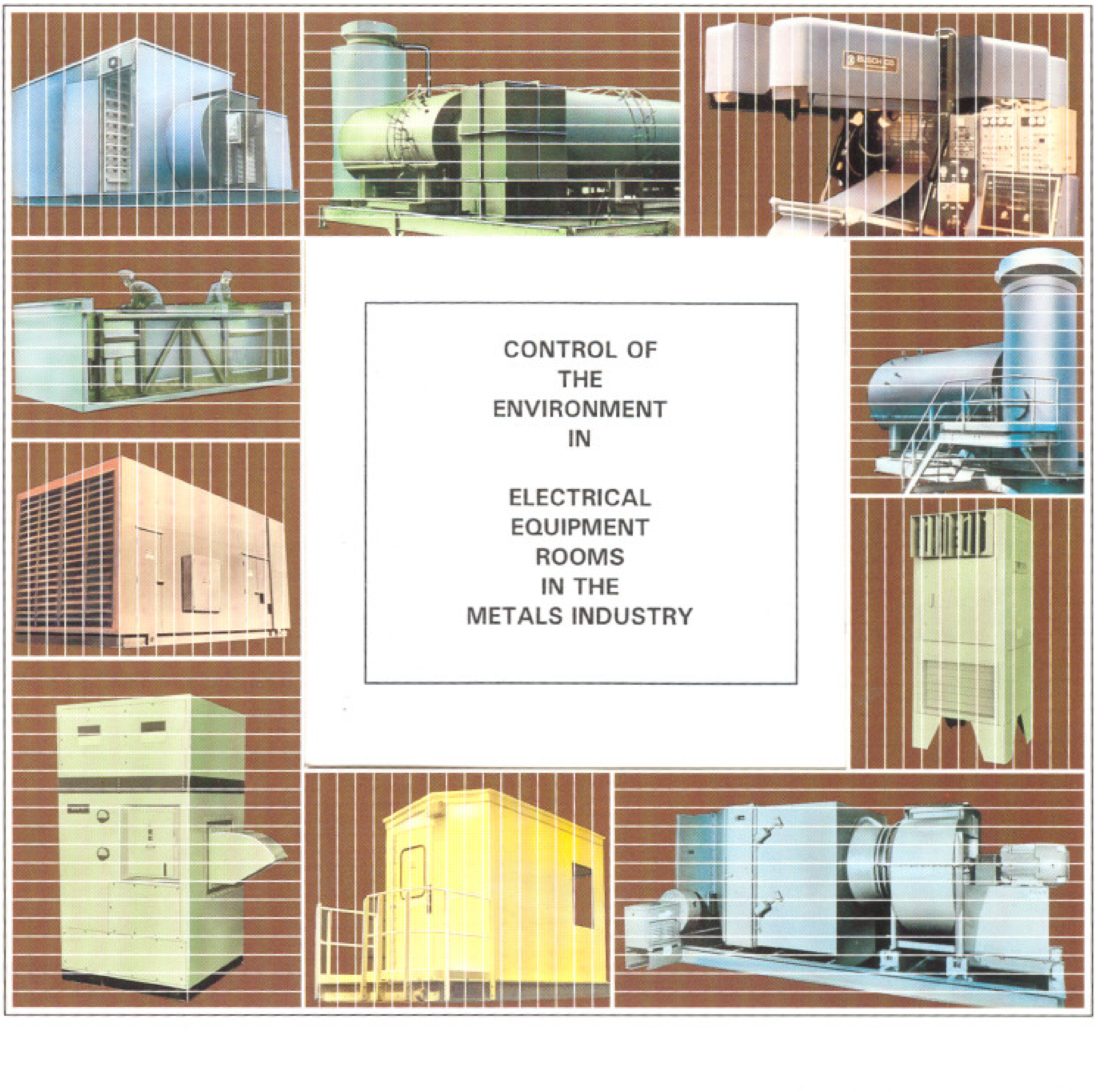
BUSCH *PRODUCTS and SYSTEMS*



CONTROL OF
THE
ENVIRONMENT
IN

ELECTRICAL
EQUIPMENT
ROOMS
IN THE
METALS INDUSTRY

BUSCH
INTERNATIONAL

CONTROL OF THE ENVIRONMENT IN ELECTRICAL EQUIPMENT ROOMS IN THE METALS INDUSTRY

A common requirement for engineers in the Metals Industry is to design ventilation systems for electrical equipment rooms. Those areas that are most often of concern include Motor Rooms, Transformer Vaults, Power Control Rooms, Computer Rooms, Pulpits and similar enclosures.

