresponding range of differential contaminant level for each sensor. The DCV signal should modulate across this full range, even if the air flow system has a more limited air flow range. Clamping of the minimum or maximum flow rates should be done through LACS configuration, not by adjusting the DCV signal range.

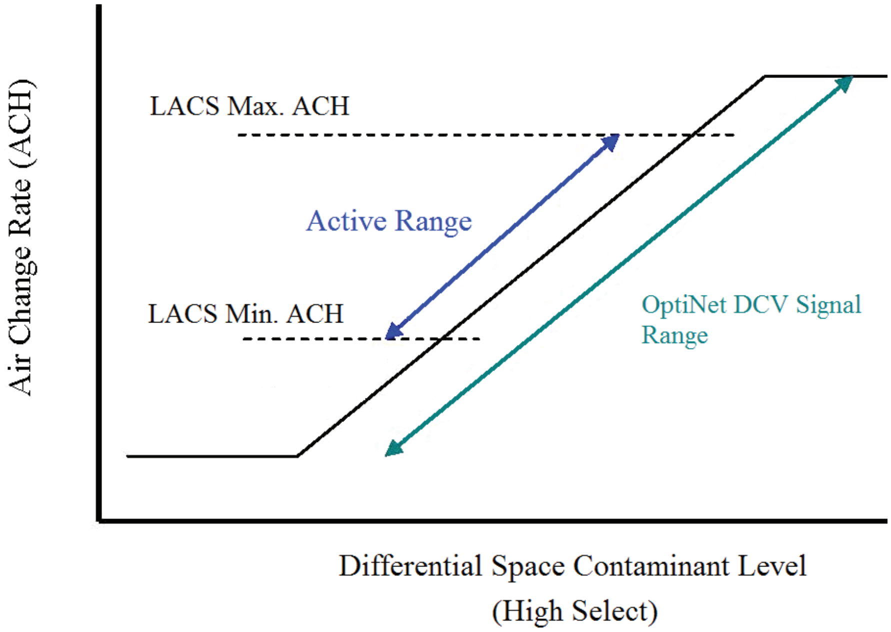

Figure 6-10. OptiNet Signal Range and Active Range

The recommended DCV setpoints are shown in Table 6-3.

DCV Signal	0	18	ACH
TVOCs – PID	0.1	1	ppm as isob
TVOCs – MOS	0.3	3	ppm as isob
CO2	300	3000	ppm
Particles	500000	5000000	pcf

Table 6-3. DCV Signal and Differential Contaminant Ranges

The values listed in Table 6-3 have been selected to provide the appropriate DCV signal based on contaminant levels and are not based on occupancy ventilation rates dictated by ASHRAE 62.1.

Figure 6-11, Figure 6-12, Figure 6-13 and Figure 6-14 show the relationship between each parameter and the air change rate commanded by the MpDCV signal, using the setpoints shown in Table 6-3.

