Process Solutions

Honeywell

White Paper

# The Environment in Control and Equipment Rooms: how important is it, and what to look for?


## Executive Summary

The importance of the control and equipment rooms' environment is discussed. The environment surrounding Honeywell's control systems and electronic equipment is extremely important in combating electronic Corrosion (eCorrosion). The environment must be properly managed for safe and successful system operation and reliability. Being aware, knowing the requirements, and how to assess and monitor corrosion rates will help. A few "less than obvious" eCorrosion failure modes are also presented.



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## Introduction

Corrosion of contacts and components on circuit boards accounts for ~30 to 40% of all equipment failures. This corrosion, sometimes called eCorrosion, is caused by an unmanaged environment consisting of combinations of uncontrolled temperature and humidity, along with harmful corrosive gases inside the electronic equipment rooms (1).

A growing number of electronic reliability problems develop when DCS (Digital Control System) equipment is exposed to environmental conditions exceeding Honeywell–HPS' specifications. Honeywell's Technical Assistance Centers (TAC) are receiving an increasing number of complaints on early life failures due to eCorrosion, resulting in unplanned warranty, and other maintenance and replacement related costs. These unwarranted complaints can develop into customer's misconception of poor DCS reliability.

The environment surrounding Honeywell's control systems and electronic equipment must be properly managed for successful system operation and reliability. The customer must manage several environmental species of airborne contamination, such as:

- **liquids**, including micro levels of condensation, sea salt mist
- **solids**, including grit, sand, and dust
- **gases**, including Inorganic chlorine, active sulfur, (hydrogen sulfide), sulfur oxides, $SO_2$ and $SO_3$, and Nitrogen oxides, $NO_x$, and hydrogen fluoride, ammonia, ozone, and other strong oxidants

A mismanaged environment, along with temperature and humidity, will affect all nonconformally coated electronic equipment, PC based servers, and controllers, systems, stand alone electronics, and 3rd party equipment operating in industrial environments, including:

- Oil Gas, Hydrocarbon (H-C) processing
- Refining
- Pulp and paper plants (P3)
- Steel making processes, blast and electric furnaces
- Other processing that produces environmental compounds that play havoc with electronic reliability.

There are several important factors to consider when striving for a safe and successful control room operation. They are:

- Absolute moisture (relative humidity), sometimes called micro-condensation
- Temperature
- Air flow
- AC operation, including compressor operation, and make-up air
- Active airborne contaminants
- Chemical filtration, supplier controlled maintenance and operation
- Control and equipment room maintenance. (know your control and equipment floor cleaning chemicals)
- Solid contamination, e.g., dust

In addition to the three airborne contaminants, liquids, solids and gases, relative humidity plays a major role in eCorrosion. Liquid contamination is transported to the equipment by condensation. This includes cleaning chemicals, misdirected cooling ducts, and dirty, muddy boots, sometimes called hidden mechanisms of eCorrosion attack.

| | | |
|---|---|---|
|  |  |  |
| Figure 1 – Multiple corrosion rings, a sign of multiple exposure or excursions to G3 or Gx levels of contamination. | Figure 2 - 0.025” gold plated pins have no chance to resist sulfide corrosion attack. | Figure 3 – Metal sulfide (likely copper) links adjacent IC leads. The resistivity can be from 1k ohm to 100k ohm. |

**Hidden mechanism of eCorrosion** can also be detected if you visually scrutinize the surroundings. Three (3) such examples are as follows:

- **The Floor Cleaning Personnel:** While investigating many HPM failures at a customer site, a wet mopping operation continued throughout the day and night. Unbeknownst to the customer, bleach and other cleaning chemicals were evaporating into the control room’s air, then going directly through the fan inlets of PCs, servers and controllers. Bleach, commonly called household "chlorine bleach", is a solution of approximately 3-6% sodium hypochlorite (NaOCl), and "oxygen bleach", which contains hydrogen peroxide or a peroxide-releasing compounds such as sodium perborate or sodium percarbonate. The hypochloride, a strong oxidizer, also known to be a strong catalyst for sulfide buildup. Chlorine is a major catalyst in the formation of copper sulfide and attack on electronic components. Chronic electronic failures were experienced. See figures 1 through 3. Please note that chlorine can come from other sources, including the sea.
- **AC cooling from overhead vents is doing more then cooling:** At another site, overhead AC vents are blowing cool 18oC (65oF) air onto several racks of LCN (Local Control Networks). The equipment was running steady state at cool 18oC (65oF). The AC compressors suddenly shut down, and hot, humid make-up air followed the cool plenum air, exceeding dew point, and condensing onto the LCN’s racks and equipment. Micro-levels of moisture condenses onto all electronics operating at temperatures below dew point. Add a small amount of sulfur and chlorine (and other sulfurous compounds), and copper creep and electronic corrosion will quickly ensue and cause electronic corrosion failures. See figures 1 through 3.
- **Wet contaminated boots:** This incident occurred on a hot, humid, clammy, and rainy morning. Several operators from the sulfur recovery plant rushed into the control room with thick muddy boots, only partially boot-scraped and brushed, and sitting right down in front of the control consoles. The muddy boots, full of ground level contamination, consisting of wet mud with yellow lined sulfur and other contamination were drying right in front of the PC cooling inlets. Chronic PC type electronic failures were also observed here.

## What can I do to recognize incidents of eCorrosion?

Take a close look at the equipment rooms, control rooms and chemical filtration cabinets. Ask if the control room operators can turn off AC compressors? If yes, recommend the practice be stopped. Air conditioning is for the equipment. Warming the air may be required for operator comfort. Always try to improve on the Checklist rating.

Do what’s needed to ensure all installed systems comply with Honeywell’s environmental specifications. If non-compliant, notify the customer and recommend mitigation steps to improve on the less than ideal environmental conditions. This will mitigate any warranty impacts and later disputes can sometimes be avoided.

Systems operating under poor environmental conditions should be reported to the Field Service Leader (FSL) or Manager of Service Operations (MSO) in order to make immediate remedial actions.

We recommend the chemical filtration be handled by a 3rd party, such as Purafil. Real time, active and passive monitors, are available to help monitor the effectiveness of chemical filtration. Optimized filtration can be monitored using either Purafil’s On-Guard systems, or reactivity monitoring, including silver and copper coupons.

An AC, Filtration, Equipment and Control Room Check list is available that will help you recognize areas of corrosion concern (3). Of course, the more items that are checked, the more your control room is running safely and successfully. Look over the checklist and check all that applies.

## ISA Standard: 74.04 Environmental Conditions for Process Measurement Control Systems

The Battelle Environmental Studies Group, ESG, of which Honeywell is a member, started their environmental study in the mid 1970s, and commenced some of the greatest work in electronic corrosion. ISA 71 series was published in 1985. Honeywell-HPS adopted the ISA 71.04 (then called ISA S71.04) in the same year. Several Battelle corrosion studies were completed during this timeframe.

At HPS we design our electronic equipment capable of reliable operation in a G1 environment, and harden products to G3 levels with any of the conformal coatings specified in the Conformal Coating Specification 51109681. Our coating of choice is Humiseal's Acrylic 1B73 conformal coating. Battelle's Accelerated eCorrosion Testing to IEC/SC 50B/WG6:Corrosion, Flowing Mixed Gas Corrosion Test, will qualify the equipment, application, and/or operation to G1 through Gx environments. Accelerated testing simulating 5-10 years exposure can be performed. The ISA 71 series is listed in Table 1. The effects of environmental variables are discussed in these 4 documents.

