CORROSION ISSUES ASSOCIATED WITH ROHS CAN BE FATAL TO ELECTRONIC CONTROL EQUIPMENT

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ABSTRACT

Electronic control equipment has been used for several decades to control processes and enhance yields in the pulp and paper industry. Control rooms housing electronic equipment typically classify the environment by the ISA-71.04-1985 standard for environments of electronic control equipment. This has served the industry well for a period of time.

However, the requirements of the European Union Restriction of Hazardous Substances Directive have caused many electronic equipment manufacturers to change from lead solder to other technologies which are more susceptible to gaseous corrosion. These types of connections can fail quickly in Mild and Moderate environments, previously thought to cause problems only after long periods of time.

This paper will present the historical relationship of corrosion to equipment reliability and the more current problems that have occurred on RoHS compliant circuitry.

Keywords: electronic equipment corrosion, creep corrosion, reactivity monitoring, restriction of hazardous substances (RoHS)

INTRODUCTION

Corrosion of electronics due to ambient air pollution has been documented for many years.[1,2,3] It historically occurred only at industrial sites such as pulp and paper mills, petrochemical refineries, and geothermal plants. These facilities produce local environments relatively high in sulfur content – hydrogen sulfide, sulfur dioxide, mercaptans, or sulfur laden particulates. Therefore, circuit boards in these plants were subject to corrosion due to reactions with the environmental sulfur and humidity. Compounds such as nitrogen oxides and chlorine can also be present at these facilities and promote corrosion of electronics.

There are various types of electronic circuitry corrosion – whisker growth, creep corrosion, and others. These forms of corrosion can cause failure by either impeding the flow of electricity or forming unintended circuit paths. Figure 1 displays an example of silver whisker growth on surface mounted components of a circuit board. It will cause failures by forming unintended circuit paths on the circuit board.

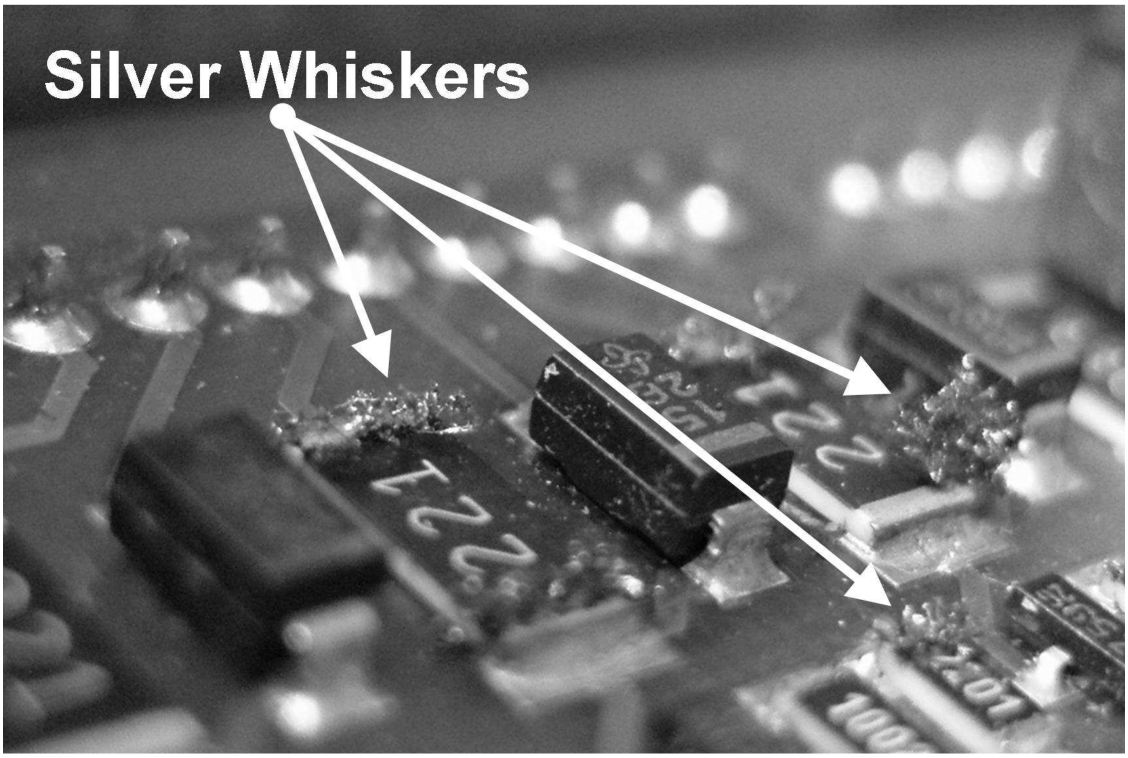

Figure 1 – Silver Whiskers Growing out of Circuit Board Components.

