Design Overview

For

Electrical Equipment Rooms

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1.0 Overview

The purpose for providing high quality air inside an electrical room (also control, MCC rooms etc) is to improve any or all of system and component reliability, safety and occupational health.

Electrical equipment, either heavy switchgear, drives or electronics will be far more reliable in a clean and stable environment. The benefits will be less failures, better production and lower operating costs.

Particulates and gaseous contaminants are of prime concern, and temperature and humidity must also be addressed as part of the indoor air quality treatment.

Treating particulate or gaseous contaminants will be separated in this guide. Most applications require particulate and a small proportion require protection from gaseous contaminants. In addition, the math will also be different.

Particulate filtration is typically lower cost to operate, simpler, and the filtration efficiency typically increases as filters become loaded. Unless, of course, they fail catastrophically by imploding, but this is an extreme situation.

Gaseous filtration requires media to be monitored and maintained. Filtration efficiency will decrease over time if the removal process requires a chemical reaction and the active media bed depth becomes less than the required minimum. Consequently a lot of damage can be done in a very short period of time if a pressurization system is operated without the necessary effective bed depth for contaminants removal.

The reaction occurs in a "Mass Transfer Zone" where there will be media that is nearly spent, up to brand new media. A deep bed of media does not expire uniformly. The mass transfer zone progresses through the bed until the depth of active media becomes less than the required minimum and breakthrough occurs.

2.0 Applicable Standards

There are several key Documents that will be referred to in this Overview. These include:

a) Instrument Society of America Standard ISA-71.01-1985. Environmental Conditions for Process Measurement and Control Systems: Temperature and Humidity (Ref 1)
b) Instrument Society of America Standard ISA-71.04-1985. Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants (Ref 2)
c) OSHA Standard 1910- Occupational Safety and Health Standards (ref 3)
d) NFPA 70, National Electrical Code. (Ref 4)
e) NFPA 496, Standard for Pressurized Enclosures and Electrical Equipment (Ref 5)

3.0 Factors and Implications of Items to be Addressed

The following are some of the factors to be addressed, and the possible implications if they aren't.

3.1 Temperature and Humidity

Water is an essential component with corrosion. It is common sense that low humidity is preferable to high humidity, and fluctuations are not going to help the situation.

Temperature also impacts a reaction rate. The higher the temperature, the higher will be the corrosion rate.

Fluctuations in temperature will also result in fluctuations in humidity.

With standard air conditioning controls, fluctuations are normal as the device cycles "On" and "Off" within the differential of the controller.

3.2 Particulates

Particulates need to be removed from the air. They are a foreign body whose behavior is often unknown in the presence of electrical equipment.

3.3 Gases

If corrosive gases are present, such as SO_2 and H_2S, for example, they need to be removed because they can corrode metals, specifically copper and silver in an electrical room situation. This is more of a problem with RoHS lead free compliance, as lead is far more resistant to corrosion attack than silver.

If corrosion has been identified as a factor in component reliability, the space needs to be "Classified". This involves placing a corrosion control coupon in the space and having the corrosion analyzed and material identified. This will allow an estimate of the challenge levels, and system sizing will follow.

3.4 Pressurization

Ideally a space will require some form of positive pressurization. This assists in reducing the ingress of outside contaminants because all leakage is “out”.

It is a common approach to try and control indoor air quality by pressurization. The theory is that all air entering the space comes through a treatment device and achieves a certain standard. By dilution, the room will eventually be cleaned.

In a real world situation, we are typically dealing with a room where people are coming and going, doors opening and closing. Maintenance of filter assemblies is also under pressure, so the quality of the incoming air needs to be monitored otherwise more damage will occur with the system running, than shut down.

Unless a space is heavily over pressurized and the filtration system has a quick enough response time, and capacity, there will be some ingress of outside contaminants.

NFPA 496, Ref 5, has standards that cover spaces for Hazardous Locations that require flows of at least 60 fpm through openings and doors when opened. In most cases we are not dealing with Hazardous Locations, but the 60 fpm is quoted as an example of how much air would be required to prevent ingress though door openings etc.

An accepted level of pressurization for clean rooms above ambient levels is in the area of 0.05 inches of water gage, or 13 Pa. This figure can be found in ISO, ASHRAE etc. and 0.05” appears to be the most accepted pressure differential. It’s roots probably stem from Federal Standard 209B, Section 30.5 (from 4/24/73) which states “The minimum positive pressure differential between the room and any adjacent area of less clean requirements should be 0.05” wg, with all entry’s closed.”