**Table 1 The ISA 71.xx series**

| | |
|---|---|
| ISA 71.01 | *Environmental Conditions for Process Measurement and Control Systems:* ***Temperature and Humidity*** |
| ISA 71.02 | *Environmental Conditions for Process Measurement and Control Systems:* ***Power*** |
| ISA 71.03 | *Environmental Conditions for Process Measurement and Control Systems:* ***Mechanical Influences*** |
| ISA 71.04 | *Environmental Conditions for Process Measurement and Control Systems:* ***Airborne Contaminants*** *(4)* |

Specification ISA 71.04 covers 4 different species of airborne contaminates, including Liquids, Solids, Gases, and Biological Influences. Although all four species are important, airborne contamination - gases is of prime interest to Honeywell - HPS. The gases that can play havoc with electronics are:

- hydrogen sulfide, active sulfur gases
- inorganic chlorine
- sulfur oxides, $SO_2$ and $SO_3$
- nitrogen oxides, $NO_x$
- hydrogen fluoride
- ammonia and derivatives
- ozone
- other strong oxidants, (see bleach), most of which are catalysts for sulfur corrosion

Specification ISA 71.04, section 6, covers airborne contamination that reacts with copper producing 4 distinct levels of total sulfide thickness. These levels of total sulfide thickness *per time* (Angstroms/month) can then be mapped into an associated ISA 71.04 Class G1, G2, G3, or GX. Process measurement and control equipment is exposed to a broad range of industrial gases, invoking reactivity with many metals. It's important to understand that some environments are severely corrosive (upper G3 and Gx), while other environments are classified mild (G1).

Reactive monitoring for 30 days, measuring the sulfide thickness, will help to classify the level of contamination at *that* location. For example, a 1200Å/month total copper reactivity thickness will classify the environment as Class HARSH low G3. 200Å/mo. would be MILD mid G1. 4000Å/mo. would be SEVERE upper Gx. ISA 71.04, written in 1985, is best specification in print. Specifications that define Environmental Classifications, and their (drawbacks), are shown in Table 2.

**Table 2 Specifications that define Environmental Classifications**

| | |
|---|---|
| ISA-S71.04-1985 | *Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants* (this specification has been adopted HPS Engineering since its original writing in 1985, see Table 3) |
| IEC 60654 part 4 | *Operating conditions for industrial-process measurement and control equipment. Part 4: Corrosive and erosive influences International Electrotechnical Commission,15-Jul-1987* (defines environmental classes, but no direct correlation to ISA S71.04.) |
| IEC 60721-3-3 | *Part 3-3 "Classification of environmental conditions Classifications of Groups of environmental parameters and their severities – Stationary use at Weather protected locations."* (defines environmental classification in terms of atmospheric concentrations. Does not define Reactivity Monitoring.) |

**Table 3 Origin: ISA Standard: 71.04 Environmental Conditions for Process Measurement Control Systems, p14**

| | | | |
|---|---|---|---|
| Class G1 | MILD | <300 Angstroms per month | Corrosion is NOT a factor in determining equipment reliability. |
| Class G2 | MODERATE | 300 - 1,000 Angstroms per month | Effects of corrosion are measurable and may be a factor in determining equipment reliability. |
| Class G3 | HARSH | 1,000 - 2,000 Angstroms per month | High probability that corrosive attacks will occur. This harsh level should prompt further evaluation and result in environmental controls or specially designed and packaged equipment. |
| Class GX | SEVERE | >2,000 Angstroms per month | ONLY specially designed and packaged equipment would be expected to survive. Specifications for equipment in this class GX are a matter of negotiation between user and supplier. |

Å = Angstrom = $10^{-8}$ cm (centimeters)

## Monitoring via: Direct Concentration Measuring and Reactivity Monitoring with meters and copper coupons:

Two methods of classifying the environment include:

- Direct measure of selected gaseous air pollution. Gas Concentration, mm3/m3, (ppb), and is rarely performed.
- Reactivity monitoring with either Purafil's ONGUARD© 2000/3000 Systems, or copper/silver coupons, both are the preferred method of monitoring.

**Direct Concentration Measuring** of gaseous air pollution is very difficult and rarely performed. The gas concentration mm3/m3 (ppb) is compared against the range, ISA 71.04. The environment concentration is then extrapolated from the chart.