In the past it was common practice for the owner to purchase ventilation equipment through an installing contractor or electrical equipment supplier. Problems have resulted from this approach due to the unique ventilation requirements associated with the mill environment. Principal faults encountered when applying standard equipment and design practice to these projects include the following:

1. Insufficient quantity of ventilation air for equipment cooling or personnel stress relief.
2. Poor performance and high maintenance requirements of air filter systems.
3. Corrosion of sensitive equipment due to condensation or airborne contaminants.
4. Use of incorrect airflow distribution patterns.
5. High noise levels.

This paper examines the most successful methods for ventilation of large electrical equipment enclosures in the metals industry. Sufficient technical improvements in ventilation equipment design have occurred in recent years to mandate increased attention to this subject. Recent innovations include self-cleaning, high efficiency filters; "packaged" ventilation units with capacities as high as 250,000 CFM; advanced corrosion protection systems; and improved heating and cooling technologies.

SYSTEM DESIGN OBJECTIVES

The primary objectives in designing a ventilation system for electrical equipment are to provide an environment that will extend equipment life, allow the equipment to operate at maximum efficiency at its rated capacity, with a minimum of downtime and do so at a cost effective level. Unfortunately, maintenance of ventilation equipment is frequently assigned to personnel based on their availability instead of their familiarity with the system and its function. Therefore, a system requiring not more than once-a-month routine maintenance could well be the design engineer's objective. Every effort should be exerted to keep the ventilation system uncomplicated. Automatic temperature controls, damper motors, alarm mechanisms, etc., should be used sparingly, and then only when there is good reason to believe they will be of practical value to the maintenance department. Complicated control systems are often not understood by the end user and are frequently "blocked-out" in favor of manual operation. System redundancy, where required, should be "built-in" and not added-on in the form of additional equipment.

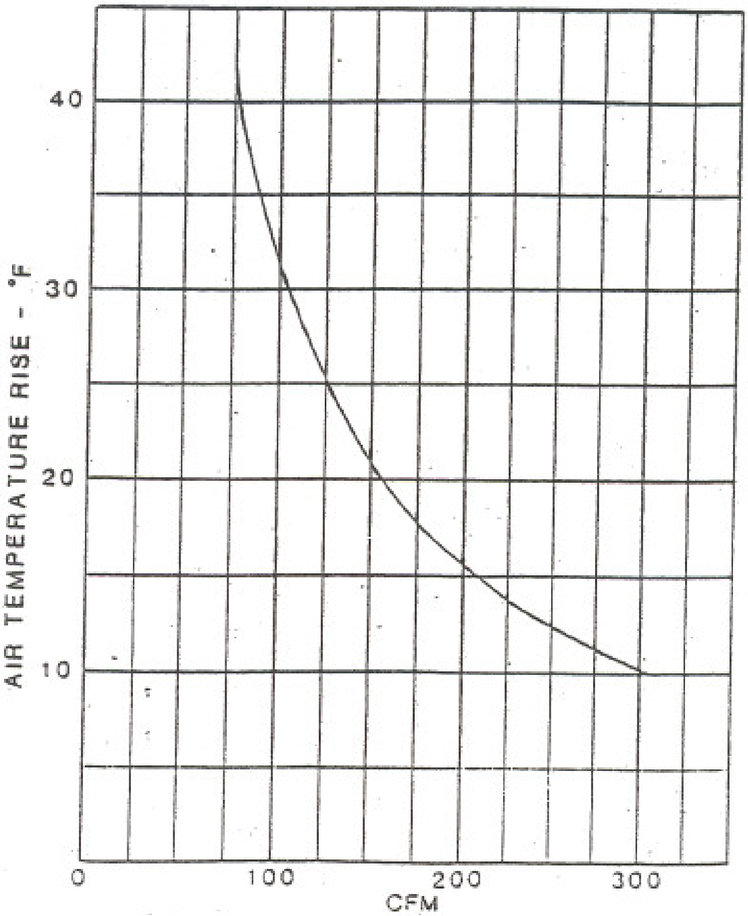
For simplicity and economic reasons, a ventilation system using filtered ambient air as the heat dissipating medium should be used where possible. Mechanical refrigeration systems involve complex compression equipment and are generally considered less desirable from a maintenance and a dependability standpoint.