Care should be taken when applying this level. It is no guarantee and an exposed room, for example, will require in excess of 0.5” wg with a 30 mph wind outside to prevent infiltration.

Pressurization is part of the solution, but not the complete one.

3.5 Recirculation

Recirculation filtration has been demonstrated to clean the air in “orders of magnitude” quicker than with pressurization alone.

There will usually be times when room integrity is breached, such as people entering and leaving, and there may also be internally generated contaminants.

The costs associated with cleaning a room internally or by pressurization are orders of magnitude less. This is not only on up-front costs, but also maintenance.

3.6 Air Conditioning

Air conditioning is often overlooked as a contributor to indoor air quality problems, and as a potential contributor to the solution.

An air conditioning system needs to be studied as a source of outside air contaminants and also for its effect on temperature and humidity control.

Biggest problems come from air handling units that are outside the controlled space.

4.0 Design Approach- Air Conditioning

Design of a suitable system is a multi step process and is logical.

This system is a very important component in the provision of a sound operating environment for electrical equipment, and is often overlooked.

ISA S71.01-1985 is a Standard (ref 1) that establishes "Uniform classifications of temperature and humidity conditions for industrial process management and control systems".

Table 1- Location, class and severity levels [Extract]

Location	Class	Severity Level	Temp. Limits (°C)	Control point tolerance (°C)	Max. rate of change (°C/hr)	Humidity Limits (% RH)	Control Point Tolerance (% RH)	Maximum moisture content (Kg/Kg dry air)
Air Conditioned	A	1	18-27	+/- 2	+/- 5	35-75	+/- 5	N.A.
		2	18-27	+/- 2	+/- 5	20-80	+/- 10	N.A.
		X	T.B.S.	T.B.S.	T.B.S.	T.B.S.	T.B.S.	T.B.S.
Enclosure temperature controlled	B	1	15-30	+/- 2	+/- 5	10-75	N.A.	N.A.
		2	5-40	+/- 3	+/- 10	10-75	N.A.	0.020
		3	5-40	+/- 10	+/- 20	5-90	N.A.	0.028
		4	5-50	+/- 10	+/- 20	5-90	N.A.	0.028
		X	T.B.S.	T.B.S.	T.B.S.	T.B.S.	N.A.	T.B.S.

N.A. – Not applicable
T.B.S.- To be specified

We are essentially concerned with Class A, situations where both temperature and humidity are controlled; and Class B, situations where temperature is controlled but not relative humidity.

By Table 1, a Class A1, for example, has temperature and humidity control where temperature should be within 18-27 °C, control point +/- 2 °C, maximum rate of change per hour +/- 5 °C, % relative humidity between 25 to 75 % with a control point tolerance of +/- 5%. This is the highest level in A Group.

Again by Table 1, a Class B1, for example, has temperature control where temperature should be within 15-30 °C, control point +/- 2 °C, maximum rate of change per hour +/- 5 °C, % relative humidity under operation results in the range 10- 75%. This is the highest level in B Group.

There are user defined Severity Levels "X" that may be selected within the Classes that allow other tolerances and ranges to be selected, as long as they are within the ranges. For example AX would be a space with temperature and humidity controls with tighter limits.

Typically if an air conditioner is sized properly, and not located in a desert situation, the room will be a B1 by definition but an A1 by functionality. Humidity will be controlled well within the humidity limits as set out in Table 1 of the Standard.

It is much lower cost to install a package system but these may not be the best investment at industrial sites. Consider:

i. Heat exchange coils are becoming smaller for the same capacity. This means a reduction in fin spacing (closer together) and geometry such as raised lanced fins (slit). These are more susceptible to clogging at industrial sites;
ii. Motors are often open type for cooling;
iii. Sheet metal panels are very thin, are not well sealed and only held in with small screws;
iv. Electrics are not well sealed;
v. They are often fitted with economizers that draw in unfiltered and un conditioned air during in between seasons to reduce heating and cooling power consumption.

