# Preventive maintenance of computer systems by environmental controls

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*Corrosion can be prevented by controlling air quality in rooms where electronics are located.*

The utilization of "environmental control" within process control centers and motor control centers as part of the millwide preventive maintenance program is often overlooked. Preventive maintenance programs for mechanical equipment components, such as bearings, were implemented decades ago and have become part of the standard operating procedures within industrial plants. Yet similar programs for electronic and electrical equipment are often not understood. This misunderstanding often leads to a lack of appreciation, acceptance, and implementation and usually results in unnecessary repair and replacement costs for circuit boards and components in process and motor control equipment.

At a recent process control conference, a four-hour symposium featured a discussion on hiring, training, and maintaining electronic repair technicians. The workload for electronic repair shops in plant maintenance departments is increasing dramatically. Coincidentally, the utilization of electronic control systems has increased dramatically. Large industrial plants are attempting to staff their repair shops around the clock. The short-term focus is just to handle the burden by training more technicians. As electronic equipment repair costs escalate, many instrumentation and maintenance managers have realized that preventive costs are less than repair costs.

Corrosion of contacts and components on circuit boards accounts for about 30-40% of all equipment failures. This corrosion is caused by combinations of uncontrolled temperature, humidity, and corrosive gases inside the electronic equipment room. This paper discusses design considerations for building "controlled environmental rooms" for electronic equipment.

## Standards for environmental conditions

As part of a preventive maintenance program, specifications are needed by which environmental conditions within electronics rooms can be measured. If the quality of the air can be controlled to remove the corrosivity, then the preventive maintenance program will extend the life of the electronics, reduce the repair and replacement costs, and, most importantly, eliminate aberrations in the revenue generating processes.

The Instrumentation Society of America has developed a standard covering the influence of airborne contaminants in electronics rooms. ISA-S71.04, entitled "Environmental Conditions for Process Management and Control Systems: Airborne Contaminants," (*1*) was officially released in 1985. This document provides the most comprehensive specifications on three types of airborne contaminants—liquids, particulates, and gases.

The preferred, or optimum, air quality ISA Classification is always designated Class G1 or Severity Level 1 for the specific airborne contaminant. Higher levels of contamination will produce environments classified as G2, G3, and GX (the most severe).

The Classification of Airborne Contaminants (liquids), shown in **Table I**, refers to liquids that will corrode

I. Classification of chemically active contaminants: liquid aerosols (measured in $\mu g/kg$ except as specified)

| *Contaminant* | *Class* | *Severity level 1* *Value* | *Severity level 2* *Value* | *Severity level 3* *Value* | *Severity level X (special)* *Value* |
|---|---|---|---|---|---|
| Vapors* | LA | <1.0 | <5.0 | <20.0 | ≥20.0 |
| Oils | LB | <5.0 | 50.0 | <100.0 | ≥100.0 |
| Sea salt mist | LC | More than 0.5 km inland | Within 0.5 km inland | Offshore installation | T.B.S. |
| Special TBS | LX | T.B.S. | T.B.S. | T.B.S. | T.B.S. |

*For example, trichlorethylene ($CHClCCl_2$)

Notes: 1.0 $\mu g/kg$ = 1.0 parts per billion ($p/10^9$)
T.B.S. = To Be Specified
< is defined as "less than"
> is defined as "greater than"
≥ is defined as "greater than or equal to"

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unprotected equipment. The severity level classifications are differentiated by concentration, and acceptable levels of vapor and oil contaminants are shown under Severity Level 1. These liquids can be transported to the metal circuitry by condensation of vapors or mists. These airborne liquids may just be high levels of humidity, or they can be high pH cleaning solutions used in general housekeeping.

