APPLYING DYNAMIC CONTROLS AND REMOTE MONITORING TO RADON MITIGATION SYSTEMS TO ADVANCE ENERGY CONSERVATION AND THE STABILIZATION OF INDOOR RADON CONCENTRATIONS

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Abstract

This paper describes the application of dynamic motor controls and remote monitoring systems that have been designed to achieve maximum operational efficiency to stabilize indoor radon concentrations and demonstrate long term performance of radon mitigation systems. The current generation of radon systems is designed with the intent of lowering indoor radon concentrations to below 4.0 pCi/l (150 Bq/m^3) or less in accordance with the USEPA standard for corrective action. To achieve these levels, systems are designed to operate at full power year round which contributes to energy inefficiencies. In most cases, very little is known about the long term performance of the system and the impacts of season variables that effect pressure differentials and ultimately radon concentrations. This paper demonstrates how the implementation of reactive circuitry and remote monitoring and management systems can achieve specified sub slab pressure differentials, regulate indoor radon concentrations, and improve energy conservation. Dynamic Controls and the associated remote electronic management system technology is a substantial improvement over the current technology in the areas of monitoring, system performance, reducing energy consumption and verifying the intended health benefits of the system.

Dynamically managed remote monitoring and system controls can provide assurance that radon mitigation systems are functioning to create a healthier living environment while providing advanced warning of potential motor failures, reducing the frequency of onsite inspections, and lowering operational costs. Dynamic Controls and Remote Monitoring are delivering the next generation of radon mitigation while advancing green engineering and sustainability in the radon mitigation industry.

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[1] This author is a developer of, and has a commercial interest in, the dynamic controls and remote monitoring described in this paper.
[2] This author does not have a commercial interest in the devices described in this paper.

The technology described herein may be subject to one or more U.S. Patent Applications. Please contact Thomas E. Hatton of Clean Vapor, LLC or Vapor Dynamics, LLC for further information regarding the above technology.

Introduction

Designing an effective and energy efficient radon mitigation system starts in the planning stage with a firm understanding of all the variables that are contributing to the problem.[1] Although there are many goals that are usually integrated into the design of a mitigation system such as aesthetics, ease of maintenance, cost to the client, etc., the primary focus should be on protecting human health followed by long term sustainability.

Since radon mitigation systems are designed to operate indefinitely, efficiency performance, maintenance and monitoring need to be key components of the design. This paper presents a method of dynamically controlling radon mitigation systems. Although significant energy savings are most appreciable in non-residential buildings, the enhanced energy efficiency, sustainability remote management and monitoring functions have benefits for all buildings.

Mitigation Design Principles

Migration of radon into buildings most often occurs because air pressure inside of a building is lower than the pressure in the soil beneath the building. These lower indoor pressures draw radon gas into the building through pathways such as floor drains, sumps, cracks in the slab, open concrete block tops, and utility penetrations. Basic radon technology functions by applying vacuum in the soil or air plenum beneath a building. This technology, first introduced in the 1980's, has demonstrated to be the most reliable and cost effective.

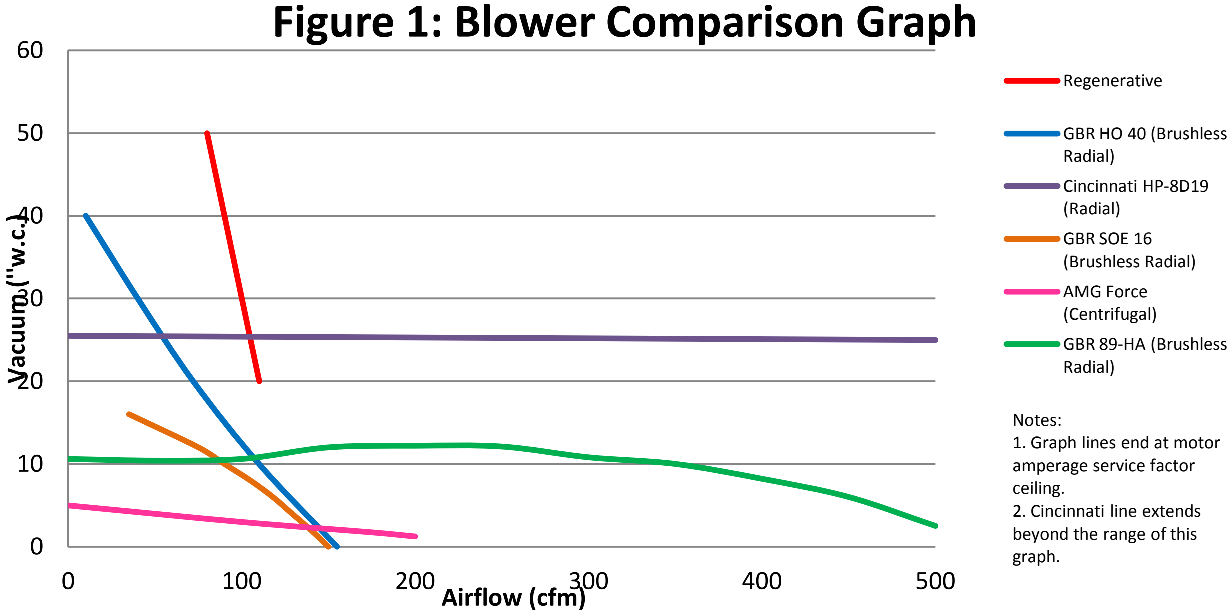
Developing an effective radon mitigation plan depends on understanding and quantifying the relationship between three key factors that contribute to radon entry: (1) the source strength of radon beneath the building, (2) the pressure differentials that draw radon from the soil into the building; and (3) the pathways that allow radon into the building.