Our recommendations for air conditioning include:

i. Size for the load, and not oversize so humidity control will be better;
ii. Mount the air handler inside the space to eliminate external ducting that can draw in contaminants;
iii. Integrate upgraded return air filtration into the air handler;
iv. Have staged cooling and heating to reduce cycling and maintain less fluctuations in temperature and humidity;
v. Either use water cooled condensers if treated water is available, or external fan forced devices. These should be configured to suit the situation. For example, head pressure control, pulse cleaning of coil in severe dust situations;
vi. Have stainless drain pans with generous slopes to ensure condensate drains effectively and prevents mold from forming.
vii. Eliminate economizer function unless air comes through a filtration system to suit the site goals.
viii. Establish a Class BX with Temperature Limits 18-27 °C, Control Point Tolerance +/- 2 °C, Max rate of change +/- 5 °C/hr, Maximum moisture content 0.012 kg/kg dry air, 2 stage cooling as a minimum.

5.0 Design Approach- Particulates

Section 5 Airborne Contaminants- Solids of ISA S71.04-1985 suggests that “every effort should be made to minimize exposure to airborne particulates”. The level required will be dependent on the nature of the contaminants and the impact on the equipment. Properties that effect equipment include:

- Magnetic permeability where particles are magnetic
- Thermal conductivity effects where heat rejection components become insulated with build up
- Electrical conductivity of dusts such as metals, carbon blacks etc
- Adhesiveness of contaminant that could coat the surface
- Chemical reactivity such as salts, ash etc
- Abrasiveness of material such as mineral ores, silica etc that will get between moving and contact parts,

Table 2 of Section 5 Classifies particulates as follows:

Classification of Airborne Contaminants

		Severity Level. Concentration measured in µg/m³			
Particle Size	Class	1	2	3	X
>1mm	SA	< 1000	< 5000	< 10000	≥10000
100 µm to 1000 µm	SB	< 500	< 3000	< 5000	≥ 5000
1 µm to 100 µm	SC	< 70	< 200	< 350	≥350
< 1µm	SD	< 70	< 200	< 350	≥ 350

The situation we are dealing with can be likened to having a glass of Coke and remove the color by adding clear liquid by dilution, with an occasional shot of Coke added. The temperature of the glass of coke must also be maintained.

To demonstrate a typical situation, we will take an example of a standard size MCC room, 100’ long x 30’ wide x 20’ high. Volume is 60,000 ft³, or 1700 m³.

Assume outside contaminants are dust to 10 mg/m³. This is a dusty industrial site that is below OSHA Standard 1910.1000 Table Z3- Acceptable Level for “Inert and Nuisance Dust”- Ref 3, which established a limit of 15 mg/m³.

Note: We are talking these levels as typical and we are not addressing respirable silica issues where the allowable levels are much less.

Particulate: There will be 17 grams of dust, or .5 ozs in the space. If we assume a flow of 5% of the room volume per minute keep the room clean, or 85 m³/min, we will have to remove 854 mg/min = 1230 grams per day = 38 oz/day.

5.1 Pressurization

For non hazardous locations, we suggest that a design figure of at least 5% of the room volume be used for filtration system sizing, or at least 30 cfm per person for normal metabolism. Ideally, this should be dynamically controlled by a pressure transducer and a speed control device.

If the area is hazardous, a complete design procedure is set out in NFPA Handbooks, and these need to be followed.

There are a lot of advantages with having the fan speed controlled by the room pressure. Consider:

- It allows filters and fans to be oversized, thus allowing for maximizing filter life;
- It allows the benefits of a room sealing program to be observed immediately;
- It is more energy efficient;
- Commonality of equipment where one size system can be applied in multiple applications.

The important thing about the pressurization is that it needs to be well filtered, and the filters maintained.

From Table 2 Section 5 of ISA-S71.04-1985, on a mass ratio, the sub 100 µm size particles represent approximately 8% of the total mass of particles in a Severity Level 1 area. Typically the smaller size particles will bypass seals etc far easier than the larger ones, so filtration efficiency must be established to effectively remove all particulates.

If there is any leakage, filter bypass, spent media, or wind induced outside air entrance, the low level of contamination required will not be met.

Our recommendations for a space should be to operate within Severity Level 1 by Table 2. For pressurization, we suggest:

i. Flow of 5% of the room volume per minute;
ii. Add heating upstream of intake filters if ambient air is likely to fall below 35-40 °F. (2- 4 °C)
iii. Evaluate whether the dust loading is severe and reverse air pulse cleaning is justified;
iv. Recommend full face seal filters to reduce bypass;
v. Use variable speed fan controls to maintain a set pressure, rather than a set volume of outside air.