SYSTEM DESIGN STANDARDS

The determination of proper air volume for ventilating electrical enclosures is generally a function of allowable temperature rise of the ventilation air. In the past, a rule-of-thumb of 120 cfm of outside air per kw loss from the electrical equipment has been applied indiscriminately and often without sufficient concern for final air temperature. For example, the air temperature rise associated with an airflow rate of 120 cfm per kw loss is approximately 26.5°F (See Figure 1). This can result in a motor room average ambient temperature in excess of 120°F on a 95°F summer day. Such temperatures are not uncommon in the zone of occupancy of older steel mill motor rooms.

FIGURE I

VENTILATION AIR FLOW RATE
CFM PER KILOWATT LOSS



In recent years, many engineers charged with design of motor room ventilation systems have insisted on increased quantities of ventilation air to obtain results more consistent with realistic equipment and personnel requirements. Based on a maximum summer outdoor design temperature of 95°F dry bulb/75 F wet bulb[1] , a 15 F maximum temperature rise for spaces infrequently occupied by personnel is suggested as a minimum design goal. This requires approximately 210 cfm of ventilation air per kw of heat rejected from the electrical equipment. This is a flow rate which will be exceeded for motor rooms on several large rolling mills now in the design or construction stage. Many engineers experienced in ventilation system design feel the maximum design temperature rise should not exceed 10°F on a 1% design basis. (Design temperatures are equaled or exceeded during 1% of the total hours in the months of June through September.)

The following data establishes the order of magnitude of some typical electrical equipment ventilation air requirements in the Steel Industry:

Equipment	Required CFM (Ambient Air)
80 Inch Hot Strip Mill	1,200,000
5-Stand Cold Mill	650,000
48 x 90 in. Slabbing Mill	650,000
80 in. Pickle Line	400,000
80 in. Galvanizing Line	300,000
Two-Stand 80 in. Temper Mill	275,000
Single-Stand Skin Pass Mill	100,000

AIR FILTRATION STANDARDS

It is a basic premise when designing ventilation systems for an electrical enclosure that the air delivered to the equipment will be essentially "clean" air. Unfortunately, no phase of ventilation is more obscure than the determination of what constitutes clean air.

In the ventilation of electrical equipment the chief concern is the deposition of dirt on circuit boards, electrical insulation, relay contacts, in internal air passages, and on any surfaces where the thermal insulating or clogging properties of the dirt might cause excessive heat build-up. In addition many dusts found in the metals industry are conductive which is also a hazard to proper electrical equipment function.

Unfiltered ambient air can be defined as air containing particulate matter naturally occurring in the environment. Quantities of particulate typically average 200-400 µgm/M^3 in or around major urban areas.[2]

> A broad definition of ambient air filtration in the industrial environment would be expanded to include the collection of <u>fugitive</u> process dust and particulate collected by methods other than direct source capture. Typical ambient dust loadings in the industrial environment may

---

[1] *ASHRAE, Summer Temperature Conditions, (1% occurrence)*

[2] *1966 EPA "Hi-Vol" Network Data (24 hour average)*

range up to .01 grains/ft.^{3} (22,880 µgm/M^3) or greater. High levels such as these might occur in poorly ventilated steel furnace melt shops, near steel hot strip mills or in slab scarfing areas.

The industry uses a variety of terms when discussing filter performance. Uniform testing standards and concepts have been established by ASHRAE[1] so that various manufacturers' products can be meaningfully compared.

Definition: ASHRAE efficiency is the general term measuring performance, and is the measure of the ability of the filter to remove atmospheric dust from an airstream. Particle sizes in atmospheric dust vary greatly, from over 10 microns to substantially less than one micron. Most of the particles that make up atmospheric dust are less than 1 micron in size; in fact in a typical atmosphere, over 99% of the particulate is less than 1 micron in size. However, it is important to note that the majority of the weight of the dust is contained in the largest particles so that in a typical atmosphere, the 1% of the particles over 1 micron in size make up 70% of the weight. Efficiency as defined by ASHRAE (52-76) test method relates only to tests made by the "Dust Spot" procedure.