After the mechanical components of the building that influence pressure are understood and the potential radon entry points have been catalogued, the next step is to understand exactly what will be required to create the desired pressure differential beneath the slab. Since most of the energy and costs required to mitigate the problem will be allocated as a result of the data collected during this phase of the investigation, it is critical to understand exactly how much vacuum is required and where it needs to be applied to achieve the pressure differential goals. Achieving system effectiveness occurs when the objective of the design is to reduce indoor radon concentrations to below the EPA standard for corrective action of 4.0 pCi/l. This usually equates to designing a system that can maintain a pressure differential with a minimum cold weather performance standard of -0.004" water column (w.c.) equivalent to 1 Pascal of sub-slab vacuum.[2]

The pathways of radon gas entry need to be sealed. These are usually fairly obvious. The next step is to determine what is required to depressurize the slab. Pressure field testing of the soil beneath the slab will determine vacuum field extensions; this is accomplished by drilling suction test holes in the slab, auguring out some soil and applying vacuum to simulate future vacuum fields. The physical characteristics of the sub-slab material should be noted and recorded. Applying different levels of vacuum to the test suction hole will determine the relationship between the vacuum applied and the pressure field extension needed for designing an effective soil depressurization system. The vacuum data from the pressure field testing and the measured volume of system exhaust are then extrapolated to project an expected radius of influence and airflow yield from the soil. Once this has been completed, several critical decisions need to be made with respect to the number and locations of suction points as well as the types and capacity of suction blowers to be used. There are centrifugal, small high speed brushless radial and 1-5 horse power (HP) regenerative and radial blowers to choose from. Each blower type has different performance characteristics and a best fit for the application.

All blowers have a common characteristic where vacuum is inversely proportional to airflow. Centrifugal blowers typically have low vacuum, high airflow and are used where the fill beneath a slab is highly permeable such as crushed stone or when depressurizing a crawlspace. Small high speed brushless radial blowers can be used on lower permeable soils that generally yield less than 120 cubic feet per minute (cfm). Regenerative blowers can develop relatively high vacuum levels, up to 80 inches water column, and can be used where there is extremely low permeability and low airflow yields. Radial blowers, depending on the horsepower of the motor and width and diameter of the radial wheel, can sustain a wide range of vacuum and airflow. Because of the increased efficiency of radial blowers over multiple smaller blowers, they are usually well suited for mitigating large commercial buildings. The long, slightly arched performance curve of the radial blower enables multiple suction points, in some cases up to twenty, to be joined into a single blower system without a sharp decline in static vacuum. See graph below for details on the operation of the various blower types discussed. The success in terms of its operational life and the allocation of financial resources required to run and maintain the system depends heavily on correctly and accurately interpreting the diagnostic data and selecting the blower best suited to achieve the vacuum field objectives. The radon mitigation system should be designed to function and meet predefined pressure differentials and maintain indoor radon concentrations that are below 4.0 pCi/l under a worst case weather and pressure loading scenarios. In some cases, where there is finished living space or there are sensitive receptors such as a hospital or a day care, 2.0 pCi/l should be the goal.

Figure 1: Blower Comparison Graph



Notes:
1. Graph lines end at motor amperage service factor ceiling.
2. Cincinnati line extends beyond the range of this graph.

Designing for Energy Efficiency

Up to this point, the large building radon mitigation design focus has been to create sufficient vacuum beneath the slab to facilitate achieving the pressure differential and a post mitigation indoor radon concentration that is less than 4.0 pCi/l. The result of this has been robust systems that have been effective in reducing radon concentrations but inefficient in terms of energy consumption. Very little focus has been applied to power conservation and long term sustainability of radon mitigation systems. Integrating dynamic controls into a radon mitigation design will ensure that the goals of protecting human health and conserving energy for long-term sustainability are achieved. There are two main categories of variables that influence the ongoing performance of a mitigation system. They are the sub-slab soil mechanics and a multiplicity of environmental variables that contribute varying pressures inside of buildings. Even though using Pressure Field Extension (PFE) modeling is the best way to project the radius of influence from a suction point and must be the starting point in the design phase; changes that occur once soil has been removed from the suction point and the moisture content of the soil beneath the slab has been reduced can alter the performance of a system to decrease the overall energy efficiency.

There are multiple variables that influence sub slab vacuum field extension and soil gas airflow yields throughout the year. Radon mitigation systems are designed to continuously operate to accommodate the worst case scenarios that exist during the heating season. If energy efficiency and sustainability are goals of radon mitigation systems, then systems should have the ability to dynamically respond to changes from influencing factors. Integrating dynamic controls with system design will enable the system to self adjust and change in response to influencing factors while maintaining a specific pressure field objective. The result could be that radon mitigation systems would not have to operate at continuous peak performance. Systems may actually only need to operate at fifty or sixty or less percent of peak performance to achieve performance goals during normal load conditions. This would provide significant energy savings and extend longevity to the operation of the blowers. Designing energy efficient systems requires accurate pressure field extension data, efficient design, and dynamic controls.

Green Energy and Sustainability Considerations

Since it has been demonstrated that using precision instruments during the diagnostic portion of the building investigation will yield data that will produce an efficient design, why not integrate the same level of instrumentation in the continuous operation of the system? EPA defines Green remediation as "considering all the environmental effects of a remedy implementation and incorporating options to maximize the net environmental benefit …" [3]. When designing systems, long term energy considerations need to be integrated into the design process. Greater design efficiency reduces operational costs and extends the time that an active venting program can be sustained for a fixed capital expenditure. Managing the application of sub-slab vacuum to counterbalance the convective forces that draw radon into buildings will increase the efficiency of applied vacuum and reduce the energy required by the blower.

There are three main components that need to be considered when attempting to lower the operational energy costs of a radon mitigation system. They are: the cost of operating the blower(s) that will maintain the negative pressure field beneath the slab, the cost of the heated, cooled, and conditioned air that is being drawn out of the buildings, and the cost of replacing the blowers themselves.[4] Blowers operating at higher RPM and loads have a shorter life span than blowers that operate at lower RPM and lower loads. When a motor runs at partial capacity it does less work, runs cooler, and lasts longer, thus lowering operations and maintenance costs.

Previous studies have indicated that one of the greatest costs associated with operating a soil depressurization system is the loss of conditioned building air that is drawn down into the sub slab though slab openings such as floor wall joints, electrical conduits, slab cracks and other openings. [4] When mitigating an existing building, many of these slab openings are not readily available for sealing. In some cases, replacing conditioned air that is drawn into mitigation systems can be a greater operational expense than the electrical cost to operate the blowers. The cost of replacing conditioned air can become the largest variable in reducing ongoing energy costs. It has been demonstrated that installing a tightly sealed vapor barrier system during new construction and optimizing the blower size can save up to $1,000.00 annually in heating, cooling and electric costs per 10,000 square feet of floor space [4] (using 2009 energy costs). The loss of conditioned air through slab openings inaccessible for sealing can be significant because existing buildings are typically constructed over low permeable indigenous fill. As a result, these buildings require fifteen or more times vacuum than newly constructed buildings with integrated crushed stone or aerated floor venting systems. Controlling the level of vacuum that is applied to the sub slab and the resulting loss of conditioned air is critical to the overall energy optimization of a mitigation system.

