Corrosion coupons may not be useful for predicting data center equipment failure rates.

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SUMMARY

Information Technology (IT) equipment manufacturers have claimed that there are increased failures of IT equipment attributable to gaseous contamination, although there is little quantitative evidence of this. This trend reportedly has occurred due to a switch from lead- to silver-based materials. The industry is considering putting more importance on using silver corrosion measurement coupons as a potential failure indicator due to the unconfirmed belief that silver coupon measurements may better predict the failure of electronic equipment.

We performed an exploratory study of 20 data centers in the United States and 2 in India. Coupons containing one copper and one silver strip were deployed for 30 days in each data center. Coupons were placed in the supply-air path starting where the air entered the building, inside the plenums and ducts feeding the data center rooms, and inside the data center rooms.

The goal of the study was to investigate the following questions: (1) What are the approximate statistical distributions of copper and silver corrosion in data centers across the U.S.? (2) Are corrosion coupon measurements repeatable? (3) What is the relation between copper and silver measurements? (4) Are corrosion rates higher for outside-air cooled data centers compared to "closed" data centers? (5) Are corrosion measurements related to IT equipment failure rates?

The results of the study indicate: (1) Copper and silver coupon corrosion rates were generally low in the U.S. compared to rates that are thought to be problematic. (2) Measurements within the same data center frequently differed by a factor of 2 or more. (3) Silver corrosion rates were poorly correlated with copper corrosion rates. (4) Copper corrosion rates are not higher for outside-air-cooled data centers than for "closed" data centers. Silver corrosion rates are not higher in most air-cooled data centers, but may be higher in some. (5) Data centers with relatively high silver corrosion rates reported no unusual equipment failure rates, although detailed analysis of this question is not possible because of the low number of data centers with high silver rates encountered.

IMPLICATIONS

The poor repeatability of the measurements, and the apparent lack of an elevated equipment failure rate in the only facility with a high measured silver corrosion rate, suggest that corrosion coupon measurements may not be useful for predicting equipment failure rates. Most facilities in the study, including outside-air-cooled facilities, did not have elevated corrosion rates, so even if measured corrosion rates do correlate with failure rates, the use of outside air cooling does not seem problematic, in the U.S.

KEYWORDS

data center contamination, gaseous contamination, air-side economizer, corrosion coupon, IT equipment reliability, copper corrosion rate, silver corrosion rate

INTRODUCTION

Data center electricity use is growing 30% annually, making it the fastest-growing end-use of electricity. A large fraction of electricity used in data centers is for compressor-based cooling of IT equipment in data centers (Brill, 2007). As the cost of electric power increases and data center designers strive for lower operational cost, direct use of outside air for IT equipment cooling is becoming more prevalent. Direct use of outside air is often a viable alternative to chilled-water cooling in many environments (Sorell, 2007). Some reports suggest that 20 to 30 percent of the total electrical energy can be saved when outside air is used for cooling compared to a "closed" data center that uses much less outside air. However, there is concern that the use of outside air poses an increased IT equipment failure risk due to corrosion caused by airborne contamination (Lopez et al., 2007).

Airborne contamination can be split into two distinct categories, particulate and gaseous. Particulate contamination can be easily controlled using commonly available filters (Shehabi et al., 2008 and Shehabi et al., 2010) and probably does not contribute to failures as most data centers have adequate filtering. But most filters do not remove gaseous contamination, so there is concern that the use of large amounts of outside air may cause an increase in failure rates due to contamination-induced corrosion (John, 1996).

ASHRAE's Technical Committee (TC) 9.9, published a white paper in 2009 entitled Gaseous and Particulate Contamination Guidelines for Data Centers. (ASHRAE, 2009). That paper raised concerns with data center designers and operators by stating that there is a recent increase in IT equipment failures, due in part to the Restriction of Hazardous Substances Directive (RoHS), associated with airborne pollutants (Cullen 2004; Veale 2005; Schueller 2007; Hillman 2007; Xu 2007; Mazurkiewicz 2006). A casual interpretation of the white paper may cause an unwarranted high level of concern for managers of operating data centers in the U.S. (Han et al., 2010).

A common way to determine the gaseous corrosivity in data centers is the "reactive monitoring" method described in ANSI/ISA-71.04-1985. This method exposes a copper Corrosion Classification Coupon to the environment for a month or more and analyzes the corrosion product thickness using cathodic/electrolytic reduction to classify the environment into one of four severity levels: G1 (Mild, <300 Angstroms(Å)/30 days; corrosion is not a factor in determining equipment reliability); G2 (Moderate, 300-1000Å/30 days; corrosion may be a factor in determining equipment reliability); G3 (Harsh, 1000-2000Å/30 days; high probability that corrosive attack will occur); GX (Severe, >2000Å/30 days; only specially designed and packaged equipment would be expected to survive). The use of copper coupons alone has some limitations: copper is not sensitive to chlorine, a particularly corrosive contaminant to many metals, and copper corrosion may be overly sensitive to relative humidity (Rice et al., 1981). It is now common to include silver coupons along with copper coupons (ASHRAE, 2009).

