

Impact of environment on corrosion of electric and electronic devices

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Electronic circuits and their components are subject to a variety of corrosion-related problems dealing with the environment. The main corrosion failures and various criteria for adopting prevention and control measures will be discussed here. These measures are based on standardized tests and are designed to reduce deterioration and attain reliable operation of all equipment.

The effects of corrosion on degradation of materials and performance are well known. The study of these phenomena (1) shows that corrosion is one of the most significant factors affecting the reliability of electrical and electronic process control equipment. In addition, about 20% of electronic failures are caused by this kind of deterioration (2).

Typically small in dimension, electronic devices and their micrometric features are orders of magnitude more sensitive to failures caused by reduced concentrations of corrosive gases, even at levels nontoxic to humans and well below OSHA limits. Consequently, corrosion appears in a subtle way.

I. Typical pollutant concentrations

Pollutant	Concentration ($\mu\text{g}/\text{m}^3$)		Influence
	Outdoors (8)	Indoors (9)	
SO ₂	3–185	1–40	Major pollutant. Known to attack many metals. Forms acidic surface.
NO ₂	26–160	3–60	Major pollutant. Known to attack Co, Ni, and Fe. Nitrate particles cause failures at interfaces of electrical contacts.
H ₂ S	1–36	0.2–1	Stress corrosion accelerator. Known to attack Cu and Ag in the presence of oxygen.
O ₃	10–90	7–65	Major pollutant. Degrades polymers and accelerates oxidation of H ₂ S, NO ₂ , and SO ₂ .
HCl	0.3–5	0.08–0.3	Destabilizes passive films by lattice impregnation and acid dissolution.
Cl ₂	()	0.004–0.015	Destabilizes passive films by lattice impregnation and acid dissolution.
NH ₃	6–12	10–150	Major pollutant. Forms complexes with Cu and Ag. Forms basic surface.

*5% of HCl levels except where local Cl₂ source exists

Environments of electronic devices

The environment to which electronic materials and devices are exposed is derived from two sources: the materials themselves and the outside world. Figure 1 illustrates factors encountered in the local environment. On the other hand, Table I provides information on "typical" indoor and outdoor pollutant concentrations and their influence on electronic materials.

Frequent failures in electrical and electronic devices

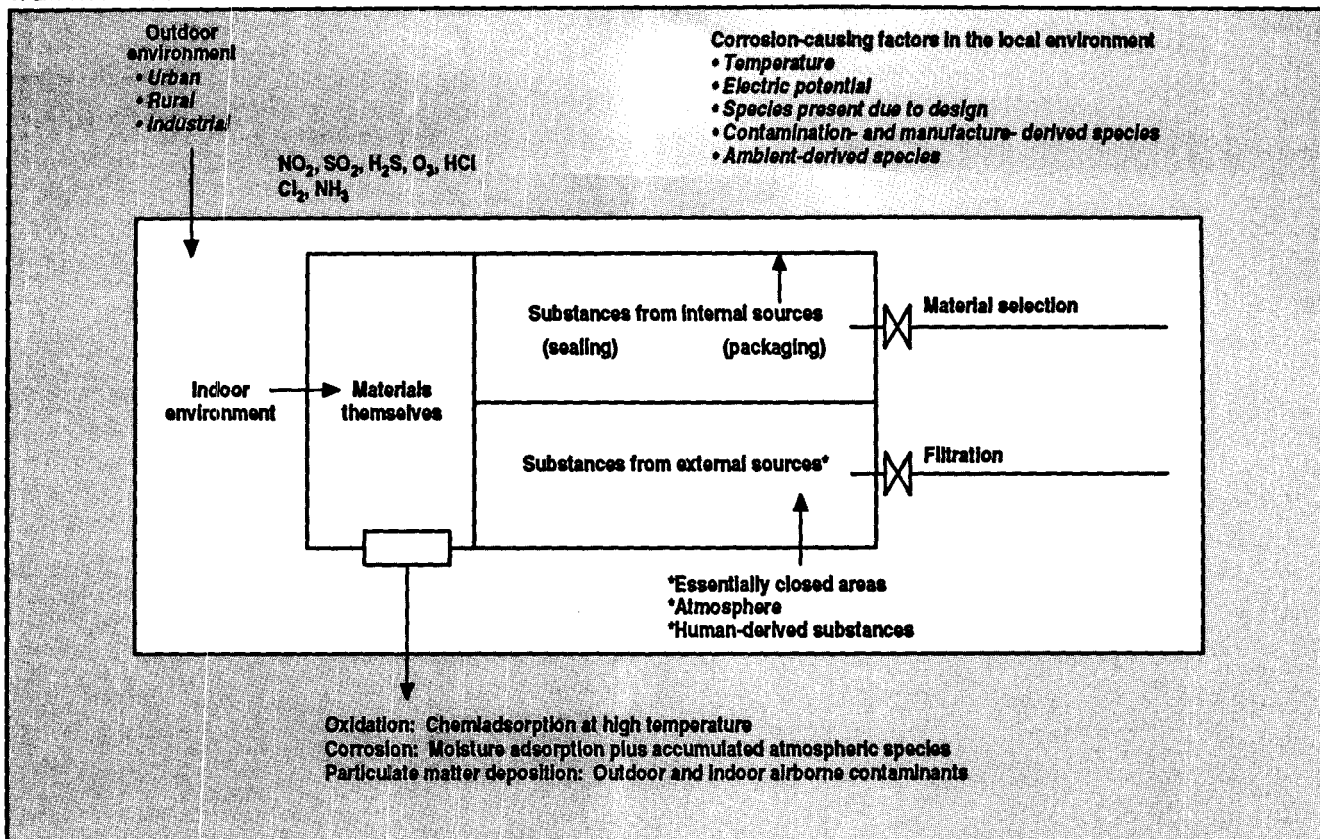
The literature points out many corrosion-related problems (3, 4). These problems keep occurring due to a lack of knowledge