Efficiency of Blower Types and Problems Associated with Uncontrolled Radial Blower Systems on Large Buildings

In 2009, an effort was started to examine the power efficiencies of centrifugal, high speed brushless small Direct Current (D.C.) radial blowers and multi-horsepower large radial blowers installed by Clean Vapor, LLC. Conclusions were reached that even though radial blowers required larger horsepower motors, greater efficiency was achieved because only a minor reduction in vacuum occurred when airflow was substantially increased by adding more suction points to the system. The higher voltage and lower amperage 3 phase power used to drive the larger radial blowers also contributed to the electrical efficiency.[4] Clean Vapor also noticed higher airflow yields over a period of a few months as soil moisture content was being reduced. This was a new phenomenon that had not occurred with the smaller brushless or centrifugal blowers since relatively small increases in airflow produce sharp declines in static vacuum that can be applied to extend the pressure field in those types of blowers. An additional problem developed in unregulated systems where the riser pipe valves were left partially or completely open in that the increased airflow yields were causing the motor to overwork and exceed the electrical service factor. Motors were running hot and increased airflow was causing multiple point suction systems to become unbalanced. The first response was to manually dampen gate valves and reduce airflow to return motor performance to a range within the service factor. This created another unexpected problem; noise. Dampening gate valves created a nonlinear harmonic slide whistle effect with varying ranges of pitch and amplitude. This is not a problem in warehouse settings, where white noise is prevalent, but it became a serious problem when suction points were in office walls. Significant time was spent with micromanometers and pitot tubes achieving the best balance between pressure field extension and tolerable noise.

The next step in the evolution of trying to achieve greater efficiency and control was the introduction of frequency inverters more commonly known as variable speed drives. This enabled us to manually control the motor speed. This solved the service factor and noise problems and added a greater degree of power consumption efficiency to the systems.

Even though integrating variable speed drives was a large step forward, it still does not close the gap on a variety of system and energy management issues. The problems associated with manually balancing motor controls to adjust pressure field extension need to be solved. Manually balancing these systems requires mobilizing personnel, gaining building access and usually off hours work for experienced individuals.

Because radon mitigation systems are designed to operate for the entire lifespan of the building, the need to automate mitigation systems to achieve system control and power efficiency for long term sustainability is apparent. In 2010, Vapor Dynamics, LLC started developing prototype circuitry to control and manage the effectiveness and efficiency of radon and vapor intrusion mitigation systems. Achieving a constant defined sub-slab pressure differential is the largest variable that influences power consumption. The second is controlling the loss of conditioned air. Applying only the level of vacuum that is required to reduce radon concentrations to below 4.0 pCi/l is the most efficient mechanism to manage the loss of conditioned air and energy required to operate a soil depressurization system.

Power Conservation

In the past, typical large radon mitigation systems have been designed using fractional HP, single phase, 115 volt fans. Efficiency has been increased by increasing the number of suction points on a single system and using larger multi-horsepower radial and regenerative blowers. The 3 phase power associated with these blowers provides an approximate 33 percent energy savings over single phase. The use of this power also allows smaller gauge wire size to be routed long distances between the electrical source and the blowers.[5] To further conserve power, frequency inverters have been included so that vacuum applied to the sub slab can be controlled by adjusting the speed of the motor.

It is common for commercial buildings and strip malls with exhaust blowers to be under a 0.25" w.c. internal negative pressure load. Development and prototype bench testing of pressure sensitive Dynamic Controls started in 2010. Several modifications to improve control stability had to be applied during the development process.

