Introduction

The purpose of this bulletin is to remind users of environmental restrictions for the installation of electrical equipment and components in a corrosive environment.

Background

The installation of electrical equipment in adverse environments containing corrosive gases, liquids, or dust can cause severe and rapid deterioration of the equipment. Historically, it has been recommended to customers to keep electrical equipment free of these contaminants through the use of special enclosures or separate rooms. Furthermore, the NEC (National Electrical Code) does not provide clear direction for certain applications, such as meat rendering or water treatment facilities.

Corrosion is defined as the deterioration of a base metal resulting from a reaction with its environment. Electrical components most affected are those fabricated of copper, aluminum, and silver compounds. For good electrical contact, silver is commonly used in the contacts in circuit breakers, motor starters, and in electrical conductor plating.

Electronic components are particularly susceptible to damage by corrosive environments because of manufacturing processes and the small size of the components. Conformal coating generally used to protect printed circuit boards from dust does not protect them from corrosive gases. Frequently, the consequences of corrosion include costly unexpected down time and additional maintenance costs. Corrosion could possibly result in fire or personal injury.

For service of electrical equipment that has been exposed to water or condensation, refer to document no. 0110DB0401 titled “Water Damaged Electrical Distribution and Control Equipment.”

Examples of facilities containing adverse/corrosive environments include, but are not limited to, the following:

- animal confinement areas
- meat packing plants
- rendering plants for animal products
- waste water/sewage treatment plants

Corrosive environments are also found in other operations, such as the following:

- pulp and paper processing
- oil and petroleum refining
- mining
- foundry
- chemical
- grain processing
- marine/coastal (salt) environments
Why does it occur?

Some typical corrosive substances found in the environments in these facilities include ammonia, sulfides (especially hydrogen sulfide), sulfur dioxide, sulfates, chlorides, chlorates, methane, urea, and uric acid. These substances most frequently exist in a gaseous state or aerosol. However, some liquids are spread when the locations are washed down with high-pressure hoses and the substances are accidentally splashed onto electrical equipment.

This practice is dictated by regulation in certain industries such as food and beverage and pharmaceuticals. Corrosion is accelerated by increased concentration of contaminants, elevated temperature and high humidity. Time of exposure (in storage, in shipment, or in use) is a factor in the degree of degradation.

Table 1: Examples of Electrical Equipment and Components Affected by Typical Corrosive Environments

<table>
<thead>
<tr>
<th>Predominate Corrosives</th>
<th>Metals Affected</th>
<th>Equipment Affected</th>
<th>Components Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Sulfide</td>
<td>Copper</td>
<td>All electrical equipment including:</td>
<td>All electrical components including:</td>
</tr>
<tr>
<td>Sulfur Dioxide and Trioxide</td>
<td>Silver</td>
<td>• Motor Control Equipment</td>
<td>• Starters</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Tin</td>
<td>• Switchboards</td>
<td>• Ground Fault Relays and Surge Protection Devices</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Aluminum</td>
<td>• Panelboards</td>
<td>• PLC</td>
</tr>
<tr>
<td>Chlorinated Compounds</td>
<td>Iron and Steel</td>
<td>• Safety Switches</td>
<td>• Computer Equipment and others</td>
</tr>
<tr>
<td>Salts</td>
<td>Nickel</td>
<td>• Switchgear and others</td>
<td></td>
</tr>
<tr>
<td>Moisture / Water</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Codes and Standards

Electrical equipment is manufactured in accordance with industry and regulatory standards for general application. A reasonably long service life can be expected when the equipment is not exposed to adverse or corrosive environments.

Few standards address the use of electrical equipment in corrosive environments. NEC 547.5 addresses the issue for agricultural buildings. Unfortunately, these buildings are often installed in locations and used under conditions in which inspection is not available or required and there is little understanding of the hazard. The installation of equipment in corrosive atmospheres is addressed in the NEC by the general statement of NEC 110.11.

Risk of Chemical Corrosion Damage

A myriad of industries use electronic and electrical control equipment to regulate various facility processes. In these industries, many plants are trying to protect this equipment from corrosive chemical pollutants. Schneider Electric representatives, in conjunction with their North American customers, have been working with third party suppliers to provide positive-pressure, airborne-contaminant free control rooms. These rooms allow for a “clean” operating environment for the electrical equipment.

Corrosion, as already discussed in the introductory section of this bulletin, may be defined as the deterioration of a metal resulting from a reaction with its environment. More specifically, it may be described as the influence of reactive gases present in an environment that cause corrosion.

Copper, silver, and gold are important materials presently used in today’s industrial plant environments. The electrical performance of the equipment may be affected by the presence of corrosive gases in the local environment. Even trace levels of these gases can cause problems because of the formation of corrosion products in and on the circuitry and connectors of this equipment. Due to the nature of various manufacturing processes, it is almost a certainty that these devices will be exposed to corrosive gases.
The most effective and practical method of protecting electronic and electrical control equipment from corrosion is to remove or reduce the concentrations of corrosive gases in the environment. This reduction can be achieved by the use of gas-phase filtration equipment. Standards have been developed to define acceptable and unacceptable concentrations of corrosive gas in specific environments.