COST OF DOWNTIME

The cost of downtime is the most significant consequence of electronic equipment corrosion. In manufacturing arenas, such as pulp and paper mills and petrochemical refineries, corrosion of electronic control equipment can lead to shutdown of the process – lost production time. In other industries, corrosion of servers means data center downtime- transactions must stop, software applications for logistics can't run, data can't be stored. Figures 2 and 3 display the costs of such downtime. Whatever the industry, the cost of downtime is significant.

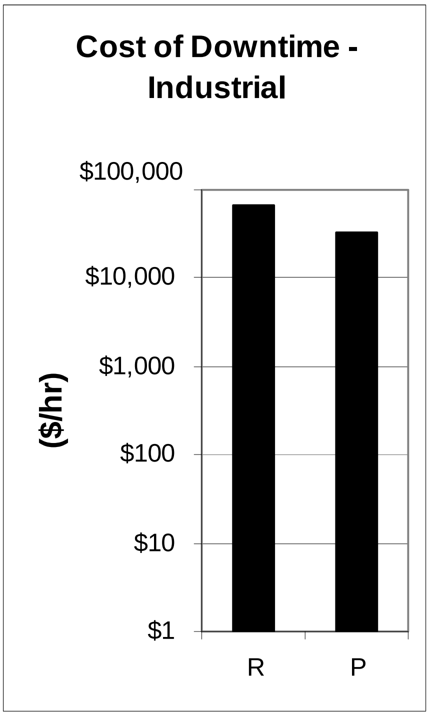

Figure 2 – Cost of Industrial Downtime[4,5,6,(1)]
R = Refinery;
P = Pulp and Paper Mill

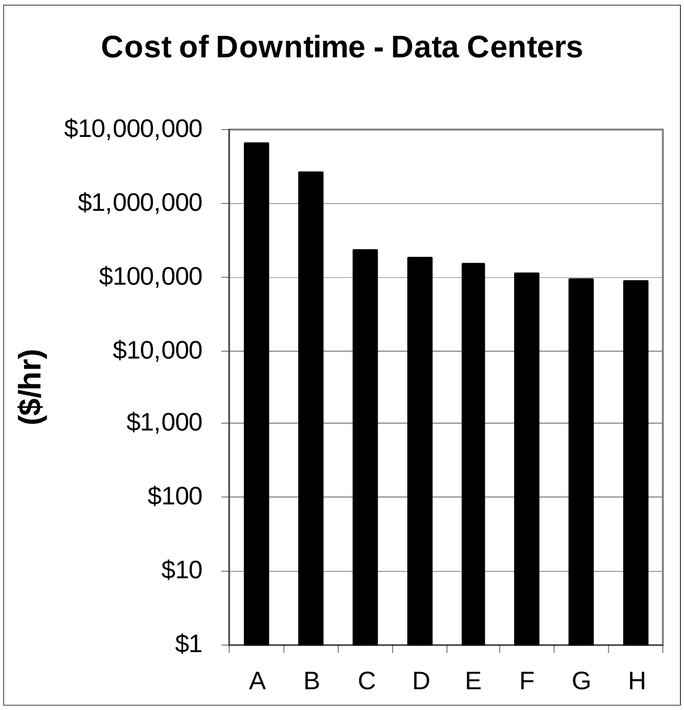

Figure 3 – Cost of Data Center Downtime[7]
A = Brokerage operations;
B = Credit card authorization;
C = Ebay;
D = Amazon.com;
E = Package shipping services;
F = Home shopping channel;
G = Catalog sales center;
H = Airline reservation center

RESTRICTION OF HAZARDOUS SUBSTANCES (ROHS) COMES INTO PLAY

The purpose of the European Union (EU) Restriction of Hazardous Substances (RoHS) Directive is to restrict the use of hazardous substances in electrical and electronic equipment in order to protect human health and promote environmentally sound recovery and disposal of such waste. The directive restricts six substances – mercury, lead, hexavalent chromium, cadmium, polybrominated biphenyls, and polybrominated diphenyl ethers.[8] Thus, the circuit board manufacturers had to remove lead based solder to comply with the directive.

