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Corrosion Prevention in Electrical Control Rooms

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Environmental guidelines to eliminate corrosion failures of control equipment were developed from studies of atmospheric corrosivity in a bleached kraft mill.

The action of extremely small quantities of corrosive gases can cause intermittent or permanent failures in electrical equipment in pulp and paper mill control rooms (1, 2). Electronic microcircuits will fail prematurely in corrosive gas concentrations as much as two orders of magnitude below the maximum concentrations permitted for worker exposure.

Corrosion failures of electrical equipment usually occur by the complete consumption or breakage of fine wires or by the accumulation of resistive corrosion products between circuit breaker contacts. Electronic microcircuits most frequently fail at mating connectors where thin resistive layers of corrosion products spread across the noble metal contact surfaces, or where condensed electrolytes allow leakage currents to flow between adjacent conductors (2, 3). Corrosion products have been found to spread across gold-plated connector surfaces at rates of up to one millimeter in ten hours in parts-per-billion (ppb) concentrations of chlorine and hydrogen sulfide (4). In one survey of pulp and paper mill control rooms, approximately 80% of the rooms monitored had environments that would cause premature failures of electronic microcircuits (1).

Our previous mill studies (5) showed that premature failures of microcircuits only occurred in environments where the total concentration of corrosive gases (the sum of the chlorine, hydrogen sulfide, and sulfur dioxide) exceeded 10 ppb. To eliminate premature failures in electronic equipment, it was recommended that the control room environment should contain no more than 5 ppb of corrosive gases.

In the present work, relationships between atmospheric corrosivity and control equipment failure were examined in a study of 86 control rooms in a single bleached kraft mill. Room environment guidelines have been developed to eliminate premature corrosion failures in electrical equipment and electronic microcircuits. The proportion of control rooms requiring environmental upgrading in the mill studied, and the relationship between the corrosivity of a control room atmosphere and its location in the mill are also discussed.

The Experiment

Monitoring of atmospheric corrosivity

Atmospheric corrosivity was measured with copper metal coupons prepared by proprietary procedures developed to produce reproducibly reactive surfaces covered by uniformly thin oxides. Copper was chosen because its corrosion rate is affected by all the major corrosive gases (chlorine gases and oxidized and reduced sulfur gases). Coupons were transported to and from the control rooms in heat-sealed multilayer polymer bags, shown by controlled environment laboratory tests to prevent the intrusion of corrosive gases. Pairs of coupons were exposed side by side alongside control equipment in the electrical control rooms for 90-day periods. Briefer exposure periods gave data that could not be reliably extrapolated, due to the variability of room environments.

After the coupons has been exposed, their corrosion film thicknesses were measured electrochemically using proprietary cathodic stripping voltammetry procedures. The average distance between the corrosion film thicknesses on paired coupons was less than $\pm 9\%$ of their average film thickness for films thinner than 0.1 micrometers, and less than $\pm 6.5\%$ of their average film thickness for films thicker than 0.1 micrometers.

To facilitate comparison of the atmospheric corrosivity results with published data expressed as the corrosion film thickness produced on copper in a year, equivalent annual corrosion rates were calculated using parabolic kinetics, i.e., the corrosion film was assumed to thicken in proportion to the square root of the exposure duration.

Monitoring of concentration of corrosive gases

Concentrations of corrosive gases were measured using proprietary cartridges containing a series of discs impregnated with reagents to chemically bind chlorine, hydrogen sulfide, and sulfur dioxide (5). Control room air was drawn through the cartridges for one week at a flow of 1 L/min. X-ray fluorescence techniques were developed to measure the concentration of bound species. Volumetric concentrations of corrosives were calculated using data from cartridge standards prepared in laboratory exposures to standard concentrations of corrosives.

Results and Discussion

Relationships between atmospheric corrosivity and equipment failure

The atmospheric corrosivity in each of the 86 electrical rooms in the mill was measured during a 90-day period, using the coupon monitoring procedures described above. Corrosion-related failure histories of control equipment in these rooms were obtained from electrical maintenance staff. **Table 1** summarizes the data, showing the minimum atmospheric corrosivity that caused the different types of failure. Electrical equipment failed in three years in rooms where the atmospheric corrosivity produced more than 0.5 micrometers of corrosion product in a year. Almost all of the 86 electrical rooms also contained electronic microcircuits in programmable logic controllers. Numerous intermittent failures of microcircuits were found in rooms where the atmospheric corrosivity exceeded 0.17 micrometer of corrosion product per

year. Complete failures of electronic equipment occurred after three to four years' service in rooms where the atmospheric corrosivity exceeded 0.19 micrometer of corrosion product per year, after two years of service where the atmospheric corrosivity exceeded 0.76 micrometer per year, and after one year of service where atmospheric corrosivities exceeded 1.3 micrometers per year.