**Reactivity monitoring,** ISA 71.04, Appendix C, (copper and silver coupons) provides a popular method, and a quantitative measure of the overall corrosion potential of any environment. The reactivity of gases commonly found in industrial atmospheres can be defined by the thickness of total sulfide films produced on copper and silver test coupons. Sampling (reactivity monitoring) may be performed by the user, TAC, or HVAC specialists. Determining the total sulfide film thickness per time is performed by specialists in electrochemical evaluation, and determined by cathodic reduction method.

Equipment designed for operation in a corrosive environment will have one of the ratings – G1, G2, G3, or GX. For example, equipment coated to Honeywell HPS conformal coating specification 51109681, with Acrylic 1B73 will perform satisfactory (up to 10 years) in an\ environment rated at G3. This level is rated as a high probability that corrosive attacks will occur on non-coated electronics. This harsh level has prompted further evaluation resulting in environmental controls, or specially designed and packaged equipment. See Notes 1 and 2.

**Note 1 Conformal Coating:** Honeywell HPS has a Conformal Coating Committee that address important decisions and questions dealing with our qualified conformal coatings, including our Conformal specification, 51109681 (latest revision).

**Note 2 Equipment with conformal coating; and equipment without:** Equipment without conformal coating must not operated above G1 (Mild) levels, unless it's packaged in specially designed enclosures, e.g. NEMA4. Examples include DCS, control room devices such as computers, monitors, disk drives, mice, trackballs, keyboards, touchscreens, Ethernet switches, etc.

A mild environment is defined as </= 300Å of total accumulated sulfide per month.

## Want a safe and successful control room operation, then follow these suggestions:

Earlier in this paper, reference was made to several important factors to consider when striving for a safe and successful control room operation. Most will be found in the Control and Equipment Room Checklist. We will further define these now.

**Temperature and Humidity**: – ISA 71.01 addresses Temperature and Humidity collectively.

| **Table 4a ISA 71.01 Location Classes – Temperature and Humidity** | |
|---|---|
| Class A | Air Conditioned Locations, locations where both air temperature and relative humidity are controlled. These locations are usually provided for computers and other electronic equipment requiring a controlled air environment. |
| Class B | Enclosed temperature controlled locations. |
| Class C | Sheltered locations, locations protected from direct exposure to the climatic elements, such as sunlight, rain, and other precipitation, and full wind pressure. |
| Class D | Outdoor locations, outdoor locations where there is no specific protection from the environment. |
| Class X | Special locations. Locations of extreme or special service conditions exist, See section 5.5 of ISA 71.01. |

| **Table 4b ISA 71.01 Location Severity Level – Temperature and Humidity** | |
|---|---|
| 1, 2,..x | Each severity level is defined according to Temperature limits, Temperature variation, Temperature, rate of change, Relative Humidity Limits, Control Point tolerance, and Maximum moisture content, (kg/kg dry air). |

For example, Class A2 (temp, humidity-severity), means environment is air conditioned, 18-27$^{o}$C+/-2$^{o}$C, +/-5$^{o}$C rate of change, 20 to 80RH, +/-10, RH controlled, See ISA 71.01, "Environmental Conditions for Process Measurement and Control Systems: Temperature and Humidity," Section 5.0, Table 1 (5).

Controlling both the relative humidity and rate of change in RH are very important factors in preventing corrosion failures. The amount of moisture in the air (relative humidity) is the most important atmospheric parameter for electronic corrosion mechanisms (6). A few parts per billion of atmosphere contaminants combined with a humidity of greater than 60 percent, e.g. micro level condensate, is very corrosive to electronic equipment. On the other hand, excessively low humidity (less than 40 percent) may cause electrostatic discharge problems; therefore, the following is recommended:

- Maintain humidity levels between 40 percent and 60 percent.
- Control humidity fluctuations to less than 6% per hour rate of change.