Airborne contaminants in solid particulate form will usually occur as dust. Contamination caused by dust produces mechanical, chemical, electrical, thermal, and magnetic equipment failures. The Classification of Airborne Particulates is given in **Table II.**

The Classification of Reactive Environments (Gases), shown in **Table III,** refers to potential damage that could occur in electronic contacts from the corrosive gases in the air. The severity levels are defined in terms of the corrosion rate of oxygen-free high conductivity copper. An important feature of the ISA standard is that the copper corrosion rate is given in relationship to the electronic equipment's reliability. This relationship is shown in **Table IV.**

Another key part of this standard is the section dealing with corrosive gas concentrations and their effects on the severity level and the copper reactivity level. This information, given in **Table V,** allows the problem to be addressed when gas concentrations or copper corrosion rate data are known.

Included in the last section of the standard is a quantification of the effects of humidity and temperature on corrosion rates. The standard specifies the relative humidity to be less than 50%. From a given gas concentration, the severity level and the copper reactivity level can be expected to increase one severity level for each 10% increase in relative humidity above 50%. Fluctuating humidity greater than ± 6% per hour is also expected to increase the severity level by a factor of one. The standard also suggests that corrosion rates could double for each 10°F increase in the temperature.

As with all standards, ISA S71.04-1985 will be changed in its first revision, because additional information is now available that was not known at the time it was drafted. Additional data on the effects of different gases on corrosion rates for copper and silver coupons have been developed. The need for silver corrosion rate information has become apparent as the use of silver contacts—in the electronics located in motor control centers, for instance—has become routine. Many of the electronic contacts now are gold-plated over a nickel-plated copper substrate. This composite has become widely used, even in residential use on phone contacts and on the pin connectors for personal computers. While the standard can provide the necessary information on copper contacts, there are some situations where the copper-based standard will indicate corrosion-free air when, in fact, corrosion is occurring on the silver contacts or on gold/nickel/copper composite contacts (*2*).

## Corrosion rate measurement

The complexity of the factors affecting equipment reliability and corrosion rates makes the determination of environmental severity levels far from simple. Airborne liquids, particulates, and gases can be present in many

**II.** Classification of airborne particles

| *Particle size* | *Class* | *Severity level (concentration measured in μg/m³)* 1 | 2 | 3 | X |
|---|---|---|---|---|---|
| > 1 mm | SA | <1,000 | <5,000 | <10,000 | ≥10,000 |
| 100 μm to 1000 μm | SB | < 500 | <3,000 | < 5,000 | ≥ 5,000 |
| 1 μm to 100 μm | SC | < 70 | < 200 | < 350 | ≥ 350 |
| <1 μm | SD | < 70 | < 200 | < 350 | ≥ 350 |

Notes: μm = micrometer = 0.001 millimeter
μg/m³ = micrograms per cubic meter

**III.** Classification of reactive environments

| *Severity level* | *G1* | *G2* | *G3* | *GX* |
|---|---|---|---|---|
| Environmental description | Mild | Moderate | Harsh | Severe |
| Copper reactivity level | <300 | <1000 | <2000 | ≥2000 |

(In Å per 30 days)

**IV.** Copper corrosion rate effect on equipment reliability

| *Severity level* | *Copper reactivity level* | *Equipment reliability* |
|---|---|---|
| G1 | < 300Å | Corrosion not a factor |
| G2 | <1000Å | Corrosion may be a factor Environmental controls probably warranted. |
| G3 | <2000Å | High probability of corrosion attack. Evaluate environmental controls or specially designed and packaged equipment. |
| GX | ≥2000Å | Only specially designed and packaged equipment would be expected to survive without environmental controls. |