Figure 2: Dynamic Controls with Integrated Monitoring

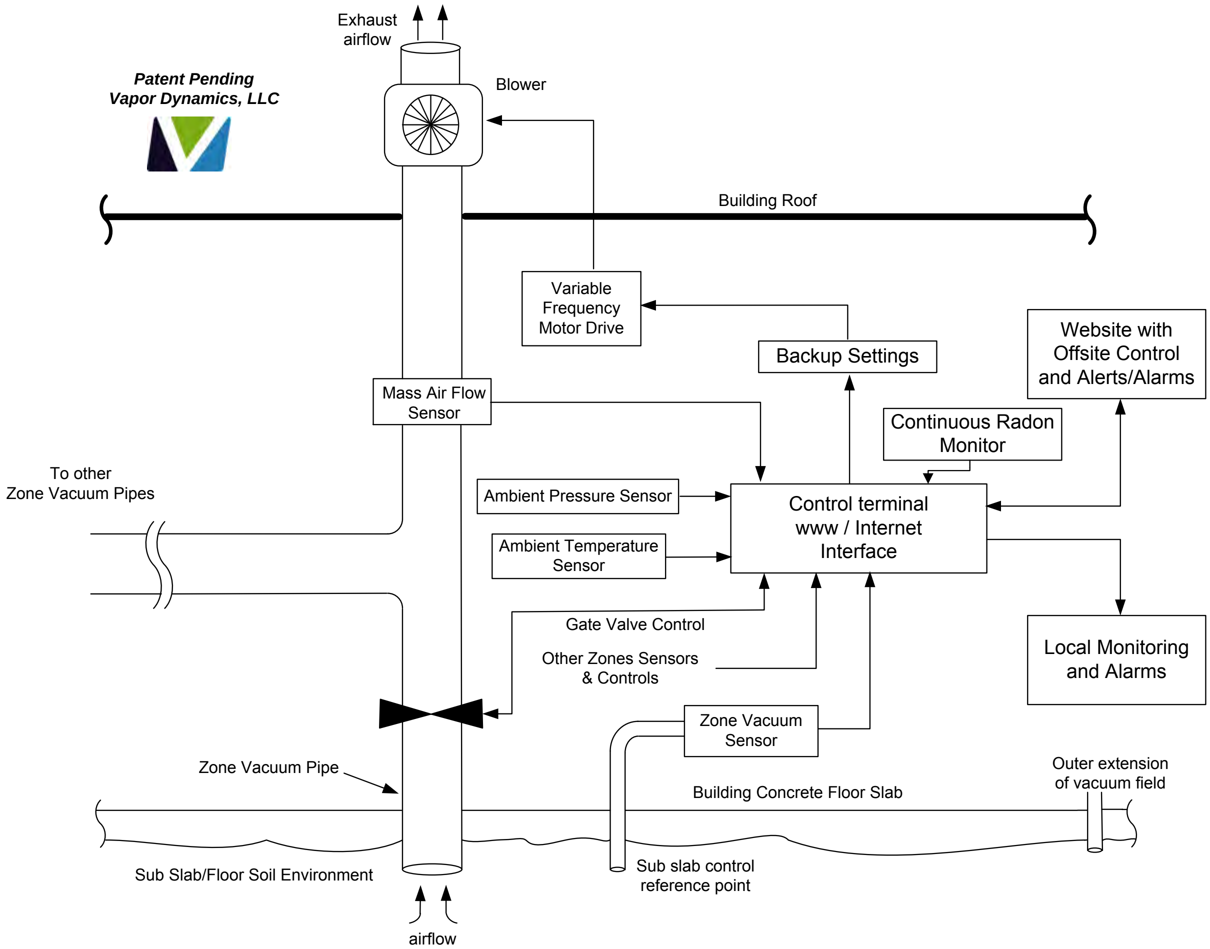


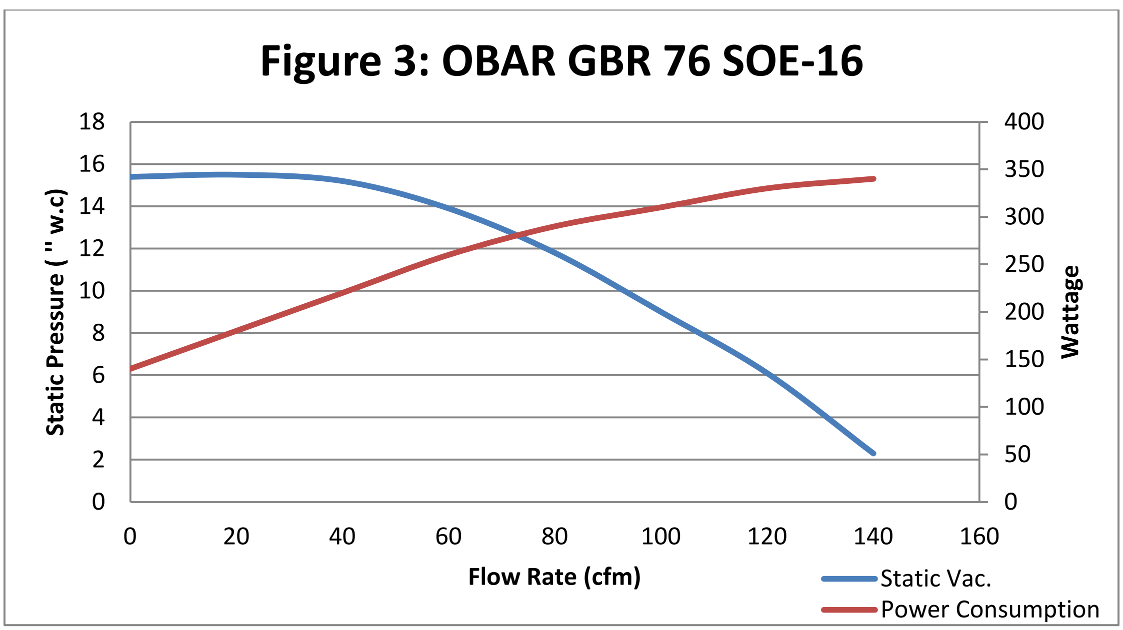
Figure 2 illustrates the basic concept of automated Dynamic Controls with integrated remote monitoring and management.

The motor speed of the blower is most commonly controlled to stabilize sub-slab pressure differentials and maintain a pre-programmed level of sub-slab vacuum as indicated by the sub-slab zone sensor. However, in crawlspaces and aerated floor depressurization systems, blowers can be controlled to achieve pre-determined air exchange rates using pitot tubes and/or mass airflow sensors that remotely transmit data to the dynamic controls terminal. Additionally, at sites with Methane and VOC (Volatile Organic Compounds) systems, dynamic controls can be set to maintain pre-determined contaminate concentrations in the rises or sub-slab.

Case Study

Over the past year, Clean Vapor has installed remote monitoring and dynamic controls at multiple vapor intrusion sites. In order to demonstrate the efficiency and functionality of the controls and monitoring on a radon mitigation system, Clean Vapor selected its Blairstown, New Jersey office which is located in the rural county of Warren, New Jersey. Blairstown has been designated by the NJDEP as a Tier 1 Radon Community[6], meaning that buildings in these community have the highest potential for elevated indoor radon.

The office is approximately 2,400 square feet and is a slab on grade structure connected to a larger manufacturing building. Our office was selected because we had monitored radon concentrations for a year and established baseline data prior to installing the dynamically controlled system. It also gave us the opportunity to physically inspect the control components and backup radon monitors as needed. The unmitigated baseline radon levels for the office in the prior year fluctuated between 5.2 and 7.8 pCi/l in the non-heating season and 7.4 and 9.7 pCi/l during the heating season. Even though the mitigation goal could have been achieved through a constant speed lower wattage blower, a GBR76-SOE16 small brushless radial blower was selected because the circuitry is designed to accommodate remote control commands to vary the speed of the motor. Below is a graph displaying airflow, vacuum and power consumption of the selected blower.



The dynamically controlled radon blower and remote monitoring were installed in 2012. The Sun Nuclear 1027 Radon Monitor was modified to wirelessly transmit radon concentrations to be recorded and viewed through the remote monitoring terminal.

The subset of data selected for this paper and the logging of radon data began on January 28, 2013 and continued through July 21, 2013. The following data analysis is an attempt to understand the relationship between required sub slab vacuum, power consumption, and external weather variables: temperature, barometric pressure and wind speed (collected from the nearest NOAA weather station) to mitigate and stabilize low radon concentrations.

The initial control sub slab vacuum reference set point was set at -0.0048" w.c. This set point remained fixed between January 27, 2013 and May 1, 2013. During this test time period, there were temperature variations of 77°F , wind speed variations of 36 mph and barometric pressures that ranged between 29.03"Hg and 30.65"Hg. During this period, the sub-slab vacuum level was maintained within ± 0.001 inches of water column of the control set point by dynamically controlling the vacuum applied to the sub slab. During the test period, one could hear the motor rpm respond to wind or open doors in the building. Figure (4) demonstrates how the system uses integrated "pulse" circuitry and a control algorithm to maintain a predetermined sub slab vacuum set point.