**Air Flow:** - Airflow is different than air exchange. Airflow is proportional to the amount of corrosion. Fans, especially PC fans will accelerate corrosion attack.

**AC operation, including compressor operation, and make-up air:** If you are looking for possible areas that cause corrosion, look closely at the AC, compressors, and makeup air inlets. They may reveal some hidden areas and origins of eCorrosion. See Hidden Mechanisms of eCorrosion. Look for AC maintenance records that summarize down time. Note the time of the year that maintenance problems are reported. The hot humid months of spring, summer, and fall will exhibit increased signs of corrosion damage. Inquire whether or not personnel can turn off compressors for comfort is a prime area of the start of eCorrosion. Too much make-up air overworks the AC; look for signs of condenser fin and copper tube pitting corrosion.

See Temperature and Relative Humidity.

**Active Airborne Contamination:** ISA Specification 71.04 covers 4 different species of airborne contaminates. The 4 species include liquids, solids, gases, and biological influences. Although all four contaminants are important, airborne contamination -Gases is of prime interest to Honeywell HPS.

**Purification System:** – Chemical purification system may be required in order to provide acceptable air quality in industrial environments. A filtration system should be chosen based on the manufacturer's ability to provide the necessary low levels of pollutants and on verification by reactivity monitoring. Positive pressure in equipment rooms at 0.1"(2.54mm) $H_2O$ should be maintained to minimize the ingress of untreated air. Temperature cycling and non-chemically treated air can cause eCorrosion problems.

In a refinery operation, the first area to be investigated should be the Sulfur Recovery Unit's DCS Control Room. This author has personal experience involving electronic damage due to prevailing winds from upwind sulfur recover units. The following filtration equipment is typical of what would be considered an adequately equipped filtration room (7).

- Objective: control or favorably modify the environment
- Deep bed scrubbing systems
- Media
  - Permanganate
    - ineffective in the removal of chloride species
    - effective in removal of sulfides
  - Impregnated Carbon
    - great for both chloride and sulfide
    - Media is good for approx. 1 year but some users try to get 3-4 years. Reactive monitoring will show the degree of effectiveness
  - Equipment maintenance should be contracted by the original equipment supplier. Who better to care for the equipment?

**Control and equipment room maintenance:** Know your control room cleaning chemicals, especially bleach and of ammonia products. See Hidden mechanisms of eCorrosion.

Solid Contamination, e.g. dust: Dust is a general name for minute solid particles with diameters less than 500um, (0.020"). Dust occurs in the atmosphere from various sources such as soil dust lifted up by wind and pollution.

Dust in homes, offices, and other human environments consists of human skin cells, plant pollen, human and animal hairs, textile fibers, paper fibers, minerals from outdoor soil and dust, and many other materials can be found in the local environment.

Dust is a solid contamination addressed by ISA 74.04 Appendix B. The dust can be crystal rock, rock and ore processing, combustion ash, blowing sand, from many industrial sources.

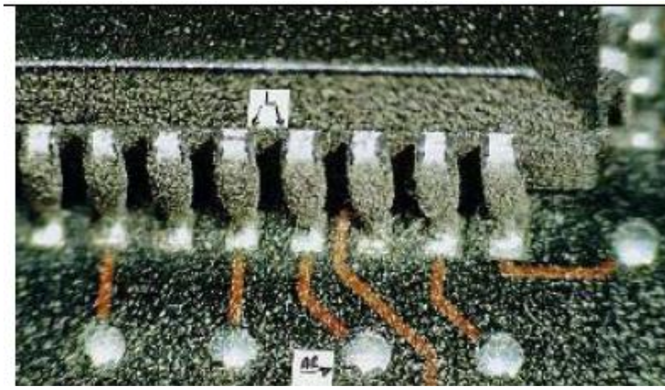

**Figure 4 Dust, and lots of it cover this SMT IC leads. The dryer the environmental conditions, the more dust is present. Excessive corrosion can also be present.**

