HVAC Design Considerations for Corrosive Environments

Course Content

PART I Overview of Corrosion

Expressed simply, corrosion is the deterioration of metal by reaction with its environment. More specifically in context with air borne contamination, the corrosion is defined as the deterioration of metal due to the presence of acid gases in tandem with elevated humidity and temperatures.

UNDERSTANDING PROBLEM

In process sensitive areas like server rooms, control rooms, and data centers, large quantity of microprocessor-based equipment is present. Given the harsh climates and diverse industrial environments, these sensitive areas are exposed to multiple threats, such as fire, dust particles, gaseous contamination, temperature and humidity.

To an extent, the HVAC design is meeting the challenge posed by fire, humidity, temperature and dust particulate contamination. Unfortunately, the potential damage to electronic equipment caused by the corrosive effects of gaseous contaminants has been largely ignored. *Since the problem of corrosion is primarily due to air borne molecular contaminants (AMC), proper design guidelines mandate the removal of all such contaminants from the air stream.* Not all the locations are same; the ambient conditions need to be carefully assessed before deciding on the HVAC design.

In today's business environment, a company's dependence on its information & data processing systems is un- debatable. Corrosive gasses can damage these systems that can have crippling effects both on cost and productivity. The common fault occurrences could be:

- ✓ Erroneous information
- ✓ Interrupted operations
- ✓ Sporadic electrical hiccups
- ✓ Ghost signals

- ✓ Lost data
- ✓ Computing or controlling errors
- ✓ Loss of ferromagnetism (stored information) on disc drives
- ✓ Mechanical failure (head crashes, wear) can occur on data tracks
- ✓ Damage to pin connectors on circuit boards, IC plug-in sockets and wire wrap connections
- ✓ Brittle connections and electrical systems overheat
- ✓ Disruption of electric current & circuit failure

In extreme cases, corrosion may lead to prolonged disruption or even complete shutdown of an entire process operation. Replacing damaged electronic components can substantially increase the operational costs.

To preclude any potential damage to electronic equipment and to avoid any acrimonious debates over warranty coverage, and, more importantly, to ensure there is no loss of system's integrity in the first place, the sensitive areas should be protected by effective air filtration systems.

The severity of the environment (i.e., humidity, temperature, types and levels of gases) will determine the speed of failure. The importance of knowing and preventing corrosion is thus very important.

HOW CORROSION OCCURS

All the metals have specific relative electrical potential. When metals of different electrical potential are in contact in the presence of moisture, a low-energy electric current flow from the metal having high (least noble) position in the galvanic series to the one having the lower (most noble) position. This phenomenon, called galvanic action, is a direct contributor to the material degradation, or corrosion, of metals. Moisture in air or humidity is conduit to corrosion.

ROOT CAUSES

The principal cause of corrosion is elevated humidity and/or temperatures in the presence of contaminant gases. These conditions alone or in combination, tend to accelerate the natural corrosion process in metals and electronic chips.

Humidity: Moisture in air can be considered the lifeblood of galvanic corrosion. A galvanic corrosion cell requires an electrolyte or current carrying media, to reach a dynamic state. The electrolyte can be water or any water-soluble substance with good conducting properties. Moisture in the air is one such electrolyte. Humid air contaminated with corrosive gasses further accelerates the corrosion rate as the air's current carrying potential increases.

Temperature: Chemical reactions in general are temperature sensitive, with increased temperature normally resulting in a faster reaction rate. It has been established that corrosion is essentially chemical in nature: its severity will also be influenced by temperature. This being the case in this instance, the corrosion rate of control equipment increases with a rise in temperature. By strictly controlling temperature and humidity, the conditions favorable to corrosion can be diminished. This represents one essential component of corrosion control.