about the mechanisms involved in the corrosion processes, and also because of the absence of adequate prevention and control measures. Some of the failures most frequently found are summarized in Table II.

Environmental control in operating rooms

Corrosion problems observed in electrical and electronic devices occur under industrial environments, as well as in urban and rural environments. Pulp and paper mills are most sensitive to these failures (5) due to the action of gaseous contaminants, relative humidity, and working temperatures.

1. Environments of electronic devices



Considering these three factors, the question here is how to successfully control the attack by pollutants in essentially closed environments so as to adequately protect all equipment and devices.

The first step is to determine environmental corrosivity, taking into account the impossibility of controlling outdoor and indoor contamination sources. Standardized measurements, through copper coupons (6), can give a useful index for the classification of corrosivity, which is dependent on the corrosion product thickness obtained (Table III).

When unacceptable values are found, a control strategy must be implemented, such as proper design of operating rooms (7). Also, the U.S. Federal Standard demands must be met in regard to air purification and speed, parallelism of electric flux, tightness, particle induction through joints and walls, overpressure in rooms, intensity of lighting, vibrations, environmental temperatures, and humidity.

Conclusions

The environment has an important impact on performance of electronic devices, involving economical aspects and determining the useful life of equipment. Hence, contaminants in

III. Classification of atmospheric corrosivity in the protection of control equipment

Equipment	Corrosion product thickness on copper coupons after 90 days		
	Unacceptable	Marginal	Acceptable
Electric	>3500 Å	3500–2500 Å	<2500 Å
Electronic	>1500 Å	1500–500 Å	<500 Å

industrial atmospheres, both outdoors and indoors, must be controlled because of their harmful effects on human health and equipment.

Standardized tests based on copper coupons, for urban environments exceeding the allowed pollutant indices, are required in order to assess corrosion amounts and achieve an appropriate control of the atmospheric conditions where electronic devices are normally found.

In the field of electronics, a minimal amount of information is necessary concerning the effect of pollutants, as well as some understanding of the atmospheric corrosion mechanisms. This information will allow for interdisciplinary work among designers, engineers, and corrosion specialists. [E]

II. Corrosion failures and mechanisms in electronic devices due to atmospheric contamination

Failures	Mechanisms
Humidity intrusion in black boxes	Creation of an electrolyte, which actuates on elastomers to degrade them and allow metals to have a corrosive medium.
Corrosion of dissimilar metals	Through action of relative humidity and dissimilar metallic pairs, with different potentials, galvanic corrosion occurs.
Corrosion caused by flux residues	Flux residues attack welded alloy and base metal, causing weakened joints and shorts and an increase in electrical resistance.
Corrosion by organic compounds	Damages caused by degassing compounds, vapors, and nonventilated, acid environment.
Growth of metallic whiskers	Sn, Zn, Cd, and Ag of plated surfaces form filaments that short out adjacent circuitry and cause equipment failures.
Migration of Ag	Form of electrolysis where Ag ions migrate to another conductor in the presence of humidity and contaminants. Changes the resistance of conductors.
Intermetallic fragility	Dissolution of conducting metals on soldered joints. Fragile, crystalline, intermetallic phases are created on the welded joint.
Degradation of electrical contacts	Oxide formation changes resistance; presence of fretting corrosion and action of corrosive gases due to high relative humidity. Also, galvanic corrosion can occur.

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