These results indicate that in order to eliminate premature corrosion failures in control rooms containing electrical equipment only (no electronic equipment), the atmosphere must produce less than 0.5 micrometer per year of corrosion product on the copper coupons. To eliminate premature failures of electronic equipment, the control room atmosphere must produce significantly less than 0.2 micrometer per year of corrosion product on the copper coupons. A guideline of 0.1 micrometer per year was chosen as a practical maximum corrosivity to safeguard electronic equipment.

Reduction of atmospheric corrosivity

From these guidelines it was predicted that 28 of the 86 control rooms contained atmospheres that would cause premature failures of electrical equipment. These 28 and 20 other rooms contained atmospheres that would be expected to cause premature failures of electronic equipment. Measures recommended to the mill to upgrade the environments in the unacceptable rooms included sealing up leakage paths that allowed the ingress of corrosive gases, controlling the humidity, and chemically filtering the corrosive gases from the control room air. Where improved sealing and humidity control were inadequate, the mill installed Westvaco Vapor Adsorber® units. Previous work (6) has shown that control room environments can be effectively upgraded by purging sealed rooms with air purified by reaction with the deep bed of specialty activated carbon in these units. Maintaining an overpressure of purified air of more than 20 Pa (0.08 inch of water) in the control rooms has been found to reduce the intrusion of corrosive gases to acceptable levels and thereby eliminate premature corrosion failures of the control equipment.

Concentrations of corrosive gases in selected rooms

In order to estimate the concentration of corrosive gases that would correspond with the guideline limits for atmospheric corrosivity measured by copper coupons, gas analysis was performed in selected rooms. The average concentration of chlorine, hydrogen sulfide, and sulfur dioxide was measured in five of the electrical control rooms during a one-week period following the coupon monitoring. The data are presented in **Table II**. The very low concentrations of these gases (low parts-per-billion levels) illustrates the high reactivity of these gases with control equipment and the criticality of the chlorine concentration.

The three control rooms in which the coupons formed between 0.14 and 0.24 micrometers per year of corrosion product contained less than 0.5 ppb of chlorine and 3 to 8 ppb of hydrogen sulfide. The two rooms in which the coupons formed 4.23 and 7.00 micrometers per year of corrosion product contained 4.2 and 3.4 ppb of chlorine and 9.2 and 1.5 ppb of hydrogen sulfide. The fact that the room where the corrosive gas concentrations were higher produced a lower copper coupon corrosion rate probably indicates a variability in the

atmospheric composition during the test periods in a poorly-sealed room. Comparing the data from the two groups of rooms indicates that increasing the chlorine concentration from 0.5 to 3 or 4 ppb, when the hydrogen sulfide concentration is between 2 and 9 ppb, produces an environment more than eight times more corrosive than the allowable guidelines for electrical equipment.

These data are consistent with previous studies from which we have concluded that to eliminate corrosion failures in electronic equipment, chlorine concentrations should not exceed 1 ppb, hydrogen sulfide concentrations should not exceed 3 ppb, and sulfur dioxide concentrations should not exceed 3 ppb, and the relative humidity should be maintained below 50%. These allowable gas concentrations could probably be doubled for rooms containing electrical equipment only (no microcircuits).

Relationships between room location and atmospheric corrosivity

The predictability of control room atmospheric corrosivity according to room location was studied by indicating the room locations and corrosivities on a plan of the mill. The rooms with the most corrosive atmospheres were generally located adjacent to and downwind and known sources of corrosives, namely the power and recovery boilers and the unbleached and bleached pulp mills. However, a few rooms with highly corrosive environments were found in locations expected to be largely free of corrosives, such as the paper mill, and a few rooms were found to have mild environments in locations close to major sources of corrosives, such as the bleach plant. It was concluded that factors which cannot be quantified, such as room construction and local wind direction, preclude the prediction of atmospheric corrosivity based on mill location. To determine the effect of room environment on control equipment life, it is necessary to measure the atmospheric corrosivity in the room concerned, using copper coupons.

It should be noted that the presence or absence of odorous gases is not a reliable indication of atmospheric corrosivity in control rooms. The allowable limits for chlorine, hydrogen sulfide, and sulfur dioxide mentioned above are far below human olfactory limits. On the other hand, related laboratory studies, as illustrated in **Table III**, have shown that even part-per-million concentrations of odorous organic sulfide gases produced in the kraft pulping process are not corrosive.

Conclusions

The likelihood of corrosion-related failures of control equipment can be determined from the corrosion rate of specially-prepared coupons exposed for 9-day periods in the environment concerned. A systematic corrosion study of all the electrical rooms in a bleached kraft mill indicated that electrical equipment failed when the coupon corrosion rate exceeded the equivalent of 0.5 micrometer per year, and that electronic equipment failed when the coupon corrosion rate exceeded the equivalent of about 0.2 micrometer per year. Within the range of concentrations of corrosive gases found in the selected rooms, the concentration of chlorine was found to be the most influential factor determining the corrosion rate. Knowing the location of a control room in relation to known sources of corrosives is insufficient to estimate its atmospheric corrosivity. Purging of control rooms with highly purified air to maintain a positive room

overpressure reduces the concentration of atmospheric corrosives to levels that eliminate corrosion failures in control equipment.

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