Corrosive Gases: Not all gases cause corrosion. Specifically, we are concerned with three types of gases:

1. Acidic gases, such as hydrogen sulfide, sulfur oxides, chlorine, hydrogen fluoride (HF) and nitrogen oxides;
2. Caustic gases, such as ammonia;
3. Oxidizing gases, such as ozone

Of the gases that can cause corrosion, the acidic gases are typically the most harmful. For instance, it takes only 10 parts per billion (ppb) of chlorine to inflict the same amount of damage as 25,000 ppb of ammonia.

PART II- Identification of Potentially Corrosive Environments

A corrosive environment must be clearly identified and understood before proper treatment is selected.

The corrosive contaminants may be due to saline coastal environment, large processing facilities (like refinery, P&C plants, fertilizers, treatment facilities etc.), heavy industrial production areas (metal & mining, paper & pulp etc), auto emissions and power generation facilities. Specific sources and nature of outdoor contamination in the immediate vicinity of a building must be reviewed thoroughly.

Within a building, gases can be produced by cleaning agents, cigarette smoke, process operations and data center printers. Internally in manufacturing plants, corrosive gases may be result of process chemicals or the typical industrial processed employed in manufacturing activities for instance in semiconductor chip facility. In some indoor environments such as swimming pool areas and water treatment facilities can also produce corrosive atmospheres

Depending upon the location of a building's supply-air intake, the HVAC system may be drawing in diesel exhaust fumes from loading docks, raising the level of gaseous contaminants in the building.

The local weather conditions play a major role in concentrating or dispersing external gaseous contaminants. Temperature inversions can trap pollutants, producing a serious air pollution problem.

Potentially corrosive outdoor environments include areas adjacent to the seacoast, industrial sites, heavily populated urban areas, some rural locations, or combinations of any of these environments.

1) Coastal/Marine

Majority of large industry, power and P&C projects are emerging in coastal areas. This leads to an increased number of air conditioning applications located in potentially corrosive environments.

Coastal or marine environments are characterized by the abundance of sodium chloride (salt), which is carried by sea spray, mist or fog. Most importantly, this salt water can be carried as far away as 5 miles from the coast. Even if the plant is at a substantial distance from the ocean, corrosion from salt-water contamination can still occur if the equipment is not properly protected.

Line-of-sight distance from the ocean, prevailing wind direction, relative humidity, wet/dry time, and coil temperature will determine the severity of corrosion potential in the coastal environment.

2) Industrial

Industrial activity particularly the mechanical and process plants have host of diverse environment conditions with the potential to produce various air-borne emissions. Sulfur and nitrogen oxide contaminants are most common. Other contaminants may include ammonia, acid fumes, and hydrocarbons depending on the type of manufacturing processes.

The captive power generation involving coal and fuel oils release sulfur oxides (SO_x) and nitrogen oxides (NO_x) into the atmosphere. These gases accumulate in the atmosphere and return to the ground in the form of acid rain or low pH dew.

Not only are industrial emissions potentially corrosive, many industrial dust particles can be laden with harmful metal oxides, chlorides, sulfates, sulfuric acid, carbon, and carbon compounds. These particles, in the presence of oxygen, water, or high humidity environments can be highly corrosive.

INDUSTRIAL PLANT	ANTICIPATED GASEOUS CONTAMINANTS	
Aluminum Plants	Chlorine	Cl_2
	Hydrogen Chloride	HCl
	Hypochlorous Acid	HOCl
	Hydrogen Fluoride	HF
	Oxides of Sulphur	SO_x
	Oxides of Nitrogen	NO_x
	Hydrocarbons	C_xH_x