**V.** Severity levels for various gases

| *Contaminant* | *Gas concentration (ppb average)* *G1 mild* | *G2 moderate* | *G3 harsh* | *GX severe* |
|---|---|---|---|---|
| $H_2S$ | < 3 | < 10 | < 50 | ≥ 50 |
| $SO_2$, $SO_3$ | < 10 | < 100 | < 300 | ≥ 300 |
| $Cl_2$ | < 1 | < 2 | < 10 | ≥ 10 |
| $NO_x$ | < 50 | < 125 | < 1,250 | ≥ 1,250 |
| HF | < 1 | < 2 | < 10 | ≥ 10 |
| $NH_3$ | <500 | <10,000 | <25,000 | ≥25,000 |
| $O_3$ | < 2 | < 25 | < 100 | ≥ 100 |

different combinations. Their synergy is even further complicated by temperature and humidity effects. The most straightforward method to determine severity levels is to measure directly copper corrosion rates using the prescribed method in ISA-S71-04-1985. The methodology can be expanded to include silver corrosion rates and gold/nickel/copper composite corrosion rates should these contact materials be present in the electronics. The application of the corrosion rates is valid both before and after the installation of clean air equipment.

The corrosion classification coupons are available from most companies who participate in the gas-phase filtration market. The data from the relative corrosion rates of the copper and silver coupons not only give information on severity levels but also help identify problems such as humidity fluctuations and the presence of gases like chlorine and oxides of nitrogen.

There are limitations in the usefulness of the data determined from the corrosion classification coupons. Because this is destructive testing of the exposed coupon, the information gathered is only a "snapshot" of the conditions in the exposed area. Information on past corrosion problems experienced in the environment may not have been detected because of coupon testing protocol. Coupons that are left in a corrosive environment for 90 days may not, by analysis, indicate a problem until 100 or more days after placement. Long-term corrosion information, giving cumulative amounts of corrosion experienced by the electronic equipment, would be useful in predicting when failures will become a factor in the reliability of the equipment. The recent development of "real-time" corrosion monitors that can electronically measure the cumulative, as well as the differential, corrosion over time will eliminate the limitations associated with corrosion classification coupons.

## Air conditioning factors

Air conditioning has special significance in the control room environment. The (usually) high sensible heat loads generated by electrical and electronic equipment (*3*) often necessitate the use of heating, ventilation, air conditioning (HVAC) equipment especially designed for control rooms. Standard commercial and industrial units are designed for high latent loads related to the number of people present in the air conditioned space and may not be suitable for control rooms.

Other air conditioning considerations include choices between air-cooled or water-cooled condensers, and whether to locate the unit inside or outside the clean air space. The importance of these factors will become evident when different room designs are considered.

## Air filtration factors

Air filtration devices can effectively remove all particulate and corrosive gas contaminants and most, if not all, of the airborne liquids when the proper considerations are made in choosing mechanical and chemical filter media. A typical air filtration device has three major sections, as shown in **Fig. 1.** The first section is a prefilter that is usually rated 20-30% American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) efficiency. For unusually high levels of particulate concentrations, such as sawdust and dried paper dust around paper mill areas, high-capacity bag filters are usually used to reduce the frequency of filter replacement.

The prefilter section is followed by a media containment section. Either carbon-based media or alumina-based media are chosen, based upon the corrosive gas contaminants and their concentrations. The carbon-based media can be unimpregnated activated carbon if simple adsorption of contaminants will provide a corrosive gas-free environment. Impregnated carbons have been dosed with special chemicals to allow for removal of those gases that are not readily adsorbed on activated carbon, such as hydrogen sulfide. However, this impregnation enhances the carbon-based media's removal capacity and efficiency by sacrificing its ability to absorb normally those chemicals that it can usually capture. Alumina-based media are usually impregnated with potassium permanganate, which is a strong oxidizer.

While impregnated carbons tend to be selective for removing a narrow range of contaminants, potassium permanganate impregnated media are broad spectrum in their ability to react with a wide variety of contaminants. The potassium permanganate media tend to have lower capacity for those gases that impregnated carbon can remove, but a mixture of carbons with quite different impregnates would be required to cover even a small part of the spectrum of contaminants that the single potassium permanganate media could remove.