5.2 Re-circulation

This area should be addressed to act as a polishing filter for the space.
By filtering the air that is inside the space, the following benefits can be expected:

i. Lower energy through reduced outside air;
ii. Increased stability of temperature and humidity;
iii. Lower contaminant levels;
iv. Forgiveness for real world situations where personnel open and close doors and allow contaminants to enter the protected environment.

Re-circulation devices should be fitted with filters that allow:

i. 5-10% of the room volume per minute circulation rate. 5% on closed rooms, 10% on open rooms;
ii. Particulate filtration efficiency to be at least MERV 11, ideally MERV 14;
iii. Ideally integrated into an internally mounted climate control unit;

6.0 Design Approach- Gas Phase

Corrosive gases such as chlorine, hydrogen sulfide, sulfur dioxide etc. may be at levels where their removal is deemed necessary. They react with metals such as copper and silver and cause failures with electrical equipment. In much the same way as particulates, providing a clean environment inside a space typically involves a combination of pressurization and re-circulation filtration.

To continue with the particulate example, we will use the same room, namely an MCC room, 100’ long x 30’ wide x 20’ high. Volume is 60,000 ft³, or 1700 m³. Assume n outside concentration of 2 ppm H2S.

The conversion from parts per million, PPM, to mg/m³ involves multiplying by a factor of 1.4 for H_2S. So 2 ppm becomes 2.8 mg/m³. The room will have 1700 x 2 x 1.4= 4.76 grams of H_2S inside. If we arbitrarily take a gas phase removal media and give it 20% removal capacity by weight, this amount of H_2S will require 23.8 grams of media. The removal capacity by weight of 20% is "in the range" of capacity as published by various manufacturers.

If pressurization is used and 5% of the room volume per minute is used to clean the room, the filtration system will be required to remove:
85 m³/min (3,000 cfm) x 1440 min/day x 2.8 mg/m³ = 342,720 mg/day = 343 grams of H_2S per day. At 20% capacity by weight, this will consume 1715 grams/day of media.

The operating costs escalate with higher levels of pressurization. There will be heating/cooling increases and media consumption with gas phase filtration. Add to this the effect of temperature and humidity, and it is clear that pressurization needs to be "managed". There is a significant cost associated with bringing in outside air where gas phase is required.

Table 3 of ISA S71.04-1985 provides a Classification Table for contaminants and their severity level.

Severity Level		G1- Mild	G2- Moderate	G3- Harsh	GX- Severe
Copper reactivity level in Angstroms		< 300	< 1000	< 2000	≥ 2000
Contaminant	Gas				
Group A	H2S	< 3	< 10	< 50	≥50
	SO2, SO3	< 10	< 100	< 300	≥300
	Cl2	< 1	< 2	< 10	≥10
	NOx	< 50	< 125	< 1250	≥1250
Group B	HF	< 1	< 2	< 10	≥10
	NH3	< 500	< 10000	< 25000	≥ 25000
	O3	< 2	< 25	< 100	≥100

Notes: 1. Copper reactivity is measured in Angstroms after 1 month exposure in the space
2. Gas concentration figures are given in parts per billion
3. Group A contaminants often occur in the same situation and the levels reflect some synergistic effects between the gases.
4. These figures are "believed to be approximate" providing the relative humidity is less than 50%.
5. The corrosion level can be expected to increase for each 10% rise in RH above 50%, and also for each rate of change of RH greater than 6% per hour.

Note: We have reservations about this Table. The Standard states that "The gas concentration levels shown below are provided for reference purposes. They are believed to approximate the Copper Reactivity Levels stated above, providing the relative humidity is less that 50%". The table should be used as a guide and we encourage spaces to be Classified before the installation, and monitored after- that is the true test of the room condition. This is the only way to determine the synergistic effects of gases, temperature and humidity. It is very difficult to even measure the low levels suggested for G1.

We also do **not** agree with the high acceptable levels of ammonia. This gas is very reactive with copper, and other metals, and therefore the levels for G1 should be much lower, certainly less than 50 ppb.

As ammonia requires a "reduction" chemistry for removal, as opposed to "oxidation", this gas may need a dedicated media stage.

There are obvious contradictions in the S71.01 and 04 standards, the most obvious being the connection of RH to severity levels. Our recommendation is to follow the recommendations as laid out in Section 4- Air Conditioning. Most MCC rooms have high sensible load and therefore humidity is unlikely to be an issue.

The significance of the Classifications by the Standard are:

G1- Mild, Corrosion is not a factor in determining equipment reliability.

G2- Moderate- The effects of corrosion will be measurable and could be a factor in determining equipment reliability.