INDUSTRIAL PLANT	ANTICIPATED GASEOUS CONTAMINANTS	
Fertilizer Plants	Ammonia	NH_3
	Hydrogen Fluoride	HF
	Hydrocarbons	C_xH_x
Petroleum & Chemical Plants	Hydrogen Sulphide	H_2S
	Oxides of Sulphur	SO_x
	Oxides of Nitrogen	NO_x
	Hydrocarbons	C_xH_x
	Organics	*
Mining & Metallurgy	Oxides of Sulphur	SO_x
	Oxides of Nitrogen	NO_x
Power Generation	Oxides of Sulphur	SO_x
	Oxides of Nitrogen	NO_x
	Hydrocarbons	C_xH_x
	Organics	*
Paper & Pulp Manufacturing	Chlorine	Cl_2
	Hydrogen Chloride	HCl
	Hypochlorous Acid	HOCl
	Hydrogen Sulphide	H_2S
	Oxides of Sulphur	SO_x
	Oxides of Nitrogen	NO_x
	Organics	*
Sewage Treatment	Hydrogen Sulphide	H_2S
	Ammonia	NH_3
	Hydrocarbons	C_xH_x
	Organics	*

INDUSTRIAL PLANT	ANTICIPATED GASEOUS CONTAMINANTS	
Steel Plants	Hydrogen Chloride	HCl
	Hydrogen Fluoride	HF
	Hydrogen Sulphide	H_2S
	Oxides of Sulphur	SO_x
	Oxides of Nitrogen	NO_x

3) Combination Marine/Industrial

Salt-laden seawater mist, combined with the harmful emissions of an industrial environment, poses a severe threat. The combined effects of salt mist and industrial emissions can accelerate corrosion. This environment requires superior corrosion resistant properties for air-conditioning components to maintain the optimum level of product quality.

4) Urban

Highly populated areas generally have high levels of automobile emissions and increased rates of building heating fuel combustion. Both conditions elevate sulfur oxide (So_x) and nitrogen oxide (NO_x) concentrations. Corrosion severity in this environment is a function of the pollution levels, which in turn depend on several factors including population density for the area.

Any HVAC equipment installed immediately adjacent to diesel exhaust, incinerator discharge stacks, fuel burning boiler stacks, or areas exposed to fossil fuel combustion emissions should be considered an industrial application.

5) Rural

Rural environments may contain high levels of ammonia and nitrogen contamination from animal excrement, fertilizers, and high concentrations of diesel exhaust. These environments should be handled much like industrial applications.

PART III- Design Standards (Environment Classification)

The Instrument Society of America (ISA) Standard recognizes the potential problem of corrosive gases. This standard describes the type concentration of airborne contaminants and characterizes the environments in terms of their overall corrosion potential.

Four levels of corrosion severity have been established by ISA-S7 1.04 (see Table below). The optimum severity level is G1-Mild. At this level, corrosion is not a factor in determining equipment reliability. As the corrosive potential of an environment increases, the severity level will be classified as G2, G3 and GX (the most severe).

The effects of humidity and temperature are also quantified in this standard. High or variable relative humidity and elevated temperatures may cause the acceleration of corrosion by gaseous contaminants. Relative humidity of less than 50 percent is specified by the standard.

Environment classification is applicable for both the indoor protected equipment and the outdoor or ambient environment. Reactive Monitoring Coupons are used to classify the environment in question based on “ISA-S71.04, Environment Classification for Process Control Equipment: Airborne Contaminants.”

The ISA provides the general guidelines of permissible limits of contaminants in space and classifies the environment into 4 broader categories.

Parameters	**G-1 Benign**	**G-2 moderate**	**G-3 Harsh**	**G-4 Severe**
H_2S	< 3	< 10	< 50	>50
SO_2	< 10	< 100	< 300	> 300
Cl_2	< 1	< 2	< 10	> 10
NO_x	< 50	< 125	< 1250	> 125
T (°C)	18 – 27	18 – 27	Not a constraint	Not a constraint
RH (%)	40 - 55	< 65	Not a constraint	Not a constraint

Benign G-1: An environment sufficiently well controlled so that corrosion is not a factor in determining equipment reliability. These are locations where both temperature and humidity is controlled with closer tolerances. (Typically for control rooms, rack rooms, technical services and laboratories)

Moderate G-2: An environment in which the effects of corrosion are measurable and will effect the equipment to various degrees. These are locations where air temperature is controlled but relative humidity limits are little flexible of not exceeding 65%. (Typically for motor control rooms, switchgear rooms and electrical substations)

Harsh G-3: An environment defined so that only specifically designed and packaged equipment would be expected to survive. This is typically of most ambient environment in chemical facilities.