The final filter section of the air filtration device ensures that the atmospheric dust that passes through the moderately efficient prefilter and any media dust are trapped in a high-efficiency filter before they can contaminate the room.

The air filtration device can be equipped with an integral blower to move the air through the particulate filters and the media bed(s). Air filtration devices are often designed with redundant blowers to provide backup assurance that clean, contaminant-free air is available to protect the electronics should a blower fail because of a motor or drive belt problem.

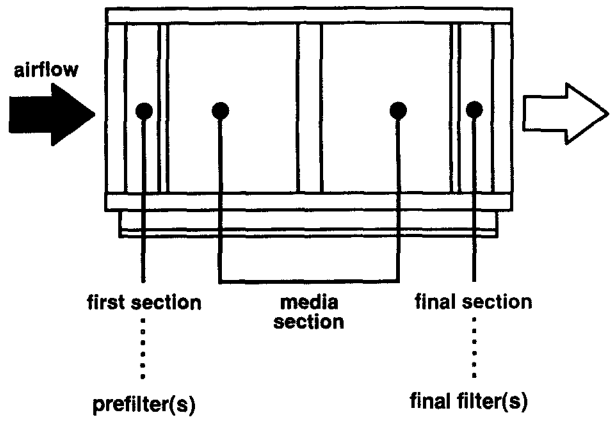
The major consideration in air filtration devices designed to remove gaseous contaminants is the removal efficiency and capacity of the chemical media for the target corrosive gases. Less than desirable protection levels have resulted because the proper media or combination of media were not specified. Applications are often different within a single plant site.

Another consideration is the quantity of media to put in the system. Maintenance personnel desire units that have long intervals between media changeouts.

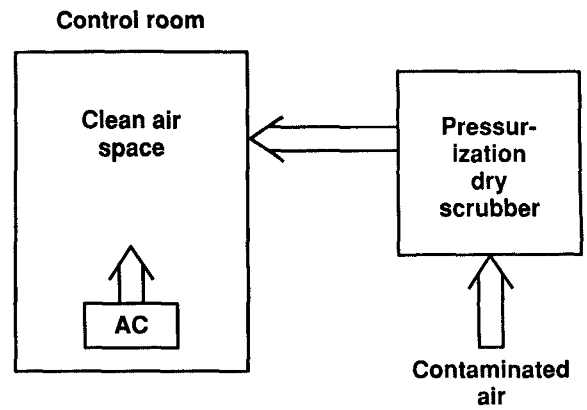
The simplest technique is to put the media in "deep beds," where sufficient quantities are used to give changeout frequencies of 12 months or longer. However, the use of air filtration units which contain "thin bed" modules filled with media can give acceptable changeout intervals when corrosive gas concentrations are relatively low. Sometimes, because of space limitations or budget restrictions, module units are selected. These applications usually require frequent maintenance to ensure the proper levels of protection.

Additional system choices available include those designed for inside or outside the protected room. These

**1.** Air filtration device



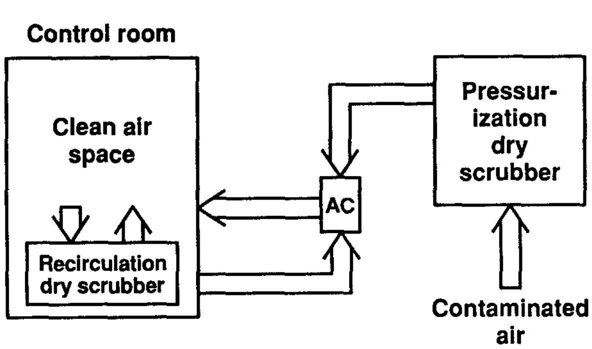

**2.** Control room layout, using pressurization only, with air-handling equipment inside clean air space




**Design considerations are that:**

- **Air-handling equipment is protected from corrosion**
- **In-leakage through ducting and air handler housing is eliminated**
- **Room humidity and temperature are difficult to control**