FIGURE II

TYPICAL ANALYSIS OF DUST FOUND IN AIR AT A VENTILATION AIR INTAKE FOR STEEL MILL ELECTRICAL CONTROL ROOM

CONTAMINANT	PERCENT BY WEIGHT
IRON OXIDE	73.6
SILICON DIOXIDE	6.8
CALCIUM OXIDE	2.0
ALUMINUM OXIDE	1.7
MANGANESE OXIDE	1.2
MAGNESIUM OXIDE	1.0
IGNITION LOSS	12.5

It is generally accepted by ventilation designers today, that a *minimum* filtration efficiency of 85% per ASHRAE 52-76 test method is required for proper cleanliness of modern electrical equipment. Automatic roll filters, oil bath filters, washable pads or metal strainer type filters as frequently applied before 1970 have an ASHRAE efficiency of less than 20% and are not acceptable by current industry standards. The challenge to today's designer is to provide high filtration efficiency with minimal maintenance requirements.

PACKAGED VENTILATION UNITS

"Packaged" Ventilation Units consist of fans, motors, filters, heating, cooling and control systems shop assembled by a ventilation supplier into a common housing. Packaged ventilation units are preferable to field erected ventilation systems because of their relatively compact size and ease

---

[1] *American Society of Heating, Refrigerating and Air-Conditioning Engineers*

of installation. Packaged units intended for continuous use in heavy industry should include features designed to provide long service life. Features to be specified should include:

- Minimum 10 ga. welded steel housing
- Structural channel base
- Industrial quality fans
- Wiring in rigid conduit
- Wide fin spacing (8 FPI) on heating coils
- Minimum 85% (per ASHRAE 52-76) filtration

SELF-CLEANING FILTER SYSTEMS

Packaged ventilation units incorporating self-cleaning reverse jet pulse filter systems have been widely applied to electrical room ventilation since about 1980. Several equipment variations exist, with the major difference being the filter media selected. The tube-type non-woven fabric filter has been employed with good success in the steel and aluminum industry. Fabric filter tube technology has been thoroughly proven in process dust collection for over 30 years. When applied to ambient air filtration applications where dust loadings are very low, filter velocities may be increased significantly over those of conventional dust collectors while maintaining good filter life and reasonable pressure differential. Fabric filter tubes are available in many media types including acid resistant fabrics and fabrics with high efficiency membrane surfaces. Typical filter tubes manufactured of polyester felt have efficiencies in excess of 90% and frequently will operate for five or more years without replacement.

Pulse cleanable convoluted fabric or pleated cellulose paper cartridges are also available. These cartridges have been applied successfully to some applications. Generally filter cartridges should only be used where space limitations preclude the use of fabric filter tubes. Filter cartridges have a typical life expectancy of 1-2 years.

CORROSION CONTROL

As modern electrical equipment has evolved, it has also become more susceptible to failure due to corrosive attack. Unfortunately, electrical equipment rooms in the metals industry are often located in areas with high levels of corrosive contaminants. Common sources of airborne corrosive contaminants include pickle lines, cleaning lines and metal burning operations.

Airborne corrosives are made up of gaseous and particulate contaminants. High efficiency filtration systems such as those previously discussed can effectively remove most contaminated dust particulate but cannot remove the gaseous component. In large air volume applications where acidic levels are high, an acid-resistant filter tube media such as polypropylene should be used to remove the particulate.

The most sensitive electronic equipment may be housed in separate smaller enclosures within the motor room. In these enclosures where reduced air volumes are involved, it is practical to remove the corrosive gases from the airstream. Acid gases are most often removed through deep bed carbon filtration. In applications where condensation is also a problem, the deep bed carbon adsorber can be equipped with steam or electric heat to help keep the enclosure above the dew point during production downturns when no equipment heat load exists.

ISA STANDARDS

The Instrument Society of America has developed a means to identify contaminant severity levels in areas housing electrical equipment. This information, when used with site generated sampling data, is useful in selecting corrosion control equipment.

Severity Level G1

Mild - An environment sufficiently well-controlled such that corrosion is not a factor in determining equipment reliability.

Severity Level G2

Moderate- An environment in which the effects of corrosion are measurable and may be a factor in determining equipment reliability.

Severity Level G3

Harsh- An environment in which there is a high probability that corrosive attack will occur.

Severity Level GX

Severe- 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.