Severe G-4: Very harsh generally never a recommended option.

The process equipment manufacturers provide necessary information on the class category their equipment is suited for and the filtration supplier provides the chemical filtration equipment to achieve the classification demanded by the process equipment supplier.

Higher the classification category of the process equipment, higher will be the equipment cost and lowest is the cost of treatment.

3 Steps identified for Corrosion Prevention

1) *Environment Assessment*

   The Environmental Assessment is required to characterize the reactive potential of an environment. As part of the assessment, ‘Environmental Reactivity Coupons’ (ERC) are used to determine the types and levels of molecular contaminants present in the air. This assessment strategy is a reliable and cost-effective to ascertain the type of AMC control measures needed for the system.

   By the use of “reactivity monitoring,” a quantitative measure of corrosion potential can be established.

   Reactivity monitoring involves placing strips of copper metal, called ‘corrosion coupons’, in the areas of concern. The coupons are left exposed to environment for a period of 30 days, and then analyzed for oxidation film and species of contaminants in a qualified laboratory. The corrosion formation is measured in angstroms. This data is used to determine the severity level of the environment that indicate the potential damage that corrosive gases in the air could cause to electronic contacts.

2) *Environment Control*

Wide range of chemical filtration media is available for control of virtually any AMC challenge. These media are the heart of the dry-chemical systems.

The new generation of filter media combines both the chemical and the particulate filtration. The chemical media present in the filter can absorb the desired gasses. Virtually all gasses such as ammonia, chlorine, methylamine, SO_x, NO_x, Ozone, HCl, and HF could be adsorbed by chemical filtration. The composition of chemical media in filtration is decided upon by the concentration of gasses present and that needs to be removed. This is usually a patented design of suppliers.

An activated carbon filters such, as charcoal filters are suitable for removing VOCs and other high molecular weight compounds. The disadvantage with this is that they are highly imflammable.

3) *Environment Monitoring*

Environmental Reactivity Monitor (ERM) provides the continuous, real-time data necessary to identify AMC and to verify the performance of chemical filters.

ERM usually consists of a quartz crystal sensor used to measure the mass accumulation of the corrosive film that results from the reaction of contaminants with the metals. The mass increase is described in terms of the corrosion film thickness measured in Angstroms (Å). This highly sensitive method of measurement will indicate the reactivity level of an environment with contaminant levels at or less than one part per billion (1 ppb). The recorded readings classify the environment to

- Pure: Contamination does not pose a measurable threat to processes.
- Clean: Contamination is measurable, but does not pose an immediate threat to processes.
- Moderate: Contamination is slightly above the levels considered acceptable for processes.
- Harsh: Contamination is above the levels considered acceptable for processes
- Severe: Contamination poses an immediate threat to processes.

PART IV- HVAC Design Considerations

The technical knowledge and equipment necessary to build controlled environments that would meet the standards established by the Instrument Society of America (ISA) on process control equipment's shall require considerations to 4 vital considerations on HVAC design.

1) ***Relative Humidity***: To be less than 50% with close control of deviations no greater than 6% per hour.

2) ***Temperature:*** To be maintained at the lowest level possible consistent with personnel comfort, typically 72°F, 22°C (±2°F, ±1-2°C).

3) ***Gas-phase Purification:*** To maintain gas concentrations to levels acceptable for a G-1Class environment as defined by the ISA (i.e., H_2 S < 3ppb, SO_2 < 10 ppb, NO_x < 50 ppb).