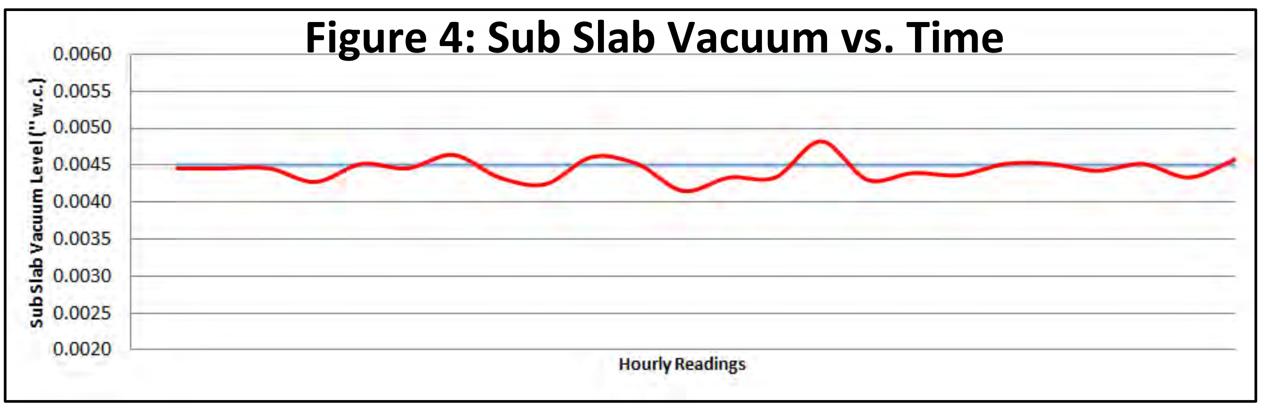


Figure (4): The Dynamic Controls system provides precise performance verification, data management and stabilization of prescribed sub slab vacuum levels.

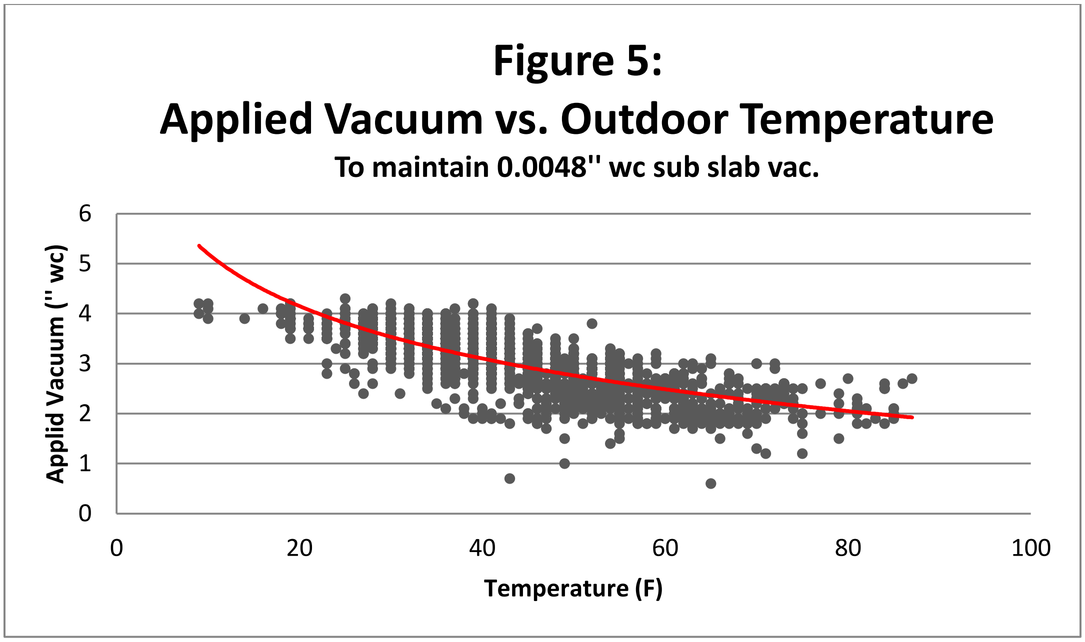
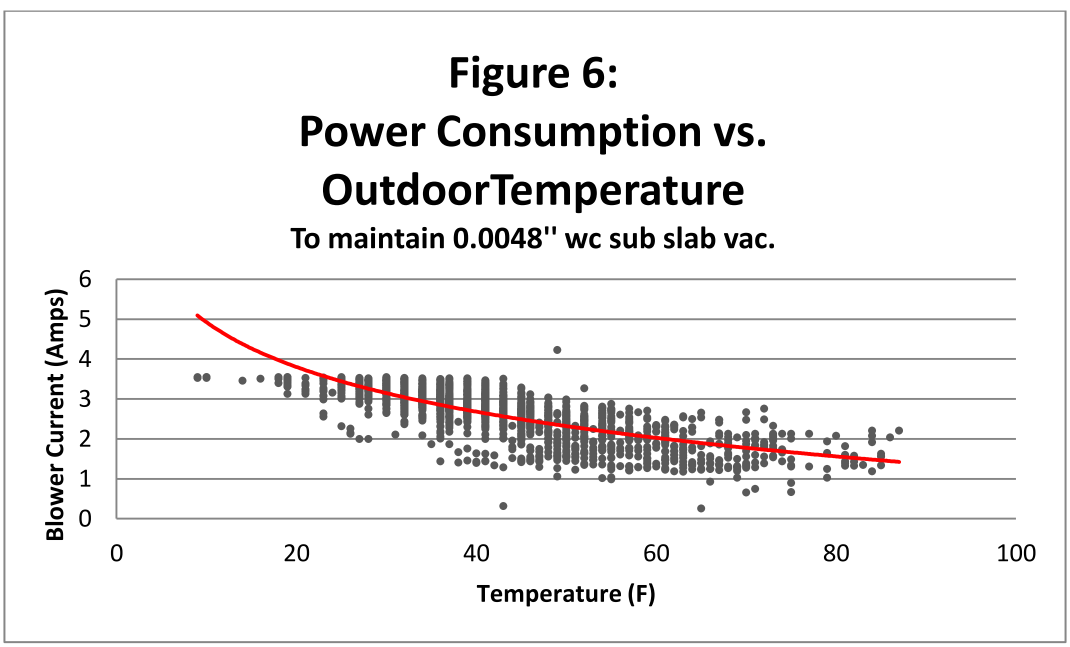
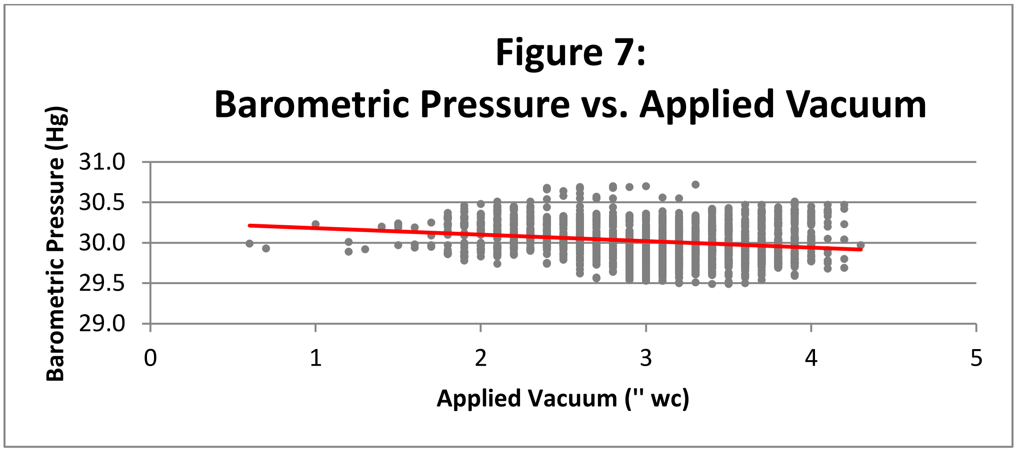