The circuit board industry had over 50 years of experience with tin-lead solders performing well. Table 1 shows circuit board failure times before RoHS as a function of environmental conditions. In the best environment, it could be up to 5 years before a failure occurred. In the worst environment, it could be as short as 4 months.

Removal of lead based solder meant moving toward other surface finish technologies such as immersion silver (ImAg), high temperature organic solder preservative (HT OSP), and lead free hot air solder level (LF HASL). ImAg was chosen by many manufacturers as the RoHS solution due to its ease of application and appealing costs. However, manufacturers found that environments containing sulfur could cause failures in as little as 4 weeks. Common failure times were 2-4 months for such products in industrial atmospheres similar to those in

[(1)] Assumptions - European styrene production; 446,000 tons/yr; 24/7 operation; $1,335/ton. 4.78 M tonnes of pulp / 46 days; 24/7 operation; Pulp price of $590/tonne;

rubber manufacturing facilities, pulp and paper mills, and water treatment plants (Table 2). Testing of the various technologies showed that ImAg suffers corrosion failures in moderate environments, invariant of manufacturer. Multiple manufacturers have also developed a white paper on the topic of gaseous contamination, showing that it is not isolated to a single manufacturer.[5,8,9,10,11]

TABLE 1 – Circuit Board Failures Before RoHS[12]

ISA Severity Level	Time to Failure
G1 – Mild	4-5 years
GX – Severe	4-6 months

TABLE 2 – Circuit Board Failures After RoHS[9]

Environment	Time to Failure
Rubber Manufacturer	2-4 months
High Sulfur Areas	4 weeks

HOW TO MONITOR FOR CORROSION

Multiple companies have investigated environmental conditions at sites housing RoHS compliant circuit boards using copper and silver coupons. This type of monitoring is termed "reactivity monitoring." Interestingly, the results show that corrosion of silver coupons significantly exceeds that of the copper coupons. Examples of such results are shown in Figure 4. For each set, the resulting silver corrosion is approximately 2 or more times greater than the copper corrosion. IBM published a larger data set of coupon results for data centers with reported corrosion issues. In that data set, 81% of the copper coupon results were in the low angstrom range of 0-100 angstroms. More than 80% of the silver coupon results were at least double this amount with more than 50% greater than 400 angstroms (Figure 5).[5] It is clear that silver coupons are serving as the indicator of corrosion and copper coupon corrosion rates alone do not indicate a safe environment.

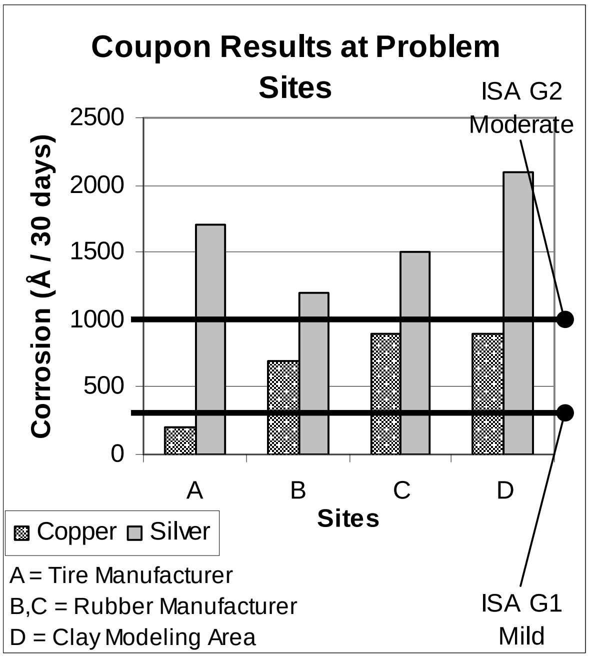

FIGURE 4 – Coupon Results for Sites which Housed RoHS Compliant Boards with Quick Failure Times[9,13]