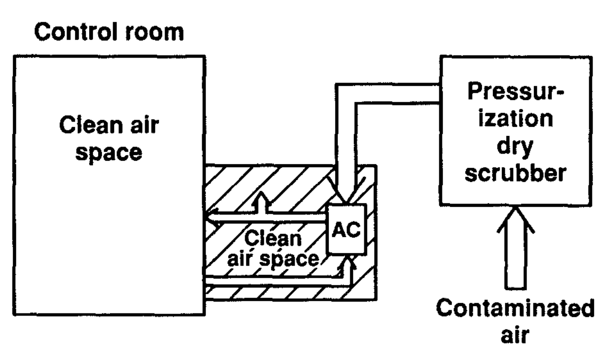
**3.** Control room layout, using pressurization and recirculation, with air-handling equipment located in an outside contaminated area




**Design considerations are that:**

- **Air-handling equipment is protected from corrosion**
- **In-leakage through ducting and air handling equipment is probable**
- **Room humidity and temperature are controlled**

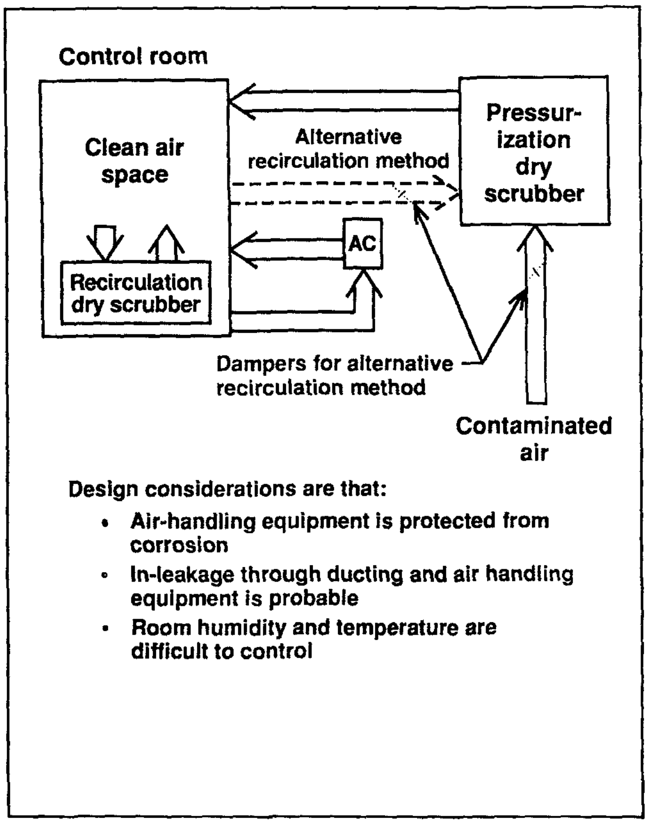
**4.** Control room layout, using pressurization only, with air-handling equipment inside adjoining pressurized equipment room