4) ***Room Air Pressurization:*** To be 0.05"wg to 0.1"wg at a rate of 1 to 3 air changes per hour (2-5% of gross room volume).

REMOVAL OF CORROSIVE GASSES (Air Purification)

The corrosive environments require special filtration in eliminating gaseous contaminants in the fresh make up and/or re-circulating air streams.

The petroleum refinery for instance, using hydrocarbons to produce primary and intermediate petrochemical materials, which are subsequently converted to plastics, synthetic fibers, and synthetic rubber; typically release hydrogen sulfide (H_2S), chlorine (Cl_2), sulfur dioxide (SO_2), and nitric oxide (NO_2) — all highly corrosive gases. These gaseous contaminants in the air can create an atmosphere hostile to electronic/electric equipment. Even quantities of a few parts per billion will have severe consequences.

Corrosion of contacts and components on circuit boards accounts for approximately 40% of all equipment failures in such industrial facilities.

Corrosive agents do not only come in the form of gaseous contaminants. Particulate matter can be equally corrosive. Minute particles of airborne dust can settle upon metallic portions of contact surfaces. If the dust is hygroscopic, i.e. water adsorbing; it will be attracted to the metal surface and gets accumulated to form electrolyte films. Non-hygroscopic dusts having high surface areas adsorb gaseous contaminants. This too can actively contribute to corrosion by concentrating reactive contaminants on contact surfaces.

Since the problem of corrosion is caused by the reaction of air borne impurities on metals, proper design guidelines mandate the removal of all such contaminants from the air stream. P & C projects, aware of the potential risks and costs associated with inadequate corrosion control, made plans early on to incorporate chemical filtration into the HVAC designs.

AIR FILTRATION

To better understand and appreciate the capabilities of air filtering systems, we must examine what contamination needs to be cleaned. There are three types of airborne contaminants: liquids, solids and gases.

The two most common techniques available to deal with low-level airborne contamination are

1) Particle removal filtration, such as mechanical filters and electronic air cleaners, and
2) Gas-phase (dry scrubbing) filtration

- ✓ Particulate filters vary in their ability to remove particulate matter, depending upon the filter's material composition (typically cellulose, fabric, non-woven cotton, synthetic blend and glass-fiber materials). Most conventional air conditioning systems come with low- to mid-efficiency filters. These are essentially provided to protect the internals of HVAC equipment and are not meant for eliminating biological or chemical contaminants. The efficiency of these filters is typically 20 to 65 percent.

- ✓ Electronic air cleaners, another form of particulate filtration, use the principle of electrostatic precipitation. Particles are charged and then captured on collecting plates. They are relatively efficient against particles of sub-micron size, but require regular cleaning. The electronic air cleaners consists of an ionizing section; alternatively spaced grounded struts & charging ionizing wires and collecting section; alternatively grounded and charged plates with insulators located out of air stream.

- ✓ High efficiency particulate air (HEPA) filtration is employed where cleanliness requirements is very stringent. A 99.97% efficient HEPA filter is designed to remove microbial and biological contaminants and can trap particles down to 1-micron size.
- ✓ The standard engineering practices suggest:
  - Transfer fan (100% recirculation) systems should use pleated 25-30% efficiency prefilters
  - System employing outside air and return air should have a minimum efficiency of 95% (AHSRAE)
  - 100% make up air systems to clean areas should have HEPA filters on the fan discharge and 95% (ASHARE) bag filers on the inlet

The principle references for filter specifications and tests can be found in:

ANSI –N101.1	“Efficiency testing of air cleaning systems containing devices for removal of particles”
ANSI/UL 586	“Test Performance of High Efficiency Particulate Air Filter Units”
ANSI/UL 900	“Air Filter Units”
ASHRAE – 52.1	“Method of Testing Air Cleaning Devices used in general ventilation for removing particulate matter”
ASTM Part 46	“Filteration”
ARI 850	“ Air Filtration….”