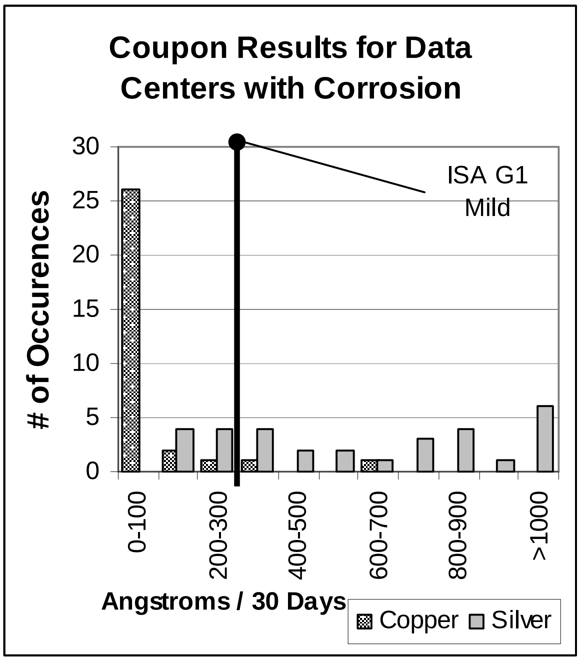

FIGURE 5 – IBM Coupon Results for Data Centers with Copper Creep Corrosion or Silver Corrosion or Both[5]

These results cause concern with the existing electronic equipment corrosion standard ISA-71.04-1985, which bases environmental classifications solely on copper coupon results. The classification scheme is shown below in Table 3. All of the above sites in Figure 4 would have been G1-Mild or G2-Moderate per the ISA-71.04-1985 classification scheme. Typical interpretation of the copper data for the G1 site would have stated that there were no corrosion issues. Typical interpretation of copper data for the G2 site would have stated that corrosion may occur and to continue monitoring. However, all these sites saw quick corrosion of the RoHS compliant boards. Copper alone is not a satisfactory indicator for RoHS compliant boards. Figures 4 and 5 display the G1 and G2 levels as points of reference. In the IBM sets, 29 of the 31 sites (93%) would have been considered safe by the copper G1 results, but all these sites were experiencing corrosion issues.

TABLE 3 – Current Classification Scheme of ISA-71.04-1985 Based Solely on Copper

Classification	**Copper Angstroms /30 days**	**Current Reliability Statement**
G1-Mild	< 300	An environment sufficiently well controlled such that corrosion is not a factor in determining equipment reliability
G2-Moderate	< 1000	An environment in which the effects of corrosion are measurable and may be a factor in determining equipment reliability
G3-Harsh	< 2000	An environment in which there is a high probability that corrosive attack will occur. These harsh levels should prompt further evaluation resulting in environmental controls or specially designed and packaged equipment.
GX-Severe	≥ 2000	An environment in which only specially designed and packaged equipment would be expected to survive. Specifications for equipment in this class are a matter of negotiation between user and supplier.

The best data to date point toward using an environmental classification scheme based on both copper and silver coupons for environments housing RoHS compliant electronics in control equipment or data centers. Other parameters such as relative humidity, temperature, and particulates should also be controlled and monitored in these facilities. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) has put forth the following recommendations for coupon results and other parameters in data centers.[5] For results above the levels in Table 4, areas housing RoHS compliant data center components or process control equipment should implement gas phase filtration to remove corrosive gases.

TABLE 4 – Acceptable Reactivity Monitoring Results for RoHS Compliant Circuit Boards Based on Best Available Data[5]

Description	**Copper Angstroms/ 30 days**	**Silver Angstroms/ 30 days**
ASHRAE Recommendations	< 300	< 300

SUMMARY

The EU RoHS Directive came into effect in 2006, causing a change of materials for multiple circuit board manufacturers. The most common solution was to use immersion silver as a substitute for lead based hot air solder level (HASL) due to its desirable traits such as ease of application and low relative cost. As equipment reached field sites, corrosion issues began to occur. The RoHS compliant boards began to fail much quicker than traditional boards with HASL. Investigation proved that this was a problem across multiple manufacturers.

A reactivity monitoring guideline for Data Centers has been produced by ASHRAE and is extended here to include electronic process control equipment using RoHS compliant circuit boards. This is a variation of the traditional ISA-71.04-1985 system which only uses copper reactivity coupons. The revised guideline allows for less than 300 angstroms of corrosion on either copper or silver coupons in such an environment. If 300 or more angstroms are found, the equipment is expected to fail in fairly short time periods and proper gas phase filtration is recommended.

CONCLUSIONS

Electronic control equipment complying with the European Union Restriction of Hazardous Substances Directive may fail quickly in industrial or mildly industrial environments due to gaseous corrosion. Industrial plants should use reactivity monitors to determine the air quality in control rooms and spaces. Control areas producing 300 angstroms or more per month on copper or silver coupons (or sensors) may incur costly failures and downtime if not protected from gaseous corrosion through methods such as gas-phase filtration.

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