FIGURE III

CLASSIFICATION OF REACTIVE ENVIRONMENTS

Severity Level	G1 Mild	G2 Moderate	G3 Harsh	GX Severe
Copper Reactivity Level (in angstroms)*	< 300	< 1000	< 2000	≥ 2000

The gas concentration levels shown below are provided for reference purposes. They are believed to approximate the Copper Reactivity Levels stated above, providing the relative humidity is less than 50%. For a given gas concentration, the Severity Level (and Copper Reactivity Level) can be expected to be increased by one level for each 10% increase in relative humidity above 50% or for a relative humidity rate of change greater than 6% per hour.

Gas Concentration†

	Contaminant	Gas	Concentration			
Reactive Species†‡	Group A	H_2S	< 3	< 10	< 50	≥ 50
		SO_2, SO_3	< 10	< 100	< 300	≥ 300
		Cl_2	< 1	< 2	< 10	≥ 10
		NO_x	< 50	< 125	< 1250	≥ 1250
	Group B§	HF	< 1	< 2	< 10	≥ 10
		NH_3	< 500	$< 10\,000$	$< 25\,000$	$\geq 25\,000$
		O_3	< 2	< 25	< 100	≥ 100

NOTES: *Measured in angstroms after one month's exposure. See Appendix C, Item Numbers 2, 3.
†mm^3/m^3 (cubic millimeters per cubic meter) parts per billion average for test period for the gases in Groups A and B
‡The Group A contaminants often occur together and the reactivity levels include the synergistic effects of these contaminants.
§The synergistic effects of Group B contaminants are not known at this time.

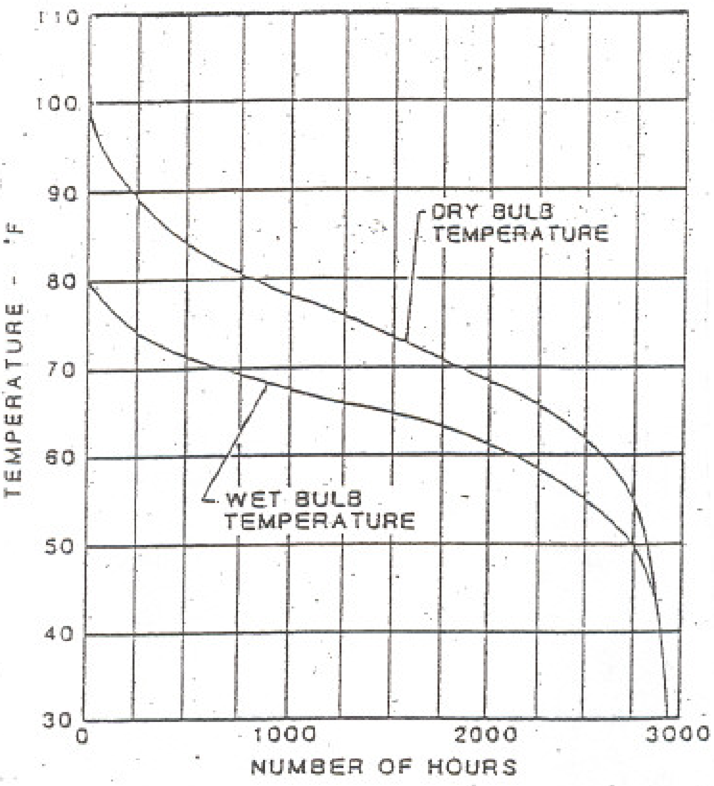
NOTE: Figure III is from Instrument Society of America (I.S.A.) Standard ISA-571.04 "Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants".

HUMIDITY AND EVAPORATIVE COOLING

In adopting standards for ventilation of steel mill electrical equipment the use of evaporative cooling is receiving increased attention. The evaporative cooler can provide a substantially lower ventilation air temperature. This will result in a significantly lower ventilation air volume requirement and a smaller and less complicated air distribution system.

Figure IV demonstrates the applicability of evaporative cooling even to a northern climate as is found in the Chicago area. Note that in this area, for 2000 of the 2928 hrs. of the summer season, a minimum 8°F wet bulb depression is available for evaporative cooling. Under peak summer design conditions this differential between dry bulb and wet bulb temperatures will be as high as 20°F. At least two major steel companies in the Chicago area consistently use evaporative cooling in their motor room ventilation systems. Many systems of this kind are now being employed in the metals industry today.