G3- Harsh- An environment where there is a high probability that corrosion attack will occur.

GX- Severe- An environment that only specially designed and packaged equipment could survive.

6.1 Pressurization

All our recommendations are based on well sealed rooms in a good state of repair. For light to no traffic, such as locked MCC rooms, we would recommend approximately 1 to 2% of the space volume per minute of outside air.

For high traffic, we suggest 2 to 3% of the volume per minute. In the case of small occupied enclosures, at least 30 cfm should be provided for natural ventilation per person.

The important thing about the pressurization is that it needs to be well filtered, and the filters maintained.

As an example, a gas phase filter with 99% removal efficiency of H_2S will have a delivery condition, based on 2 ppm outside, of 20 ppb. By Table 3 of ISA S71.04-1985 this delivery condition would be considered G3, or "Harsh". Clearly the room will never get to Class G1, "Mild" if the air coming in is at G3 Level. (G1 is stated as requiring less than 3 ppb and G3 is between 10 and 50 ppb of H2S).

This also raises a question about module type systems for outside pressurization, and we do not recommend this approach at industrial sites. In Section 1.0 the concept of superficial residence time was raised. This is the time it takes for air being filtered to pass through a given volume of media.

It is calculated as follows: Rt in seconds= (media in ft³) x 60/(airflow in cfm). A general "Rule of Thumb" for better than 90% removal efficiency is to have at least 0.1 seconds residence time. There will be variations based on temperature, humidity, pressure, concentration etc., but we need some base math.

It is common sense that a deep bed with several seconds residence time is going to out-perform a typical module system with less than 0.3 seconds residence time. In addition, a bulk fill system will exhibit the lowest cost per unit of contaminant removed, be less environmentally damaging because only the media and not disposable plastic modules which will be in a landfill for hundreds of years.

Media utilization will also be a factor. Once bypass starts to occur, media should be replaced. A bulk fill system with 2 seconds residence time will be good for "1.9 seconds, or have a utilization factor of 95%. A module system with 0.3 seconds will only have a 67% utilization factor.

A factor that needs to be taken into account with gas phase filtration is the effect of temperature on a chemical reaction. Many contaminants are removed by a chemical reaction once retained on a surface such as carbon or alumina. The reaction is far more effective if water vapor is available above freezing.

To our knowledge, no independent testing has been done on the rate of reaction, the change in media residence time required, the effect of humidity or the challenge concentration at low temperatures. It is reasonable to assume that the lower the temperature, the lower the reaction rate. Some reactions are exothermic, but at normal challenge levels it is unlikely that enough heat would be generated to sustain the reaction chemistry.

With gas phase filtration systems, it is often feasible to mix return air from the space with the outside air to temper the outside air, and possibly eliminate the recommendation to add heat. This blending also acts to polish the room return air and further lower contaminant levels.

If cold air is introduced directly into an occupied room, personnel will find a way to stop that flow unless it is mixed!

Our recommendations for pressurization are:

vi. 1 to 2% of the room volume per minute for closed or light traffic rooms;
vii. 2 to 3% of the room volume per minute for traffic areas;
viii. Add heating upstream of intake filters if ambient air is likely to fall below 35-40 °F. (2- 4 °C)
ix. Design media bed life to exceed 12 months service life with full removal capacity, and if contaminant levels are know a figure of 15 months should be the design target;
x. Evaluate whether return air from the space is an option to remove any contaminants that may enter through doors etc;

As with particulates, we recommend variable speed controls on the pressurization fan.

6.2 Re-circulation

This area should be addressed to act as a polishing filter for the space. The example given under 5.0 and 6.0 demonstrates very clearly how low the total amount of contaminants exists on a mass basis within a contaminated space. Logically filtering those contaminants rather than flushing will result in far lower operating costs.

Importantly, the model we use for analyzing a space demonstrates that return air filtration does not have to be extremely high efficiency to have an order of magnitude difference on the room cleanliness level. Compare this with an outside pressurization system where the efficiency drops below 99%- it could well make the situation worse in the space. Certainly running a gas phase scrubber with spent media is a disaster.