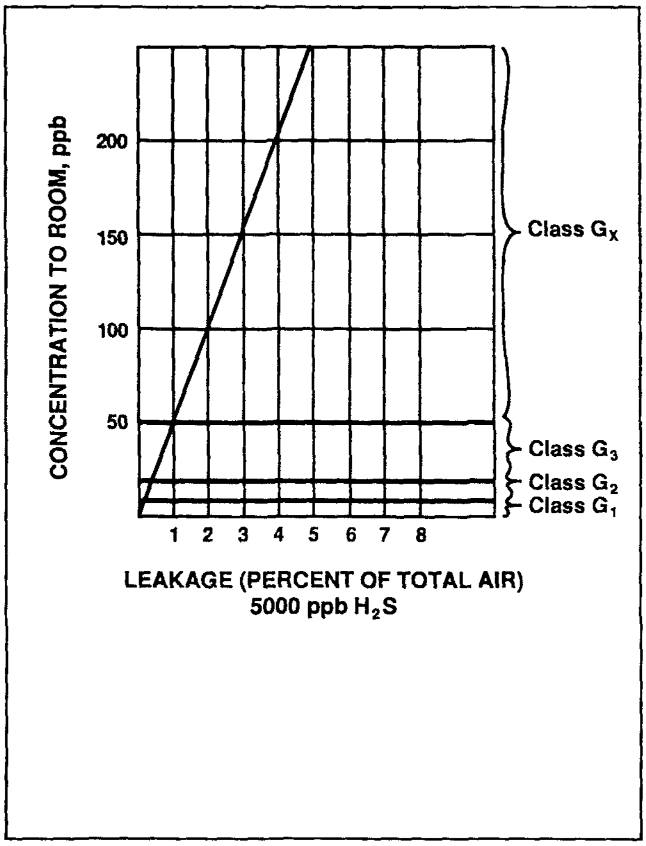

**Design considerations are that:**

- **Air-handling equipment is protected from corrosion**
- **In-leakage through ducting and air handling equipment is eliminated**
- **Room humidity and temperature are controlled**

5. Control room layout, using pressurization and circulation, with air-handling equipment located in outside contaminated air




6. Leakage effects




systems are available in a variety of materials—painted steel, galvanized steel, aluminum, stainless steel, and fiberglass.

Maintenance and instrument engineers have a number of options to choose from that can satisfy the primary protection objective, as well as meet most budget requirements.

## The control room

The condition of the room to be used as the control room is an important consideration. The key to corrosive gas control is to maintain a sufficient quantity of "clean air" going into the room (*4*) to maintain a positive pressure. If funds are not allocated to install airlock doors, and to close and seal the multitude of holes and cracks in the walls and ceilings, then do not spend money on air filtration equipment. Instead, set aside the cost of the air filtration equipment to be used for repair of the installed electronic systems. The need for a well-sealed room cannot be overstated. A room that has been sealed will have minimum leakage.