Figure (5) illustrates the required increase in applied vacuum to maintain a desired sub slab vacuum set point as temperature decreases.

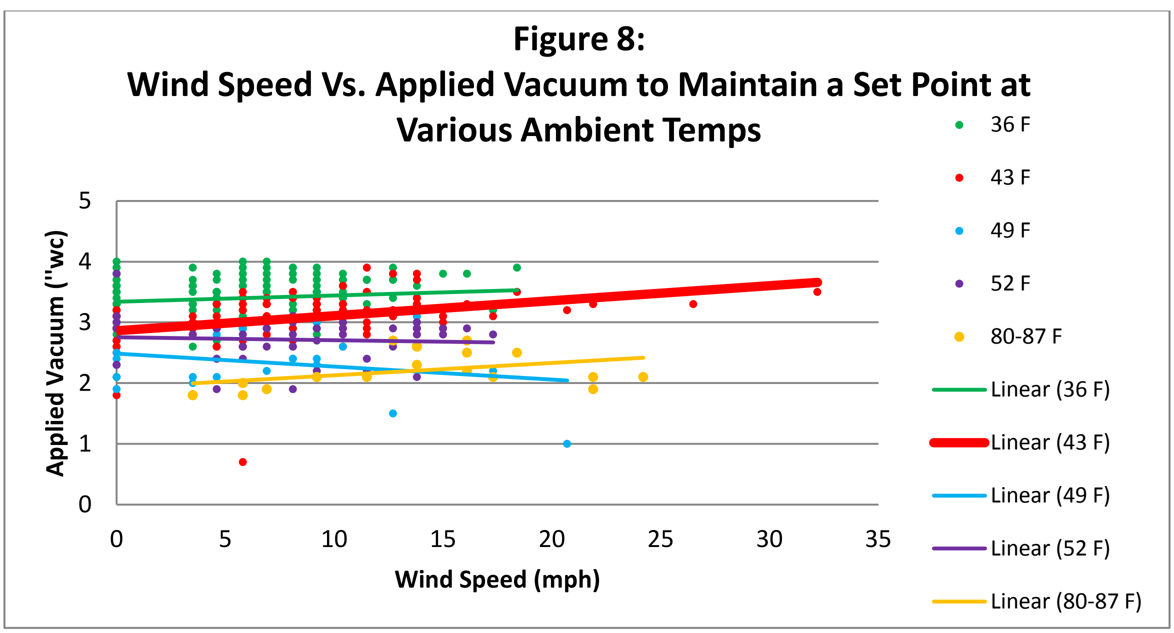
As expected, the blower power consumption varied proportionally with the static vacuum applied. These graphs illustrate that colder temperatures require an increased applied vacuum and power to maintain the predefined sub slab set point of 0.0048 " w.c.



The same data set was used in Figure (7) to graph the effects of changes in barometric pressure. The general trend line indicates that lower barometric pressures require greater power and applied vacuum to maintain constant sub slab pressure differentials.



Wind speeds varied from 0 mph to 36 mph during the test period. Control data was analyzed in millisecond intervals. The varying of the base motor speed in response to wind gusts and open doors could be heard and was graphically observable on the remote control terminal. The data sets were summarized and stored in hourly intervals and an attempt was made to isolate the effect of wind by selecting data sets from the median temperature of 43° F. The analysis of this data set indicates an increase in applied vacuum is required to maintain a predefined sub slab pressure differential as a response to an increase in wind speed. Additionally, other temperature data sets were selected to determine if a similar response would occur at other temperature ranges. This effect is graphically illustrated in Figure (8). It is theorized that this relationship can be more effectively demonstrated by shortening the data periods to about five minutes.



The average daily concentration during the initial January to May monitoring period was 0.7 pCi/l with the measured maximum daily average being 1.5 and the minimum daily average being 0.2 pCi/l.