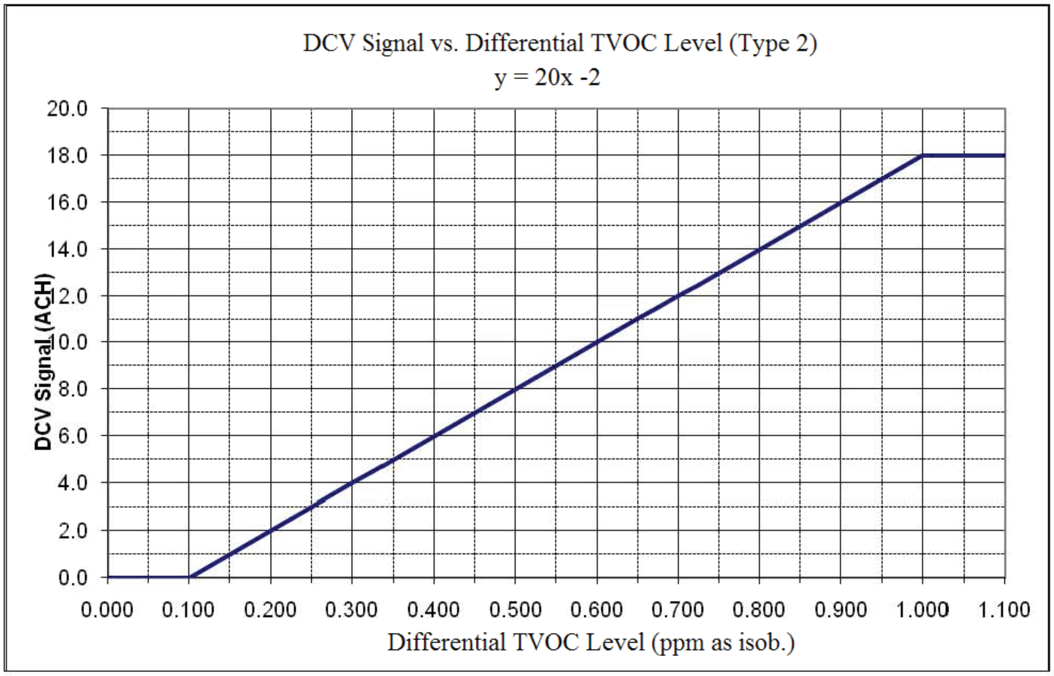

Figure 6-11. DCV Signal versus TVOC Level

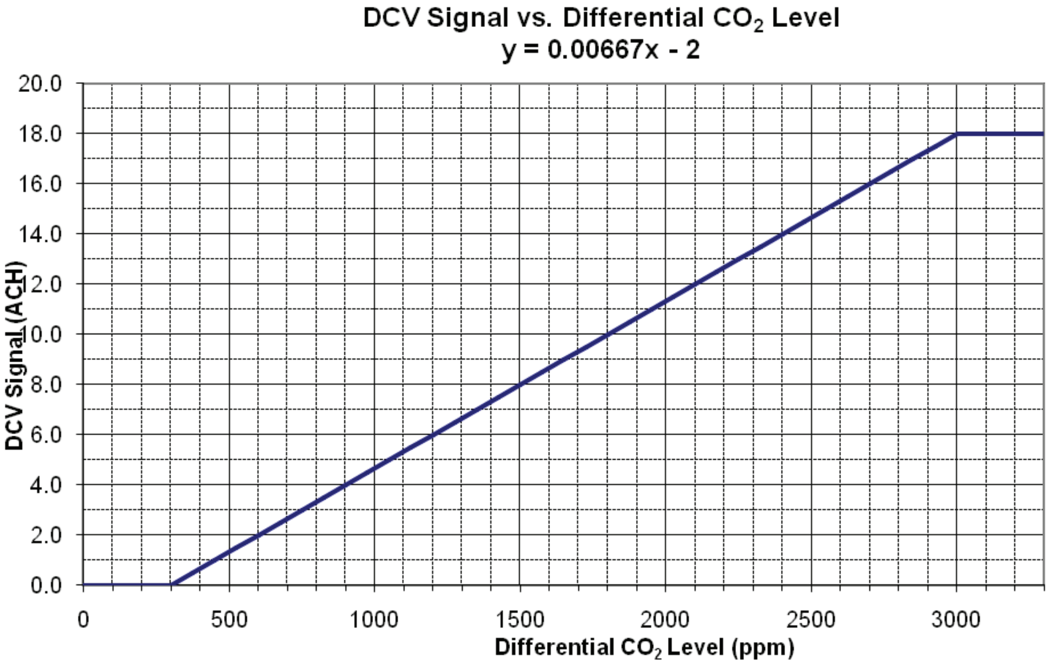

Figure 6-12. DCV Signal versus CO2 Level

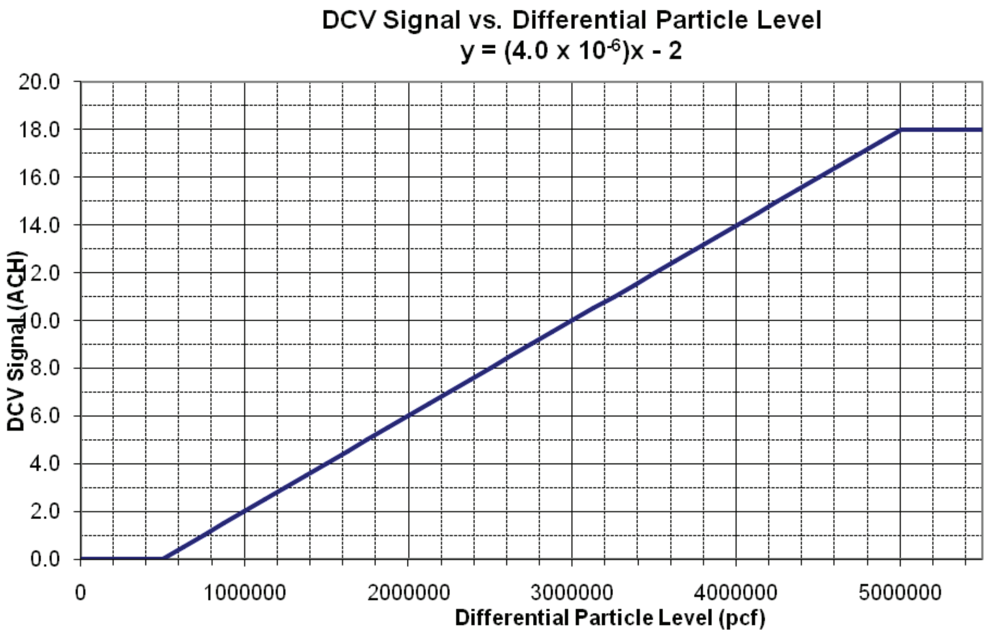

Figure 6-13. DCV Signal versus Particle Level

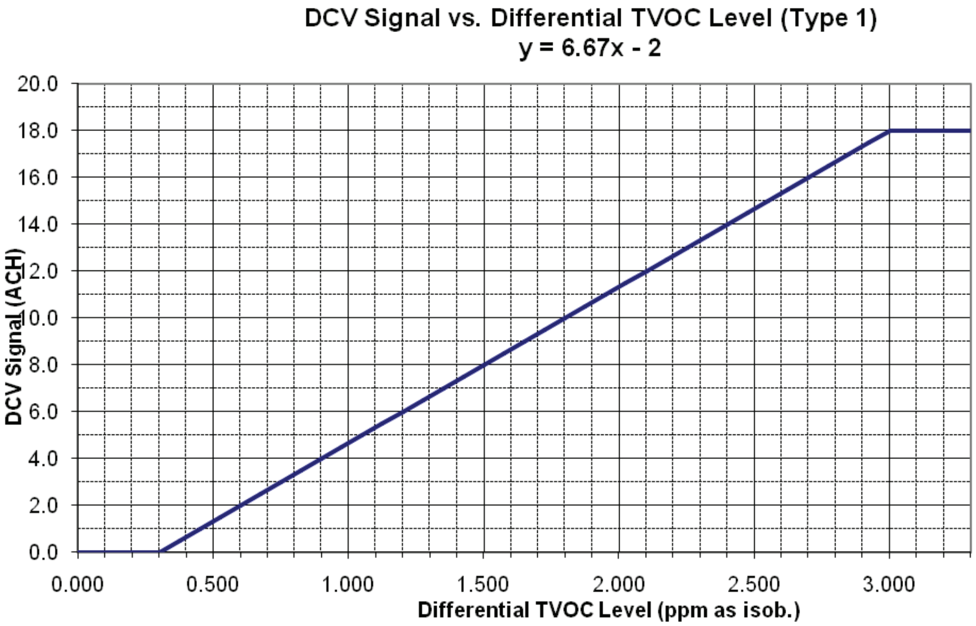

Figure 6-14. DCV Signal vs. TVOC Level

6.5 Solution Verification

6.5.1 Feedback Signals from the LACS (Total Supply and/or Total Exhaust)

To verify or validate the performance of the OptiNet system within a specific lab it will be necessary to incorporate additional points that are being uploaded to the Aircuity Knowledge Center. This is accomplished by means of taking in physical points (Universal Inputs: 0-10Vdc, 4-20mA) to the Aircuity System.

Specific points of interest are the supply flow feedback signals. By tracking the supply flow feedback the customer will be able to see if an incident has occurred that the supply air to the room has been increased as prescribed by the Aircuity system. Similarly, the average airflow reduction vs. the previous standard for air changes can be monitored to measure how often and the amount the supply air flow has been reduced using the Aircuity OptiNet system.

For each AHU where energy savings are to be achieved, it is recommended that the following inputs be provided to the OptiNet system:

- Power data from the variable speed drives on the supply fans, particularly due to the nonlinear relationship between flow and fan power.
- Metering of chilled water and steam/hot water
- Metering of the hot water for VAV reheats

6.5.2 Proper Certification Procedures

End users may want assurance that their system performs as designed and therefore may require validation from a 3rd party testing agency. Below is a synopsis of the 3rd party calibration procedure:

The critical parameters of any 3rd party testing are:

1. The sensors cannot be bench-top tested; the sensors must remain installed in a fully operating Sensor Suite. Doing so provides proper power, communications and airflow. If the sensors are removed and tested on another system not only are the results not guaranteed but they will void the sensor's warranty.
2. Therefore, the testing agency needs to present a gas sample (certified bottled gas) to the OptiNet system. This shall be introduced at the end of a duct probe using the following procedure:
   a. An inert 'gas sample bag' such as those made by Tedlar® should be filled with a known concentration of certified bottled gas (do not use 'batch certified' cylinders).
   b. The gas bag must be more than large enough for the sampling of at least one cycle: (20) l/m transport flow for 30 secs plus (2) l/m sensing flow for 60 secs = 12 liters volume minimum per test.
   c. The gas cylinder must be sized based on the expected number of tests at 12 liters/test. Recommended concentrations: CO2 = 1,000ppm, TVOC = 5ppm isobutylene.
   d. The gas cylinder must be provided with a high flow regulator, at least 5 l/min.
   e. The gas bag must be fully sealed to the end of the Duct Probe (which is removed from the duct) and the bag must stay in place until the normal OptiNet sampling is fully completed (both high flow and low flow) and the OptiNet system has switched to the next test area.
   f. The gas bag must not be under significant pressure (filled but not blown up like a balloon).
3. The time and test area name (i.e. which specific DPB) of each test needs to be recorded.
4. No sooner than 20 minutes after each test, the testing authority can log into the Aircuity Knowledge Center account to retrieve the OptiNet measurements.

Testing of the BAS and LACS should also be performed to prove that each system is responding as intended to an increased contaminant level within the lab zone. Reference the individual manufacturer's instructions or recommendations for this testing.

For life safety applications such as Lab DCV, each zone should be tested using the referenced method to assure an end-to-end verification that all systems and equipment (FMS, BAS, LACS, etc) are functioning as intended.

This test method does not address variations in airflow dynamics within each lab space that may inhibit the actual sensing of the contaminant concentration.

6.6 TVOC Sensors Used By OptiNet – Lab DCV Applications

OptiNet's Laboratory/Vivarium Demand Controlled Ventilation (DCV) application incorporates both Photoionization Detector (PID) and Metal Oxide Semiconductor (MOS) sensing technologies for the detection of low parts per million (ppm) volatile organic compounds (VOCs). The PID and MOS sensors have the ability to detect a broad array of commonly used organic (as well as some inorganic) compounds found within most research laboratories and vivariums. The two sensors are used together to ensure maximum coverage as, even though the range of VOC species that can be detected by the PID is extensive, there are a few important compounds that it does not pick up that can be sensed sufficiently by the MOS sensor.

OptiNet is designed to consolidate the separate PID and MOS sensor measurements, as well as that derived from other sensors (such as the laser-based particle counter) in order to create a "blended" DCV signal used to provide a command that is proportional to air change rate. The objective of this control technique is:

"To provide a proportional ventilation command signal that will call for at least the design ventilation rate before the exposure limit of a given compound is reached."

The "design ventilation rate" is the assumed minimum air change rate that the lab would be designed with when demand control ventilation is not used. Recent trends throughout the industry are (when DCV is not used) to set the design minimum ventilation rate to between 6 and 8 air changes per hour (ACH). However, higher minimum flows may be prescribed, depending on the anticipated use of compounds as well as exposure risks. Therefore, when applying DCV, a "good' response to the release of a particular compound would be one that at least ensures that the ACH command is brought to design levels (6 ACH) before the applicable exposure limit of that substance is reached. The logic behind this is that that level of dilution performance would be on par with that for typical lab design. Of course, one of the benefits to dynamically varying ventilation rate in proportion to spill or fugitive emission concentrations is that it allows for much better performance than this but with much lower average energy usage.

6.6.1 PID Sensing Technology

OptiNet's Photoionization Detector will respond to compounds that have an ionization potential less than or equal to that supplied by the detector's ionization source, in this case, an ultraviolet (UV) lamp. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and form a positive ion. This will occur when the ionization potential of the molecule in electron volts (eV) is less than the energy of the photon.

Figure 6-15 shows the design of the PID sensor. The first major component of a PID is an ultraviolet (UV) light source (1). This source produces ultraviolet light particles (photons) with discreet energy measured in electron volts (eVs). When these high energy ultraviolet photons are passed through a gas chamber (2), an electron can be ejected from the molecule by a process called ionization. After ionization, the molecule becomes positively charged. The negatively charged electrode (3) forces the charged molecule to the collector electrode (4).The amount of ionization and the current produced is proportional to the concentration of gas present in the chamber. Thus, the output signal resulting from this current can be related to a gas concentration displayed in ppm.