Environmental Classifications

In 1985, the Instrument Society of America (ISA) issued a standard covering the influence of airborne contaminants in electronic equipment rooms. This standard, ISA-S71.04-1985, “Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants” classifies different types of environments, giving acceptable gas concentration levels within these classifications.

Four levels or classes of equipment reliability, based on the level of corrosion severity, have been established by this standard.

Table 2: Levels of Equipment Reliability

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Equipment Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>Mild</td>
<td>Corrosion is not a factor</td>
</tr>
<tr>
<td>G2</td>
<td>Moderate</td>
<td>Effects of corrosion are measurable and may have an impact</td>
</tr>
<tr>
<td>G3</td>
<td>Harsh</td>
<td>High probability that corrosive attack will occur</td>
</tr>
<tr>
<td>GX</td>
<td>Severe</td>
<td>Only specially designed and packaged equipment could survive</td>
</tr>
</tbody>
</table>

These determinations were made on the basis of the measurement of the corrosion rates of oxygen-free high-conductivity copper. Corrosion is defined in terms of the corrosion film thickness that builds up on the metal after 30 days of exposure. The thickness is measured in Angstroms (Å):

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Reactivity Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>Mild</td>
<td>0-299Å/30 days</td>
</tr>
<tr>
<td>G2</td>
<td>Moderate</td>
<td>300-999Å/30 days</td>
</tr>
<tr>
<td>G3</td>
<td>Harsh</td>
<td>1000-1999Å/30 days</td>
</tr>
<tr>
<td>GX</td>
<td>Severe</td>
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</table>

While this standard has been widely accepted by major manufacturers of electronic computer equipment, there may be cases where these classifications may not provide a strict enough standard to stop corrosion of electronic equipment. In particular, the ISA standard does not address the synergistic effects of certain gases. For example, the reactivity of sulfur gases is greatly increased by just a few parts-per-billion of chlorides. Nitrogen dioxide by itself is not particularly corrosive, but when present with hydrogen sulfide, corrosion rates increase fourfold.

Summary of Control Specifications

For reference purposes, 1Å is equal to 3.94 x 10^-9 inches.

Instrument Society of America – Standard S71.04-1985

Relative Humidity: 50%, with a rate of change of less than 6% per hour.

Corrosion Rates: Total Copper Corrosion, <300Å/30 days.
The greatest problem today is not whether these gaseous pollutant or corrosion levels can be maintained, but whether they can be accurately measured to assure compliance with any standards or control specifications.

**Air Monitoring**

Air monitoring is central to any environmental control program. It can provide the data required to manage and reduce pollutants in the environment. Air monitoring, along with stringent visual examination of the electrical equipment that is located in the affected environment, is a useful research method. Air monitoring is designed to determine relationships, if any, between pollutant levels and possible damaging effects to the metals used in the electrical equipment. Special modifications and protocols are often needed to adapt the monitoring instruments and methodologies for use in industrial environments.

Several characteristics of any measurement technique must be evaluated to determine its appropriateness for use in industrial air quality monitoring. Among the more important characteristics are sensitivity, cost, and complexity. Sensitivity is often a particularly demanding parameter for industrial site monitoring where low levels of many pollutants may be encountered. Likewise, cost may be quite important when deciding on a measurement technique, particularly in large surveys. A final point of consideration is the complexity of the technique and the degree of skill and training required to obtain quality results.

In addition to the outdoor pollutants requiring measurement, a variety of other parameters must be considered when assessing air quality. Among these are temperature and relative humidity which strongly affect the formation and rate of corrosion on metals.

**Gas Monitoring**

Gas monitoring identifies gaseous pollutants and their levels within an environment. However, it has several drawbacks. The simultaneous collection of gases which give a similar analytical response may result in measured values higher than actual concentrations. The positive interference of these gases would decrease the accuracy of the analytical technique. Alternatively, gases can interact in a way that measured values are less than concentrations actually present (negative interference). Furthermore, gas analysis can be an expensive technique and requires thorough training for implementation.

Even though it is possible to identify and quantify all chemical species one may encounter in plant and mill environments, the question still remains “What do I do with this information?” To date, there have been few published studies which provide definitive information as to the cause-and-effect relationship between levels of gaseous pollutants and the amount and type(s) of corrosion they may produce in electronic equipment. Because of this lack of information, many have turned to what is referred to as environmental classification via corrosion or reactivity monitoring. The validity for this monitoring technique lies in the fact that the control of corrosive pollutants may be the primary concern in plant and mill environments.
Atmospheric Corrosion

Atmospheric corrosion of copper has been studied extensively and tests have been devised to measure the rates of copper corrosion. These corrosion rates are currently being used to gauge electronic equipment reliability. The higher the rate of copper corrosion, the higher the probability of equipment damage and/or failure. Studies of both laboratory and field data collected by Purafil® have shown that using copper corrosion alone as a gauge for equipment reliability can seriously understate the corrosive potential of the local environment. Examination of silver corrosion data has shown instances of environments which are noncorrosive to copper but extremely corrosive to silver. Based upon this examination any testing which attempts to predict electrical/electronic equipment reliability should incorporate both copper and silver corrosion as determinants.