Gas-phase Filtration

Traditional particulate filters, found in most conventional HVAC systems remove dust and dirt from the make up or re-circulation air.

And while HEPA filters shall trap biological contaminants or spores, these are ineffective against chlorine gas, H_2S and other corrosive gaseous contaminants.

Complete protection requires multiple stages of filtration.

Gas-phase air filtration employs adsorbent-impregnated media to remove chemical gases from the air. Gaseous contaminants, both externally and internally generated, can be effectively removed down to the low parts per billion levels through the process of adsorption, and/or chemical reactions. Oftentimes, these systems are used in tandem with particle removal filters or HEPA filters for complete protection.

Adsorption is the most common form of gas-phase filtration. The material most often used is carbon (activated and/or impregnated charcoal). Carbon is a very effective gas-filtration media specifically for volatile organic compounds (VOC) due to its high porosity, large surface area presented to the airstreams and high removal capacity. The standard engineering practices require 8.8 lb (4.0 kg) of activated carbon per 2000 CFM (944 L/s) of airflow or in extreme cases it may be 12 lb (5.4 kg) of activated carbon per 500 CFM (236 L/s) of airflow.

Activated carbon, is often used in conjunction with activated alumina impregnated with potassium permanganate filtration where called for assured occupant safety and to protect vital processes. The other chemical filtration media composition may be selected, which is dependent on the nature of the contaminant present in the vicinity. Chemical filtration activated materials are usually manufacturer’s trademark and the suppliers like ‘Purofil’ need to be consulted for appropriate filtration technology specific to the industry.

Gas-phase filtration systems typically have gas removal efficiencies of 99.95 percent. To reach this level of efficiency, a system may employ multiple media beds - taking advantage of the strengths of the media to target specific gases. The outdoor/ambient air classification is required to determine the type and filter bed thickness.

Dry Chemical Scrubbers

Dry Chemical Scrubbers (DBS) are utilized for areas exposed to very high levels of gaseous contaminants. The scrubbers are available to deliver G1-class air (as defined by the Instrument Society of America) and are typically suitable for any of the following industries:

- Mining & Drilling Operations
- Refineries and Petrochemical Plants
- Pulp & Paper Mills
- Waste Water Treatment Facilities

- Heavy Manufacturing, Pharmaceutical & Chemical Plants
- Semiconductor & Photo Film Manufacturing
- Various Other Corrosive Environs Coastal & Marine

The DBS is constructed of corrosion-resistant materials, making it suitable for installation outside of the space it is protecting. Systems are available from 700 CFM and higher, and are often custom built for specific applications.

Advantages of the DBS include:

- Multiple media stages for broad-spectrum removal of gases
- Offers high-efficiency gas removal at a low cost per CFM.
- Flexible system designs make it easy to meet specific pressurization requirements

Advanced designed DBS equipment comes with integral air monitor controller. The controller verifies the cleanliness of the scrubbers' discharge air, as well as the air within the controlled space. The readings are displayed on real time basis to check the performance of the system.

Determination of the bed-depth is dependent on:

- ✓ Indoor environment classification required
- ✓ Outdoor environment classification measured
- ✓ The gross volume of area to be protected
- ✓ Contaminant type for chemical media selection

The bed configurations can vary from one stage of 1.25" (30 mm) to 48" (1200 mm) bed depths in modules. The commercially available equipment configurations include:

- High-density scrubber, deep bed hopper style, providing counter flow
- Deep bed Air System providing various media stages
- Air Purification Unit, thin bed 3" (75mm) design, providing various media stages

In addition to the equipment the dry scrubbing chemical systems protect production personnel from toxic gas emissions. For instance, the production of silicon wafers in semiconductor industry exposes personnel to hazardous gases, such as diborane, silane and phosphine. Even in low concentrations, these gases are strong irritants to the eyes, skin and lungs.