Since no reports of coupon readings in data centers located in the U.S. have been published we decided to obtain some data. Consequently we selected twenty data centers across the U.S. along with two in India, and exposed coupons for 30 days at each data center. A more comprehensive survey should include measurements spanning a complete calendar year and that is suggested for further studies.

In this paper we consider the following questions:

1) *What are the approximate statistical distributions of copper and silver corrosion rates?*

2) *Are corrosion coupon measurements repeatable?*

An assessment of the accuracy and precision of silver and copper coupon measurements is required to provide a basis for interpreting the results of the field measurements.

3) *What is the relation between copper and silver measurements?*

In the past copper was considered the best measure of corrosion risk and currently only copper corrosion rate limits are listed in the ISA guidelines for IT equipment reliability. Because of the recent shift to the use of silver based materials there is increased interest in how silver corrosion coupon measurements correlate to copper corrosion measurements.

4) *Are corrosion rates higher for outside-air cooled data centers compared to "closed" data centers?*

A key question is whether data centers using large amounts of outside air for cooling have more risk of IT equipment failures. Data centers of both types were included in the survey.

4) *Are corrosion measurements related to IT equipment failure rates?*

None of the operators of data centers participating in the study reported unusual equipment failure rates. Unfortunately we were not able to address this question with statistical results, as none of the data centers reported quantitative failure rate data.

METHODS

Coupon Measurement

Corrosion Classification Coupons (CCC) that include copper and silver strips were used to quantify the corrosive effect of gaseous contamination. Coupons were exposed for 30 days, then analyzed using cathodic/electrolytic reduction. The magnitude of corrosion was quantified by normalizing the measurements in units of Angstroms (Å) per 30 days. To minimize background corrosion during transport, coupons were placed in a sealed plastic bag with a material that acts as a scavenger for ambient contamination.

Coupon Placement

The coupons were placed in 20 data centers located in: California, Texas, Illinois, New Jersey, Georgia, North Carolina, and Massachusetts. Since recent anecdotal evidence suggests IT equipment reliability issues exist in developing countries, two data centers in Bangalore, India were included. The coupons at each data center were placed in three different placement categories: (1) outside-air at the building entry point prior to filtering or conditioning, (2) inside duct work or plenums feeding the data center room and (3) inside the data center room. All data were collected from August to November 2010.

RESULTS

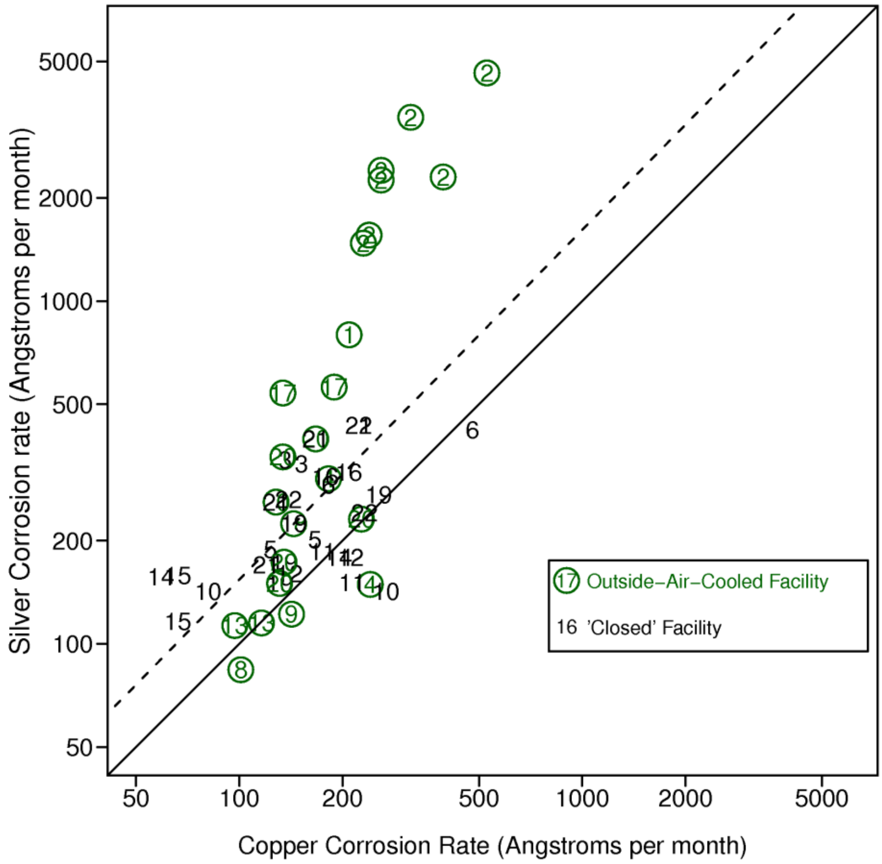
Figure 1 shows the copper and silver measurement for the coupons that were located inside data center rooms. The site number is plotted for each coupon; most sites have more than one coupon. A number with an O around it means the coupon is from a center that is cooled using outside air.