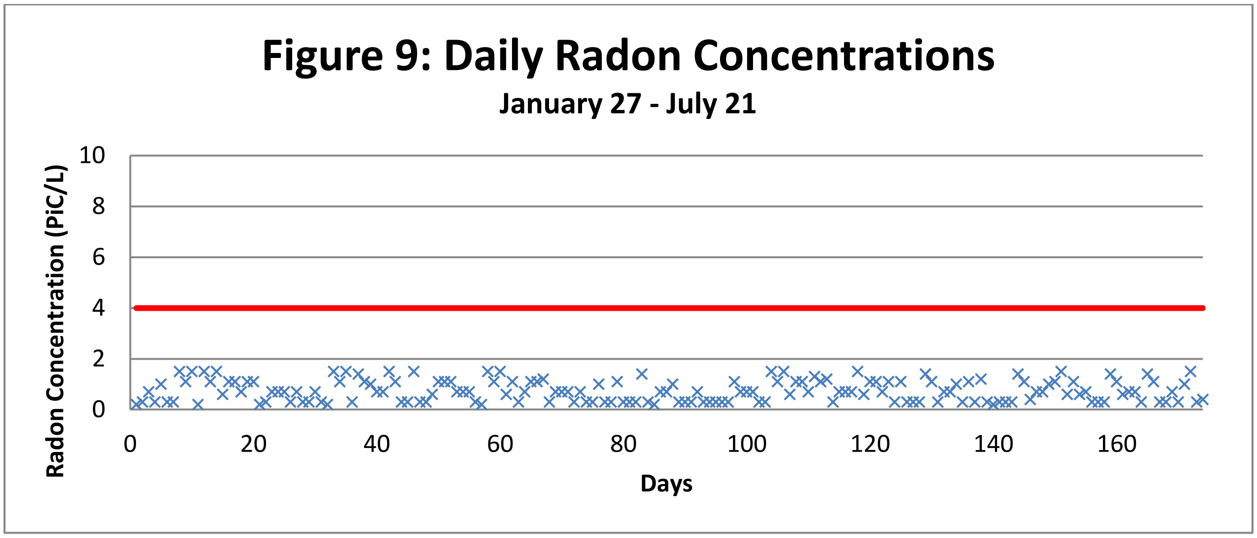


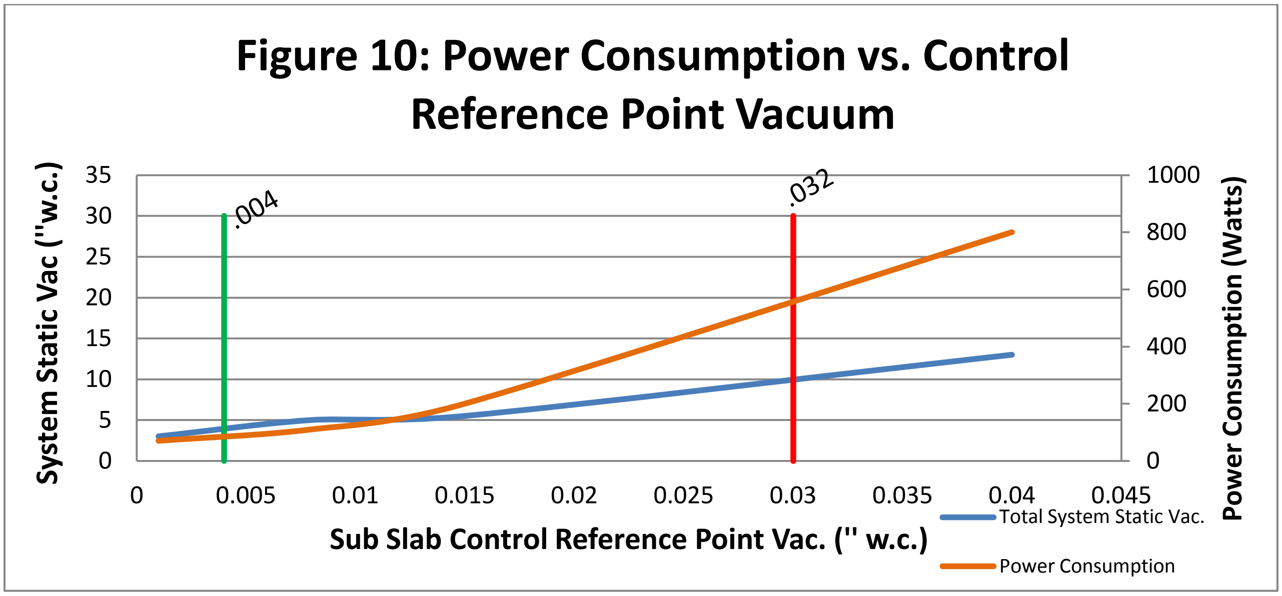
Figure (9) shows the radon concentrations during the course of the experiment. The red line represents the national standard of 4.0 pCi/l.

Continuous control of sub slab vacuum yielded radon concentrations that remained consistent within a narrow band of variation even though there were large variations in temperature, wind speed and barometric pressure.

In addition to remotely monitoring and dynamically controlling the radon mitigation system, performance metrics can be adjusted either manually while on site or through the remote system log in. This includes changing blower speeds, altering sub slab vacuum set points, and changing notification alert settings. During the case study, the sub slab vacuum set point was changed remotely through the remote login to measure the effects on radon concentrations that may result from altering the level of vacuum applied to the sub slab over the initial level of -0.0048 "w.c. On May 2, 2013 the sub slab vacuum set point was changed to -0.0080 "w.c.

The Vapor Dynamics, Vapor Guardian™ 5500, has the ability to monitor up to 55 inputs and dynamically control up to 10 blowers. Only a small portion of the Vapor Guardian's full suite of features were used in our case study building. The flexibility offers contractors the ability to install one panel in large commercial buildings, strip malls, schools and multi-family residential buildings while controlling and managing the data collected from multiple performance parameters at complex sites.

Although varying sub slab vacuum levels from -0.0048 to -0.0080 "w.c. did not have a measurable effect on radon concentrations, the power consumption associated with raising sub-slab vacuum increased at an exponential rate. The graph below displays the relationship between a sub slab vacuum set point and the power required to maintain such a set point. Also shown on the graph are vertical lines representing the minimum mandated sub slab vacuum levels required for Vapor Intrusion Mitigation by New Jersey's Vapor Intrusion and Technical Guidance (VITG) 2012[7.] (green) and *Radon Reduction Techniques for Existing Detached Houses*, EPA 1993b[8] (red).



As previously mentioned, the sub-slab vacuum remained constant throughout extreme temperature variations. However, the static vacuum generated by the blower required to maintain these predefined levels varied. During the heating season, the blower needed to produce higher levels of static vacuum in order to overcome the natural increases in interior-exterior pressure differentials induced by colder weather and the associated stack effect. This results in a radon system that consumes more power and is more expensive to operate in the colder months than in the warmer months. This also advanced the conclusion that there would be significant energy and cost savings yielded by applying only the minimum required sub-slab vacuum levels to maintain the desired radon concentrations.