Chronic exposure may pose serious health risks. Dry scrubbing systems remove these gases from re-circulation air and ensure controlled and safe work environment.

MAKE UP AIR AND BUILDING PRESSURIZATION

Typically many of the critical electronic room installations have their own dedicated air conditioning systems. These are supposedly controlled environments. While this is good design strategy, many of the installations rely purely on re-circulation system without paying much attention to pressurization. Without pressurization, gaseous contaminants can seep into these sensitive rooms through cracks in wall and ceiling joints, cable and utility penetrations, and spaces above drop ceilings and below raised floors.

Positive pressurization is the basis of assuring that uncontrolled and untreated air does not infiltrate the protected area. The ambient air used to provide the positive pressurization must be treated to ensure environment free of both the gases and particulates. The recommended minimum amount of positive pressurization gradient is 0.03” to 0.05” (~0.75 to 1.25mm) water column for clean room applications. This would normally equate to 3- 8% of gross room volume.

Optimizing the make up air requirement

Careful attention needs to be paid ‘not to’ over-pressurize the system.

With pressurization, the requirement for make up air and the treatment costs due to cooling /dehumidifying and chemical filtration also increases. The cost of treating the make up air shall be very high, particularly for the extreme ambient environment conditions.

The amount of outside air required is a function of

- Equipment exhausts and exhaust through toilets/kitchen/pantry/battery rooms etc.
- Leakage through pass through, conveyor openings, strip curtains, air locks, door under cuts etc
- Duct leakage, wall and ceiling leakages
- Level of positive pressurization required

- ASHRAE 62 ventilation guidelines on indoor air quality

The HVAC design must optimize the use of make up air and shall minimize the uncontrolled air leakages while maintaining the controlled ventilation.

Impact on Energy Use

Over pressurization is waste of energy that not only entails high capital costs but also increases the operating costs. Just to give an idea, one-inch water gauge pressure is equivalent to wind velocity of 4005 feet per minute (~45 miles/hr). Internally in a building this is equivalent to 5.19-lb/sqft force on glazing.

The makeup air requirements depend on the level of positive pressure required in the room. High positive pressure requirement require high makeup air quantities. With higher pressurization the leakage velocity, leakage rates and the processing costs shall also increase.

Leakage through the fixed openings should be restricted as much as possible. The amount of expected leakage can be calculated from the following:

$$\text{LEAKAGE IN C F M} = \sqrt{\text{Room Positive Pressure}} \times 4005$$

Assuming 0.05” wg,

Leakage = 0.223 x 4005

= 895 feet per minute

With a total of 2 square feet opening size

Leakage = 2 x 895 = 1800 CFM

Higher positive pressure of say 0.1” wg (2.5 mm) shall mean higher velocity pressure of 1266 fpm (~6.4 m/s). The amount of leakage for 2 square feet opening shall be 2532 CFM an increase of 40%. Higher the velocity pressure higher shall be the ex-filtration or the leakages.

Assuming an ASHARE design condition of 95°F DB/72°F WB (~35°C DB/22° C WB) and room conditions of 72°F DB/60°F WB (~22°C DB/15.5°C WB); ~50% RH, the enthalpy difference is 9.5 BTU/lb (~22 kJ/Kg) of air.

For 1800 CFM leakage: this corresponds to heat load of

= 1800 x 9.5 x 4.5

= 76950 BTU's/hr or 6.4 TR

For 2532CFM leakage: this corresponds to heat load of

= 2532 x 9.5 x 4.5

= 108234 BTU's/hr or 9.0 TR

Thus with extra pressurization; 9.0 -6.4 = 2.6 TR of additional refrigeration capacity need to be provided. Plus all the downstream equipment such as air-handlers, filter media, ducting & auxiliaries shall increase. This is an extra capital cost.

The recurring cost on energy shall be again of the order of 2.6 KWh @ 1KWh per TR of cooling load. Plus the replacement of activated carbon/chemical filtration media of higher size shall cost more.