FIGURE IV



Curves represent number of hours that the temperature in Chicago, IL. was at or above a given point. Difference between wet and dry bulb temperatures is the wet bulb depression available for evaporative cooling. Data are based on a five-year average for a period from June to September.

Typically the evaporative cooler is installed downstream of the air filtration section in order to keep the water distributing media clean. Properly designed, an evaporative cooler will operate at approximately a 90% saturation efficiency. This results in a temperature reduction equal to 90% of the wet bulb depression.

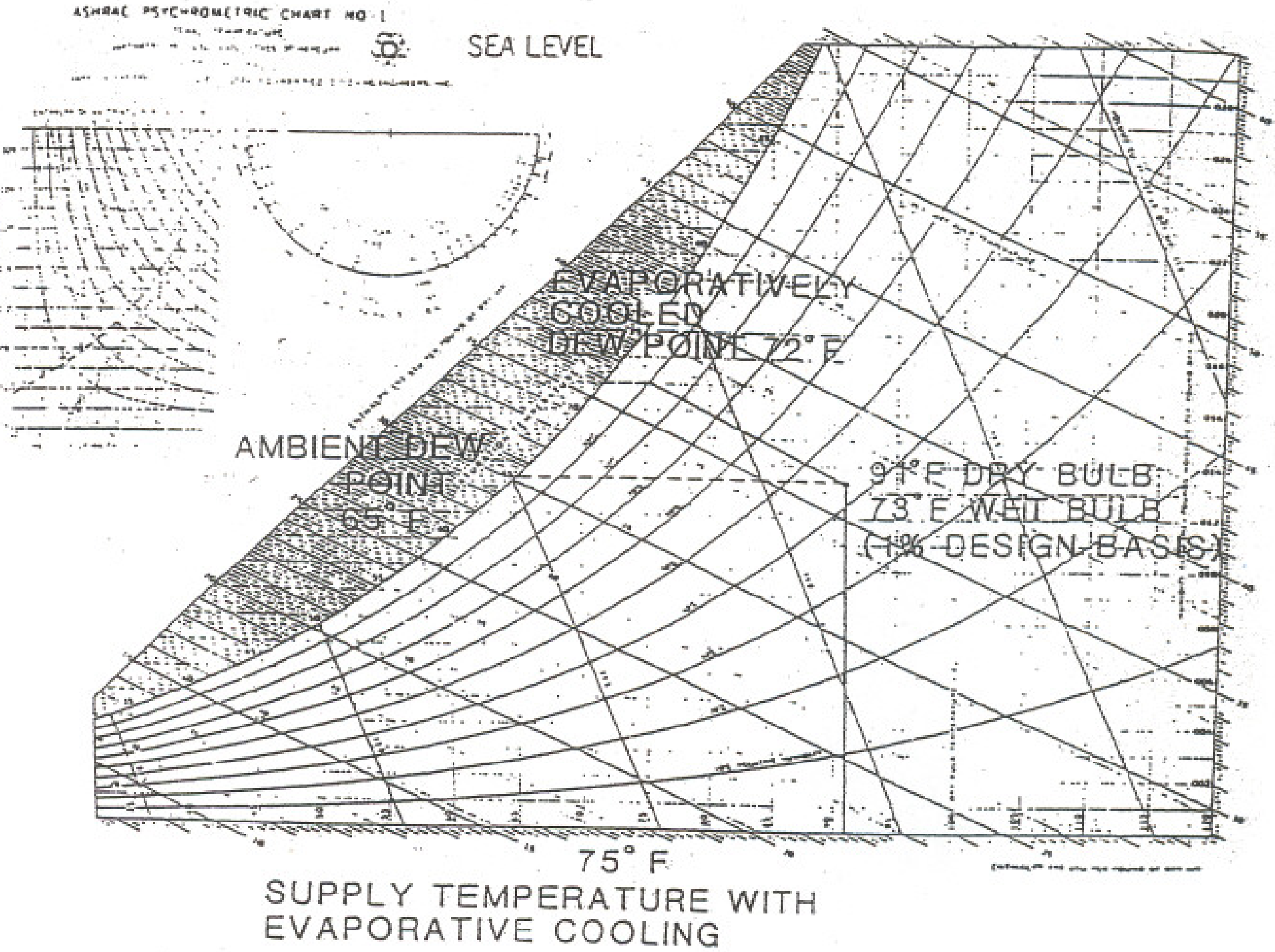
Modern evaporative cooler design has been improved to help reduce maintenance requirements. Most systems supplied today utilize a simple distribution header and convoluted media. This design is more tolerant of less than ideal water purity when compared to older designs that employed spray nozzles or pad media.