The required static vacuum to maintain a predetermined sub-slab vacuum level was reduced in the warmer months. In order to illustrate the cost savings associated with reducing static vacuum levels, controls were installed on a larger scale system which features the same GBR76-SOE16 blower and eight suction points. This system depressurizes a 3,500 square foot engineering building. The results below show that a 94% energy reduction is achievable when running a system in the summer months at the minimum required sub slab vacuum level as opposed to the full static vacuum that was required to generate the same sub slab pressure field during the initial startup and winter months.

Table: 1

Sub Slab Control Reference Point (" w.c.)	Average Sub Slab PFE Vac. (" w.c.)	Total System Static Vac. (" w.c.)	Total System Airflow (cfm)	Watts	Kw-H	Annual Cost (USD)	Percentage Savings
-0.0665	-0.3491	-14.9	46	224	1962.24	$ 337.51	-
-0.0500	-0.4390	-8.6	31	96	840.96	$ 144.65	57%
-0.0160	-0.2116	-3.5	15	21.6	189.216	$ 32.55	90%
-0.0080	-0.046	-1.9	10	13.2	115.632	$ 19.89	94%

Performance Monitoring

Since radon mitigation systems are design to operate indefinitely, each system should be delivered to the client with a solid Operations, Maintenance and Monitoring (OM&M) plan as part of the post mitigation deliverables package. The same group of sensors and circuitry that are controlling performance commands can be integrated to supply information to monitoring systems that enables the consultant and owner to monitor a wide variety of performance parameters including, sub-slab vacuum fields, total system vacuum and airflow, radon concentrations, power consumption, and the cost savings realized by dynamic controls. Monitoring motor performance characteristics can provide system managers with advanced warning of potential motor failures thus protecting building occupants from unnecessary exposure to radon. The days of time consuming building access issues and technicians traveling to sites with a clipboard only to find out that a critical system component is malfunctioning may soon be a problem of the past. Whether it is an existing building that has been retrofitted with a radon mitigation system or a new building that is constructed in an area where there is high potential for the building to be impacted by radon, property managers can now have continuous documented assurance that all radon system components are functioning correctly and building occupants are protected from health risks associated with elevated radon concentrations.

The value of reduced liability associated with an assurance of continued sub-slab vacuum and lowered indoor radon concentrations cannot be overlooked. Consultants and owners now have the ability to continually view the radon system's performance metrics and have evidence of uninterrupted operation if the need to document such proof were to ever to arise.

Additionally, the ability to monitor system power consumption opens up new opportunities for tenant reimbursement. The scenario frequently arises, especially in strip malls with multiple tenants, where the owner is forced to install an additional panel for the radon mitigation system's electrical service in order to prevent increasing power consumption on a single tenant's electric meter. Another common situation is the need to run electrical wire and conduit hundreds of feet in order to service system components from a single "house" panel. With the ability to accurately track power consumption of individual systems, blower(s) can now be powered to the most convenient electric panel(s) on the site and the tenant can be reimbursed for exact electric costs of running the system(s).

Mitigation and Green Energy Policy Considerations

Although well intentioned and presumably published to promote more effective radon mitigation systems; requiring a minimum negative pressure beneath the slab of 8-10 pascals (0.0321 0.0401 inches of water) as published in EPA 1993b "*Radon Reduction Techniques for Existing Detached Houses*[8] and the vacuum field performance standards of 0.025 to 0.035 inches water column (6 to 9 Pascals(PA)) as published in ASTM E2121-12, *Standard Practice For Installing Radon Mitigation Systems In Existing Low-Rise Residential Buildings*[9], should be reevaluated and new lower pressure values adopted. These new pressure differential standards should be backed up by solid data acquired from continuous monitoring of the system performance metrics and after developing a firm understanding of the relationship between maintained sub slab vacuum levels, required power and stabilized indoor radon concentrations. New Jersey's minimum pressure differential standard 0.004" w.c. as published in the January 2012 VITG[7] would be a good starting point since it has demonstrated to be sufficient vacuum to mitigate vapor intrusion. This would promote the conservative application of engineering controls in terms of blower power consumption and reduce the frequency of suction points in large buildings.

Applying these high residential pressure differential standards to commercial buildings can result in thousands excess of pounds of CO_2 and hundreds of excess pounds of SO_2 being exhausted into the atmosphere if coal is the source of electricity. Increasing the continuous minimum sub-slab vacuum field requirement at the outer extension of the negative pressure field beyond -0.004 w.c. has not demonstrated to have significant benefits in terms of further reducing attenuation rates and lowering the presence of soil borne contaminants such as radon in indoor air. Pressure differential standards that were intended for residential homes should never be casually reassigned as criteria to determine the success of large building mitigation systems as the additional power required is costly and counter to EPA's Green Energy Goals.

Conclusion

Integrating dynamic controls with radon mitigation system design represents a departure from earlier technology where radon mitigation motors were designed to continuously operate at near peak performance in order to maintain sub slab pressure differentials required for meeting radon concentration standards under worst case load conditions that are induced by severe weather or mechanical depressurization. There is a non-linear relationship between change in sub-slab pressure differentials and the electrical power required to achieve the proscribed pressure field benchmarks. An order of magnitude increase in sub slab pressure differentials, measured in inches of water column, can result in more than twenty times the power consumption and annual operational costs.

Through the use of dynamic controls, radon mitigation systems will have the ability to automatically self adjust vacuum levels to ensure radon levels do not exceed the standard of 4.0 pCi/l or a specified preferred concentration. Maintaining acceptable radon levels during the heating season can represent significant power consumption and cost which creates waste during the non heating season. Integrating dynamic controls with optimally designed systems can continuously maintain a match between a specified performance standard and the minimum energy required to meet that performance standard. The electrical information that controls the speed of the motor as well as other system critical information can be integrated into a remote monitoring system where the consultant can remotely monitor and even alter the operational parameters further increasing efficiency. The data management and performance notification function provides an instantaneous electronic summary of all system functions when a single system component is functioning outside of a predetermined range. Quarterly Operations and Management reports are automatically provided to meet the OM&M Plan requirements thus easing the inefficiencies of field inspections. Dynamic controls enable radon mitigation systems to achieve year round standardized pressure field differentials that in turn yield significant cost savings, energy conservation and future system sustainability.

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Tom Leonard, Michael Salcone, David Everett, Vapor Dynamics, LLC
John Kitchura, Jr., Esq., Proskauer Rose, LLP

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