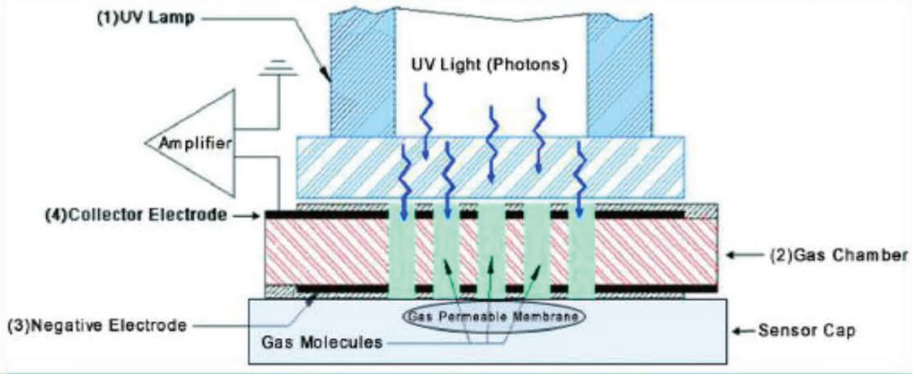

Figure 6-15. PID Sensor Design

The energy required to remove an electron (ionization potential or IP) varies from compound to compound; therefore ionization will only occur for compounds which have an ionization potential less than the ionization energy of the ultraviolet source. Gases with IP values below the eV output of the lamp will be detected. Gases with ionization potentials higher than that of the lamp will not be detected.

There are several possible energies that can be used by an ultraviolet light source. OptiNet incorporates the most commonly used lamp - 10.6 eV. Many compounds including a majority of the commonly found VOCs have IPs less than 10.6 eV. Water vapor, CO2, nitrogen and oxygen are examples of background gases that have IPs greater than 10.6 eV. These background gases will not be detected by the PID. Hence the PID sensor at 10.6 eV is selective at detecting most VOCs without being significantly affected by environmental changes such as humidity, oxygen, or carbon dioxide levels.

6.6.2 MOS Sensor Technology

OptiNet's metal oxide semiconductor (MOS) sensor is another "broad band" sensor that, similar to the PID, is capable of detecting a large number of both organic and inorganic compounds, with varying response factors for each. The MOS device, however, is better suited for measurements at higher concentrations, from a few tenths of a ppm to tens of ppm, whereas the PID is capable of making measurements from a few ppb to tens of ppm.

The MOS sensor is a catalytic device made up of an amorphous film of tungsten trioxide that is heated to a specific temperature. The electrical resistance of this oxide film varies with the concentration of the detectable gases that it is exposed to as a result of a complex reaction between the surface oxygen of the film and the reacting compounds.

This sensor has a high sensitivity to a number of compounds (such as, for example, methanol, allyl alcohol, and nitromethane) that either cannot be detected or can only be poorly detected by the PID. For this reason, it provides a complementary function, enhancing OptiNet's detection capabilities, when used in conjunction with the PID.

6.6.3 Calibration and Response Factors

The optimal way to calibrate a PID or MOS sensor for detection of a specific compound is by using a standard of the gas of interest. However, this is not always practical as it requires that a number of different and sometimes hazardous gases be kept on hand for calibration. To address this issue, the industry commonly uses a span gas such as isobutylene for calibration. This gas is easy to handle and can be stored at high pressure. PIDs and MOS sensors typically detect gases at low concentrations, and most of these gases are normally evolved from liquid solvents or other gases that are either not easy to produce in a controlled manner or that can be hazardous to handle. Thus, it is much easier to calibrate these instruments using isobutylene as the calibration gas.

Response factors, which are a measure of the sensitivity of a PID or MOS sensor to a particular gas, can then be used to relate the isobutylene response to the gas of interest. One can simply multiply the detector's reading (calibrated for isobutylene) by the response factor to get the corrected value for the compound of interest. With response factors, a user can measure a variety of compounds using a single calibration gas.

For example, the PID has a response factor of 4.2 for Ethyl Acetate, which means that a reading of 20 ppm as isobutylene from the sensor indicates a concentration of 84 ppm Ethyl Acetate. For ammonia, for which the PID has a response factor of 9.4, a reading of 20 ppm from the sensor would indicate an ammonia concentration of 188 ppm.

Important: While both the PID and the MOS sensors are extremely sensitive, they cannot determine if a spill or release is from a specific compound. Both the PID and MOS sensors can detect that a compound is present and can alert the user to potentially hazardous situations, but additional steps will be necessary to properly identify the substance and how much of that substance is present.