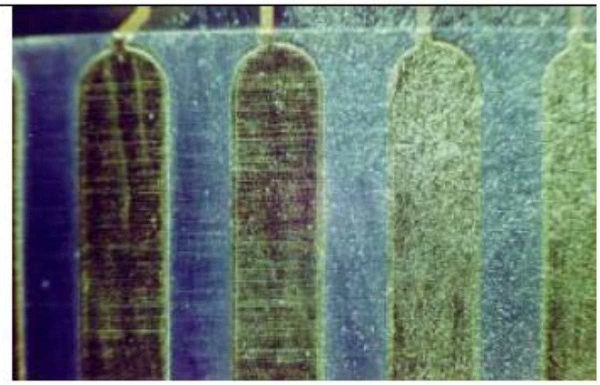

**Figure 5 Shown above are card edge fingers covered with dust. A reliable connection is questionable.**

More hidden mechanism of eCorrosion can be detected by the presence of layers of dust and rodent damage. Be aware that more then sulfur and chlorine can cause eCorrosion. If you visually scrutinize your surroundings, you may find some of the following examples:

- **Dust:** is often considered benign until boards and contacts are reseated and the contact's sweet spot rolls onto non-conductive dust and other insulating particles. PCs mounted at floor level are especially prone to dust pick-up and dust passage through the PC fan inlet. Often the fan has a very thin, almost non-effective prefilter on the inlet side of the fan. Components, and peripheral cards and memory slots and card-edge fingers are covered with dust. See figure 4 and 5.
- **Rodent damage:** This is another very different form of eCorrosion damage, as shown below in figures 6 and 7. Often when everything is right and the area of fault can not be located, examine boards for obvious signs of board corrosion due to rodent damage. Shown here are the effects of rodent damage on a large control system. The rodents make a nest and spread urine and excrement between the boards warmed by the power supplies directly below. Nothing can be done except to replace the board, and recommend the customer contact personnel who specialize in rodent control.

Figure 6 Rodent urine damages components and boards. Sometime the components will actually fall off the board.

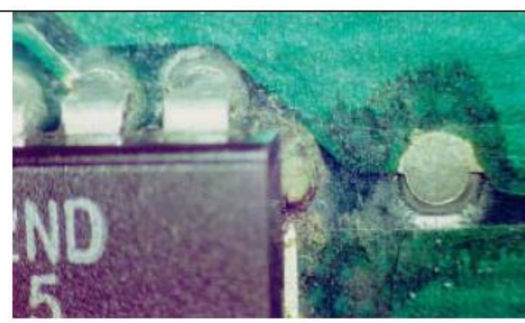

Figure 7 Rodent urine damage results in pin to pin leakage and corrosion.

### General Operating Practices: (see Environmental Guidelines Published)

- Do not defeat temperature and humidity controls by opening doors and windows to enhance comfort.
- During process upset or air conditioner breakdown, priority should be given to prevent high concentrations of gaseous contaminants from reaching equipment.
- Chemical purification systems should be placed on a strict maintenance/ replacement schedule.
- Keep equipment doors closed at all times except when accessing equipment. Use airlocks, and pressurized rooms to 0.1" (2.54mm) H2O, minimum.
- Traffic through equipment rooms should be restricted to minimize the amount of pollutants brought in.
- Avoid rapidly changing temperature and cool air distribution directly on operating equipment as it can foster condensation leading to several forms of eCorrosoin.
- In any doubt, install copper and silver reactivity coupons (Battelle©) or atmospheric corrosion monitors (ONGUARD© 2000/3000) in both equipment and control rooms.

## Summary

The information and data presented in this paper are tried and proven recommendations. They are based on real case exposure and personal experiences. The more aggressively they are followed, the more benefits the end user can expect to receive in terms of trouble-free equipment operation. Keeping the humidity at 40 - 60% levels, and keeping the environmental pollutants within an acceptable G1 range (see table 3), will produce an environment for electronic equipment that will result in long term successful operation.