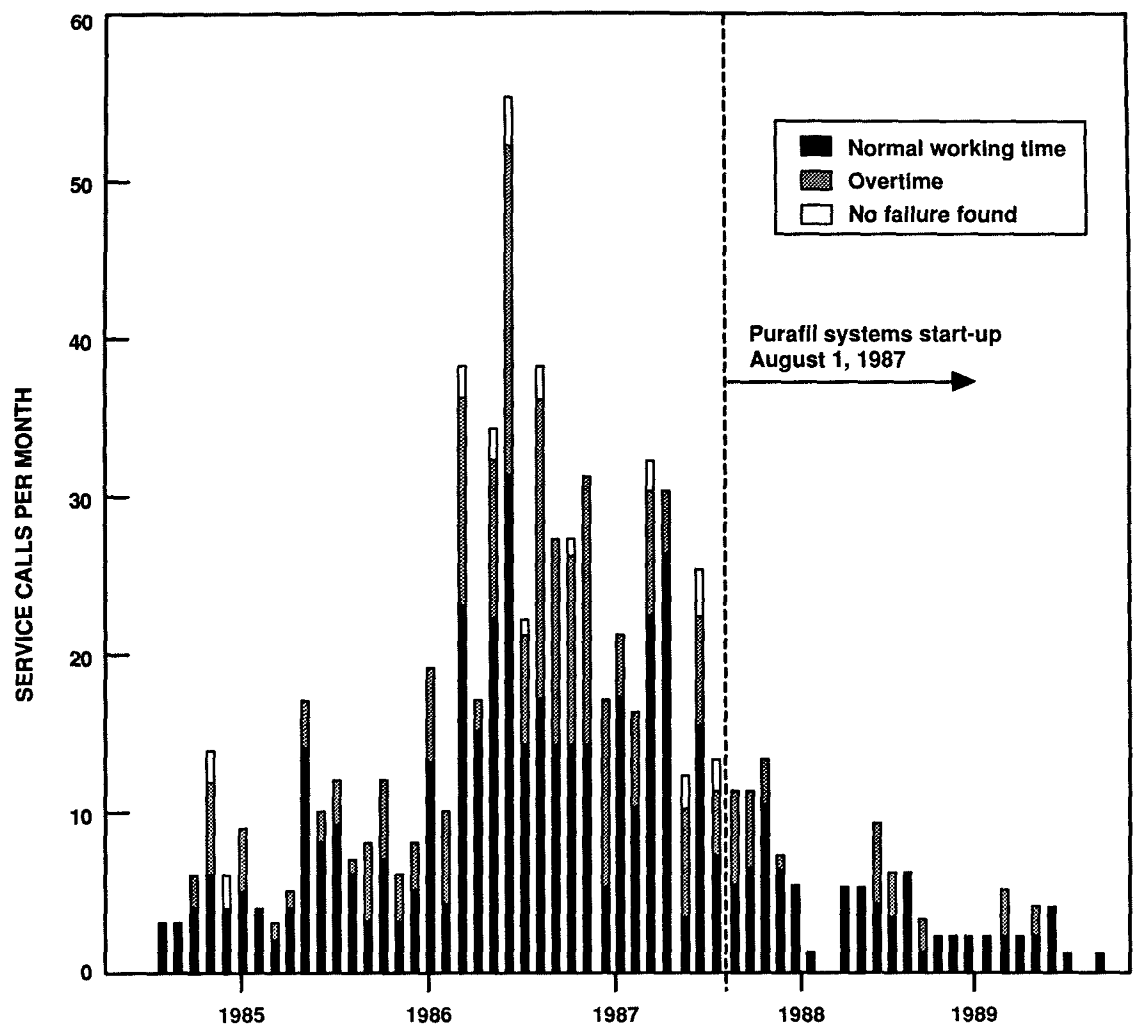
A well-sealed room requires less air to maintain positive pressure, which means that a smaller-sized (in terms of air flow-rate capacity and media fill) air filtration device is needed. A smaller air filtration device will reduce the size of the air conditioning, because the latent load associated with dehumidification of the outside air is reduced in proportion to the quantity of outside air. There are operating cost and energy savings in conditioning less air. Operating expenses for the media changeout in the air filtration devices is also reduced, because less total contamination has to be removed as the total amount of treated outside air is reduced. These projected savings in the capital budget for air conditioning and air filtration, plus the operating cost savings, should be sufficient to cover the cost of sealing the room. In one sense, sealing the room is "free," and not sealing the room only causes the incursion of unnecessary expenses.

The typical control room or motor control center layouts are shown in **Figs. 2-5.** The design considerations (*5*), as noted below each figure, are provided to show the positive or negative points of each system.

Room pressurization, as shown in Fig. 2, is straightforward. The room is pressurized between 0.05 to 0.10 in. of water. Depending on how well the room is sealed, the required air flow rate will be equal to 2-12% of the room air volume per minute. For reference, an air pressurization flow rate of about 1.7% room air volume per minute equals one air change per hour. As the amount of outside air is increased to about two air changes per hour, or about 3.5% room air volume per minute, control of the room's relative humidity becomes more difficult.

Therefore, the preferred method is to direct the filtered outside pressurization air into the air conditioning system so that this air crosses the coils. This allows air tempering of the outside air as well as protection for the coils. (The significance of this design strategy is reflected in the ISA standard that says a 6% change in relative humidity in a one-hour period may raise the copper corrosion level or severity level one class. The standard also indicates a possible increase of one level of severity for each 10% of relative humidity above 50%.) The necessity to seal the

7. Monthly service calls, Finnish pulp mill, cross connection room




room to reduce the quantity of pressurization air cannot be overstressed, especially when it is not feasible to couple the air filtration and air conditioning systems to temper the pressurization air.