In summary, the building positive pressure should be limited to 0.03" to 0.05" (~0.75 to 1.25mm). The high positive pressurization is inefficient and shall be considered only if called for by the safety and loss prevention advises on critical areas.

Air tightness of building shell

Positive pressurization can be maintained only if the sealing integrity of the building is maintained. The building should be air tight for low air leakage performance. There are areas with in the facility that require negative exhausts such as toilets, pantry, laboratory or battery room but these are controlled ventilation areas having fixed amount of exhaust. Uncontrolled leakages areas in the building are door undercuts; pass through, walls, ceilings and duct joints etc; that should be restricted as far as possible.

Remember a slogan:

"Build tight -ventilate right"

The building shall be pressurized to 0.03" to 0.05" wg (0.75 to 1.25mm) to achieve low capital costs, overall energy conservation and treatment costs on chemical filtration.

Additional thoughts on HVAC Specifications

To prevent the potential of corrosion, a proper selection and specification of HVAC equipments / materials is necessary in HVAC designs. Once corrosion starts to develop, a unit's capacity decreases rapidly resulting in reduced efficiency and increased energy consumption. In some conditions, the operating performance of unprotected coils can decrease by over 50% in less than 6 months.

Strict control of temperature and humidity diminishes the impact of corrosion. In addition, proper control instrumentation & logics, HVAC equipment protection, indoor air quality codes and generally accepted practices must be addressed.

In dealing with the corrosive environments, plant may be required to operate within an area where an explosive atmosphere may occur. Special precautions must be undertaken to ensure that the HVAC equipment itself does not provide a possible source of ignition to the atmosphere present.

HVAC equipment operating in corrosive environments needs special precautions.

- ✓ Ensure HVAC air-handling equipment casings are fabricated from galvanized sheet steel that is epoxy powder coated including all divider panels and motor mountings. All bolts, screws and fittings shall be stainless steel. Where the ambient environment is very harsh consider specifying all steel metal casings, components and fittings in 316-grade stainless steel

- ✓ Ensure all external exposed equipment located outdoors is provided with cathodic protection.

- ✓ Two major components in HVAC/R unit are the Condenser and Evaporator coils, which are comprised of copper tubes bonded with thin aluminum fins. The system efficiency depends on the cleanliness and integrity of these coils. When HVAC/R equipment is installed near coastal or industrial polluted areas, the coil's finned surfaces are exposed to salts and other corrosive substances as air passes through the coils during operation. The coils particularly the condenser coil, which is always located outdoors is rapidly attacked in marine and saline environments. Metallic impregnated polyurethane coatings should be applied to such applications. Other options include providing electro-tinned coils or providing fins coat Chemical Grafting similar to electroplating.

- ✓ Ensure the galvanized steel frames of coils, filters and other equipment are epoxy powder coated. Stainless steel cases may be left unpainted with the option of powder coating.
- ✓ As per ASHRAE Standard 62-1999, specify equipment with the slopped, non-corrosive drain pans, cleanable surfaces and accessibility. Use stainless steel drip pan beneath the cooling coil.
- ✓ Locate equipment in a way that prevents exposure of equipment to the air stream.
- ✓ Fans provide airflow and static pressure to cater for positive pressurization and required ventilation air changes per hour. Fans are often exposed to toxic or corrosive fumes laden environments. Consider stainless steel fan or fiber reinforced plastic (FRP) assembly option. Designed for continuous operations consider, galvanized housing with powder coat enamel. Electrically provide fan motors that are certified flameproof for zone 1 operation. Consider polypropylene axial fan assembly with alloy hub non-sparking type for condenser unit fans located outdoors in harsh environments.
- ✓ All units must be designed for excellent thermal and acoustic performance using high-density insulation with good efficiency and low noise.
- ✓ Provide service access on both sides and front of the unit by means of removable covers to give full access to all major components.