The reliability of electrical/electronic equipment in corrosive environments must be accurately gauged to avoid equipment failure. It has become apparent that using a standard which employs copper-only testing is inadequate for this purpose. Field-exposed Corrosion Classification Coupons (CCCs) have shown that environments, which would be considered noncorrosive by copper–only standards, can be extremely corrosive to other functional materials. This fact was observed first on CCCs with copper and silver coupons (test strips) and, more recently, with copper, silver, and gold coupons. Laboratory testing has produced similar results and has shown that the presence or absence of certain corrosive gases affects the formation of corrosion on these metals.

The growth of various corrosion films on specially prepared copper, silver, and/or gold coupons gives an excellent indication of the type(s) and level(s) of any and all corrosive pollutants present in the local environment. Specifically developed for the classification of environments for computers and control rooms, CCCs may be used to indicate the presence of sulfur dioxide, nitrogen dioxide, hydrogen sulfide, and chlorine compounds that can cause corrosive attack on integrated circuit chips, circuit boards, relay switches, transformers, motor controls, and instrumentation systems. These corrosive attacks can lead to ghost signals, misinformation, improper process controls, and production downtime.

These CCCs normally contain copper-only or copper in combination with other metals to provide an environmental assessment. However, recent studies have shown that while copper coupons are good indicators of corrosive gases in an industrial environment, they are not sufficiently sensitive to all of the contaminants of concern in these environments.

The use of copper and silver (and gold) coupons for assessing the corrosive potential of an environment gives a more complete picture of what is actually occurring in that environment. By using the results obtained from these CCCs, one can tell what type of contaminants were present and thus can develop proper control strategies. Looking beyond copper-only environmental classifications can practically eliminate the probability of electronic equipment failure due to corrosive attack.
Atmospheric Corrosion Monitor

Those who work in the plants and mills are expected to provide and maintain well-controlled environments to prevent corrosive attack on electronic equipment. One way they do so is by continuously monitoring gaseous pollutants, temperature, and relative humidity.

Purafil® has established the shortcomings of direct gas monitoring and why the use of corrosion monitoring for environmental classification is being used as a replacement. However, corrosion coupons are not without limitations. The most important of these is the inability to provide a continuous environmental classification.

To address this issue, Purafil has developed another tool which is currently being used in plants and mills around the world. The OnGuard® 2000 Atmospheric Corrosion Monitor is the first electronic instrument which provides real-time information on the amount of corrosion occurring due to the presence of gaseous pollutants in the industrial environment. Square D/Schneider Electric Materials Technology Lab currently utilizes one of these units as an aid in helping customers determine if they have corrosive environments or if the environment has been sufficiently cleaned when existing corrosive failures have already occurred. This device monitors corrosion on a continuous basis and calculates cumulative and incremental corrosion rates. This monitoring allows for preventive action to be taken before serious damage due to chemical contamination has occurred. It also measures the temperature and relative humidity, both of which can cause increases in corrosion rates with both being important control parameters in industrial environments. Optional room pressure sensors are also available to ensure that positive pressure conditions are being maintained.

The OnGuard system may be operated by itself, using the visual information displayed on corrosion severity levels, temperature and relative humidity, or wired directly into a central computer system. By making use of the OnGuard system’s ability to interface with computers, Square D/Schneider Electric customers can obtain up-to-the-minute information on these important environmental parameters. Environmental corrosion databases can be established and maintained to provide historical data to those charged with the maintenance of industrial electronic equipment. Upsets in plant operating conditions or changes that may occur in the environment during plant shutdown can also be established and a correlation can be made to any corrosive damage which may have occurred to Square D/Schneider Electric equipment.

Recommendations:

Heightened industry and construction business awareness is needed; most electrical equipment is not intended for exposure to corrosive environments. Appropriate solutions include installing electrical equipment such that it is not exposed to the corrosive environment. Factors for consideration include:

- Placement of equipment in locations away from the corrosive environment
- Selection of appropriate plating and component materials for the environment (for example: tin plating versus silver plating of copper bus bars)
- Placement of equipment inside enclosures designed for the environment
- Placement of equipment inside sealed electrical equipment rooms that are maintained with a positive pressure source of clean air
Proper selection, installation, housing, and scheduled maintenance/inspection (as recommended) of electrical equipment used in a corrosive environment will minimize the likelihood of an unexpected shutdown of the equipment, potential property damage and/or personal injury as well as costs associated with the repair or replacement of the equipment.

In summary, it is imperative to know the airborne contaminants contained in your environment prior to installing Square D/Schneider Electric Equipment as described in the table in the introductory section of this bulletin. If you suspect a corrosive environment or have questions about a possible corrosive environment in which Square D/Schneider Electric equipment is currently operating, we suggest that you contact an environmental consulting or corrosion engineering firm, such as Purafil®. These firms can determine the extent of your problem and can make recommendations for environmental remediation to include air purification and filtration.