By filtering the air that is inside the space, the following benefits can be expected:

- v. Lower energy through reduced outside air;
- vi. Increased stability of temperature and humidity;
- vii. Lower media consumption;
- viii. Lower contaminant levels;

Our recommendations for re-circulation filtration are:

- iv. 3-5% of the room volume per minute for closed or light traffic rooms;
- v. 5-10% of the room volume per minute for traffic areas;
- vi. Design gas phase media life to exceed 12 months based on G3 contaminant levels (lowest range);
- vii. Particulate filtration efficiency to be at least MERV 11, ideally MERV 14;
- viii. Ideally integrated into an internally mounted climate control unit;

7.0 Modeling Examples

We have taken the room discussed in 5.0 and 6.0 and will demonstrate the impact of various factors. We are taking the outside ambient as having “100” contamination units.

Site ID	Typical Room	
Variable	**Description**	**Value**
C	outside air contaminant concentration, units	100
Q_1	intake air quantity into room, cfm	1200
η_1	intake filter efficiency, %	99
Q_L	air leakage around intake filter, cfm	12.00
Q_R	recirculation filter airflow, cfm	3000
η_R	recirculation filter efficiency, %	60
Q_W	wind quantity infiltration into room, cfm	12.00

Result

Pen	ratio of outside contamination to inside	0.01
x	inside air contaminant concentration, units	1.20

Input Table	
Space volume, ft3	60,000
Pressurization air, % volume per minute	2
Re-circulation air, % volume per minute	5
Wind entrance, % volume per minute	1
Filter bypass, % outside air per minute	1

This is a typical set up with 2% outside air pressurization, 5% re-circulation with some wind entrance and filter bypass. Intake filter efficiency is 99% and re-circulation 60%. The air inside has 98.8% of the contaminants removed.

Site ID	Typical Room	
Variable	**Description**	**Value**
C	outside air contaminant concentration, units	100
Q_1	intake air quantity into room, cfm	1200
η_1	intake filter efficiency, %	99
Q_L	air leakage around intake filter, cfm	12.00
Q_R	recirculation filter airflow, cfm	0
η_R	recirculation filter efficiency, %	60
Q_W	wind quantity infiltration into room, cfm	12.00

Result

Pen	ratio of outside contamination to inside	0.03
x	inside air contaminant concentration, units	2.99

Input Table	
Space volume, ft3	60,000
Pressurization air, % volume per minute	2
Re-circulation air, % volume per minute	0
Wind entrance, % volume per minute	1
Filter bypass, % outside air per minute	1

This is the same room without any re-circulation filtration. The level is still good at 97% of the contaminants removed.

Site ID	Typical Room	
Variable	**Description**	**Value**
C	outside air contaminant concentration, units	100
Q_1	intake air quantity into room, cfm	600
η_1	intake filter efficiency on 1 micron, %	90
Q_L	air leakage around intake filter, cfm	6.00
Q_R	recirculation filter airflow, cfm	0
η_R	recirculation filter efficiency on 1 micron, %	60
Q_W	wind quantity infiltration into room, cfm	6.00

Result

Pen	ratio of outside contamination to inside	0.12
x	inside air contaminant concentration, units	11.90

Input Table

Space volume, ft3	60000
Pressurization air, % volume per minute	1
Re-circulation air, % volume per minute	0
Wind entrance, % volume per minute	1
Filter bypass, % outside air per minute	1

This example shows what happens when the outside filtration efficiency drops to 90%. The inside level goes up dramatically.

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Site ID	Typical Room	

Variable	Description	Value
C	outside air contaminant concentration, units	100
Q_1	intake air quantity into room, cfm	600
η_1	intake filter efficiency on 1 micron, %	90
Q_L	air leakage around intake filter, cfm	6.00
Q_R	recirculation filter airflow, cfm	3000
η_R	recirculation filter efficiency on 1 micron, %	60
Q_W	wind quantity infiltration into room, cfm	6.00

Result

Pen	ratio of outside contamination to inside	0.03
x	inside air contaminant concentration, units	2.98

Input Table

Space volume, ft3	60000
Pressurization air, % volume per minute	1
Re-circulation air, % volume per minute	5
Wind entrance, % volume per minute	1
Filter bypass, % outside air per minute	1

This is the same room with re-circulation filtration. It covers a lot of issues in service from pressurization only systems. The level drops down to 3% of the outside level of contamination.

Obviously there are many scenarios to be looked at, but we strongly recommend that the key elements be:

1. Pressurization with some very well cleaned (and heated air when necessary) air from a system that is maintained;
2. Re-circulation filtration to mop up any spills, leaks, ingress that normally would be removed by flushing only;
3. Air conditioning and climate control housed within the space.
4. Follow the recommendations according to the focus contaminant, either particulate or gas phase.