Following the guidelines and the checklist will help the DCS (and other stand alone equipment) to operate safely and reliably. Do copper and silver reactivity monitoring, control the total sulfide thickness through properly maintained rooms (pressurized) and incorporate effective, properly maintained chemical filtration. And above all, develop a sense of control and equipment room ownership and pride.

For more information about monitoring devices or corrosion, contact your Technical Assistance Center, TAC.

Additional info on corrosion, photos and guidelines and checklists can be found on the Micro Analysis Lab Corrosion website: http://acsnet.honeywell.com/sites/MicroLab/Corrosion/Forms/AllItems.aspx

This Honeywell intranet site may not be viewable outside of Honeywell's network.

## ANNEXURE: Checklist for Control and Equipment Room Installation

**We assembled a list of safe and reliable conditions that you can use as a checklist for determining the potential for safe reliable electronic equipment. Of course, the more you have checked as being implemented, the more successful will be your control rooms.**

**Notes:**

- Customers must be aware of the environment of all rooms where electronic equipment is being installed utilizing appropriate monitoring equipment, temperature and humidity testing.
- Special attention must be given to storage and equipment installation as well as seasonal changes, when the environment may not be maintained.
- Some Honeywell PWA boards and 3rd party equipment are conformally coated for additional corrosion protection, some are optional and some are not available as coated options.
- Customers are cautioned to make sure the environment is suitable for long-term reliability. See *ISA-S71.04-1985 "Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants", page 2:*

**Date:** ___________________________________

**Customer:**__________________________________

**Plant:** _________________________**Room** ______________

**Name of person completing this checklist:** ______________________________

**Transportation**

- ☐ The equipment was delivered to the customer's site in a safe and reliable manner.
- ☐ At the time of installation, the control room was complete and HVAC was operating and running effectively.
- ☐ Monitor and control the temperature in control and equipment rooms (dry bulb) 20oC – 26oC (68oF to 79oF) with humidity at 50% +/- 10%.
- ☐ A positive pressure is maintained in equipment and control rooms at approx. 2.54mm (0.1") of water.
- ☐ The equipment's delivery was concurrent with the completion of the control/equipment rooms.
- ☐ There was no signs of transportation damage
- ☐ Container/pallet's/plastic wrap was not damaged.

**AC**

- ☐ Dehumidification both controlled and monitored throughout the pre-installation life cycle.
- ☐ If necessary Installed heaters are for comfort, maintaining 50%RH +-10, approx 70$^{o}$F.
- ☐ Personnel are not permitted to turn off AC compressors.
- ☐ The %RH does not fluctuate greater than 6% per hr.
- ☐ The site has redundant AC system(s)
- ☐ Maintenance does record all incidents of AC down time.

**Chemical Filtration**

- ☐ The site is operating at ISA 71.04 classification of G1 or lower. (<300A of accumulated sulfide
- ☐ The in-room environment monitors are tied into a computer system and immediately report any upset conditions. (e.g. Purafil On-Guard system).
- ☐ The site immediately responds to upset conditions, excursions to higher level of Humidity.

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**Control and Equipment Room:**

- ☐ All control and equipment rooms would be considered running the way they should be.
- ☐ Installation, grounding, and proper operation have been verified.
- ☐ The control and equipment rooms are pressurized, to 0.1inch (0.039") H2O.
- ☐ No eating allowed in the rooms.
- ☐ No dirty boots are allowed in the rooms, boots are removed before entering.
- ☐ Cleaning personnel do not use harsh cleaning materials.
- ☐ ***Only qualified cleaning products are used for cleaning, once a week. NOT EVERY hr.***
- ☐ Air locks, separate entrances are installed. Rooms within rooms are ideal.
- ☐ Doors are not propped open.
- ☐ Chemical monitors are present.
- ☐ Personnel respond immediately to any upset conditions.
- ☐ The control and equipment rooms show a real sense of pride and ownership.
- ☐ Someone is personally responsible for the control and equipment rooms.

**Notes/Comments/Observations:**

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