Another consideration is the effect of leakage on the inside room air quality. **Figure 6** shows the relationship (*6*) among the control room gas concentration, the leakage rate, and the outside room concentrations. For example, if the leakage rate is 1% and the outside gas concentration is 5000 ppb, then the control room concentration will contain 60 ppb. If the gas contaminant is $H_2S$, then this 1% leakage is enough to raise the room classification from G1 to GX.

Where does leakage occur? Gases infiltrate cracks and holes in rooms that are tight enough to be pressurized. Even sealed, pressurized rooms with exposed walls toward prevailing winds will have contamination blown through the small cracks, because the static pressure of the wind can be greater than the internal room pressure. Leakage will also occur in the low pressure fan and duct sections of the air conditioners mounted outside the clean air space. Commercial and industrial quality air conditioners are not designed to be leak free, and leakage of 4% or 5% is not unusual.

Besides leakage, airborne contaminants can enter the clean air space on gas-saturated personnel clothing, cleaning solutions, and especially in dirt tracked into the room on workers' shoes. Standard practice at some mills is to mop the control room floors at least once a day to remove dirt. This dirt is saturated with contaminants. There are very few bright yellow raincoats after a few weeks' use in the mill. Most are stained and saturated with contaminants. It only takes some casual observation in a mill to see how contaminants can be introduced into a room that otherwise is well sealed, pressurized with clean air, and under temperature and humidity control.

If leakage and tramp contaminants are problems, then recirculation of air inside the room through air filtration devices will reduce the contaminant levels. A reasonable approach toward recirculation is warranted. If a room like a motor control center, which is otherwise well-sealed and has well-designed and well-placed air filtration and HVAC equipment, gets little pedestrian traffic, then pressurization alone will probably suffice. If the room is critical, such as the control room on the wet end of the paper machine, where proper operation of the control system is essential and where there is a lot of foot traffic through the room, then recirculation should be seriously considered. Recirculation can always be added at a later date, should coupon testing indicate that contamination inside the room is threatening the reliability of the electronics.

The recirculation rate is usually specified to be between 10% and 25% of the room air volume per minute. The higher recirculation rates are usually specified when the higher ambient contamination levels outlined in the ISA standard are present. Recirculation can be accomplished by utilization of "deep bed" air filtration devices, but economics usually warrants the use of "thin bed" units.

## Air filtration reduces service calls

An example of how air filtration devices can reduce preventive maintenance cost is graphically shown in **Fig. 7**. This figure shows the monthly frequency of service calls for a pulp mill's cross connection room in a Finnish paper mill. The room had been initially installed without air filtration. Over a period of several years, the electronics started deteriorating. Repair and replacement costs are reflected in the number of service calls.

Note that the number of service calls are broken down by those required during normal working hours and on an overtime basis. Also shown are the number of times during a month that a problem was intermittent, and no problem was found during the service call.

Air filtration equipment was installed in the room on Aug. 1, 1987, as indicated by the dotted vertical line. After that time, there was an obvious decrease in the service calls required in this room. There are still some intermittent problems, probably associated with corrosion during the time period when air filtration was not installed in the room.

## Summary

Air filtration to protect electronic instrumentation should be viewed as a critical component of the millwide preventive maintenance program. The damage to electronic controls not only puts the operation of the mill systems in jeopardy, but the damage is being repaired at an expense greater than the preventive cost. Standards from the Instrument Society of America provide guidelines for monitoring the status of a preventive maintenance program. The program needs to include an awareness of the need for properly sealed rooms, as well as properly selected and located air filtration and air conditioning equipment. The use of corrosion classification coupons of copper/silver and gold/nickel/copper composites that correspond to the contact materials in the electronics should be used as part of the monitoring program. The inclusion of air filtration devices in electronics rooms have been shown to significantly decrease the number of service calls into the room.□

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