Detailed results of measurements for outside air and air traveling to the data center room are not reported in this paper due to limited space. In this paper we focused on the measurements found inside the data center. See the final report for more complete findings.

What are the approximate statistical distributions of copper and silver corrosion rates?

The average corrosion rate in each facility was calculated, for both copper and silver. Most facilities have an average copper corrosion rate between 125-200 Å/month, and a silver corrosion rate between 140-350 Å/month.

Figure 1: Copper and Silver Measurements from Coupons Placed Inside the Data Centers. Numbers Indicate Data Center Identification. Data Center 2 has high silver corrosion measurements.



Are the corrosion coupon measurements repeatable?

If two measurements are made at the same location at the same time, they should ideally yield the same result. If they do not, the measurements are said to be *imprecise*. Even if measurements are precise, they may not be *accurate.*

We have no way to assess the accuracy of the coupon measurements, but the precision can be assessed by examining: (1) the variation in measurements among the 5 co-located coupons; (2) the variation among the 4 "blank" (uncorroded) coupons; and (3) the variation among coupons that were placed in the same data center. All of these approaches yield roughly the same result: two corrosion rate measurements in the same data center have about a 20-30% chance of differing by more than a factor of 2, for either copper or silver. Even the coupons that were kept sealed in their bags, and should have had no corrosion, had highly variable measurements; in fact, the highest silver measurement was more than five times higher than the lowest, and was higher than the measurement from many coupons that were placed in data centers for a month.

Do data centers using outside air for cooling have different inside coupon corrosion rate measurements compared to "closed" data centers?

In our data, the statistical distribution of copper corrosion rate measurements is comparable in the two types of data centers.

In our data, the statistical distribution of silver corrosion rate measurements has approximately the same median in both types of data centers, but is more variable in outside-air-cooled data centers than in "closed" data centers. The highest and lowest silver corrosion rate measurements were in outside-air-cooled facilities. However, the sample includes only 9 outside-air-cooled facilities, and only facility #2, which is outside-air-cooled, has notably high silver corrosion measurements. It is possible that the high corrosion measurements in this facility are unrelated to the use of outside air for cooling.

Do silver coupon corrosion measurements correlate to copper corrosion measurements?
The correlation between silver and copper corrosion rate measurements is poor, as can be seen in Figure 1. The best-fit relationship is shown by the dashed line. Many points fall far off the line, implying that one cannot use a copper corrosion rate measurement to accurately predict the silver corrosion rate measurement in the same facility, or even on the same coupon. (Technical note: the best-fit power-law relationship is linear, and the silver corrosion rate is, on average, 1.4 times the copper corrosion rate. However, the value of R^2 for the fit in log space is only 0.33).

Do measurements from corrosion rate coupons relate to noticeably higher failure rates of IT equipment?
Quantitative failure data are not available. The data centers participating in this survey report no unusual failure rates during or in the few months after the survey, even in data center #2 with its relatively high silver corrosion rate (1500-4600Å/30 days).

DISCUSSION
The occurrence of high corrosion measurements on coupons that were kept sealed inside their bags implies that corrosion measurements may be inaccurate, at least at relatively low corrosion rates such as those that occur in many data centers. The factor-of-two variation among measurements within a given data center also suggests that the corrosion measurement process is rather error-prone at the corrosion rate levels measured in this study.

Copper and silver corrosion measurements can differ substantially, which is not surprising since these elements react differently to different corrosive gases. There is some correlation between these measurements, suggesting that the coupons are in fact measuring something real about the corrosivity of the environment, in spite of the substantial measurement errors.

Without quantitative error rate data we cannot definitively determine whether high corrosion measurements are associated with high failure rates. Only one data center had a high measured corrosion rate – only for silver – and that center reported no unusually high failure rate. We found no evidence that a high corrosion rate measured by the coupons implies a high equipment failure rate. Possibly there would be a relationship if corrosion rates were higher, but at the observed rates the time to a corrosion-induced failure may be longer than the normal equipment replacement time.

CONCLUSIONS
In this study corrosion coupon measurements were shown to be imprecise. Measured copper corrosion rates were about the same on average in outdoor-air-cooled data centers as in "closed" data centers; measured silver corrosion rates were typically about the same in both

types of centers, but may be higher in some outdoor-air-cooled facilities. There was no evidence that higher silver corrosion rates are associated with higher equipment failure rates, at the levels of corrosion encountered in our study. As a result, the utility of coupon measurements is questionable.

ACKNOWLEDGEMENT
Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE)
California Energy Commission (CEC) Public Interest Energy Research (PIER) Program

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