When evaporatively cooled air is introduced directly into an electrical basement, the wall temperatures below grade may be below the dew point temperature of the evaporatively cooled air. If this air impinges directly upon the cold wall, some condensation may occur at the wall. A dew point controller, suitably located near such a wall, can be used to shut down the evaporative cooler pump until the wall temperature has reached a suitable level. Properly designed air distribution systems will also minimize this phenomena

FIGURE V

DEW POINT/CONDENSATION TEMPERATURES
TYPICAL OF CLEVELAND, OH AREA

ASHRAE DESIGN - 91°F DB 73° WB 1% Basis



VALUE OF POSITIVE PRESSURE IN ELECTRICAL EQUIPMENT ROOMS

One of the few areas in which all designers of ventilation systems for electrical enclosures are in agreement is in the requirements for positive pressure within the enclosure. With positive pressure, the ventilating air exfiltrates from the enclosure; when negative pressure exists, infiltration of raw air containing dirt and/or corrosive contaminants will take place and a controlled environment cannot be maintained.

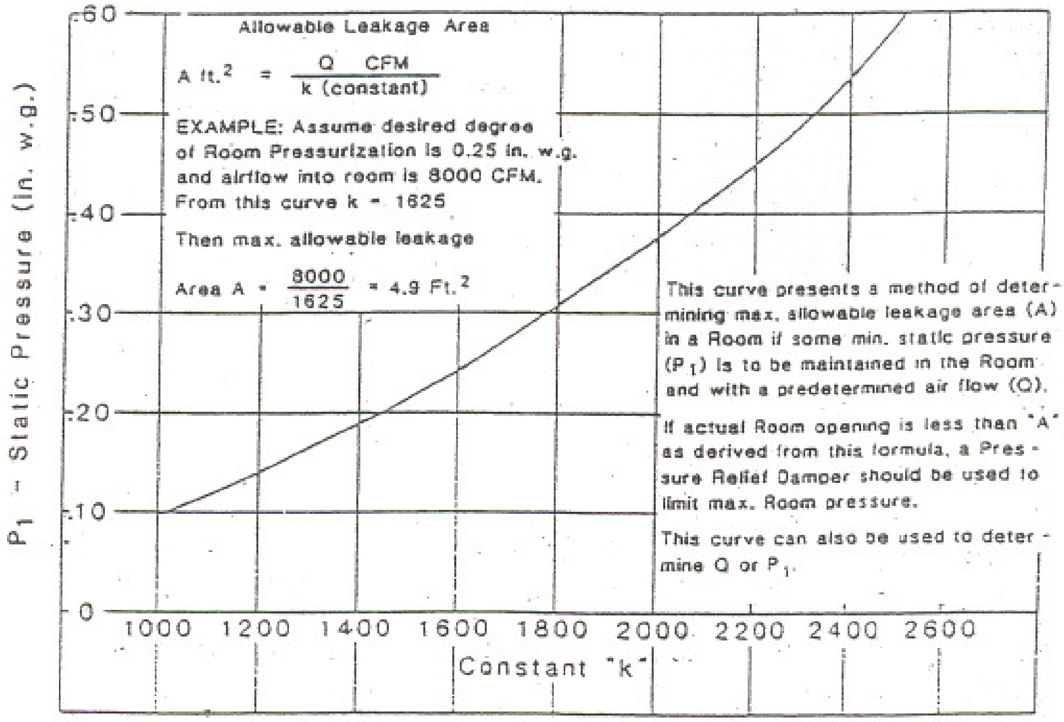
How much positive pressure should be maintained in an electrical enclosure to guarantee exfiltration? Experience indicates that satisfactory conditions are maintained when the system relief dampers are set to open at static pressure between 0.10 and 0.25 in. of water. The higher value is recommended when two or more sides of the enclosure are exposed to the outside since under these conditions the wind pressure may be a factor in producing infiltration.

The type of building construction is also a factor in determining the amount of positive pressure that can be maintained. For example, large mill motor rooms often have single thickness corrugated steel siding and roofing and are not tightly sealed. Several years ago a differential pressure reading was taken between a motor room and an adjacent hot strip mill during a period when 800,000 cfm of outside air was being used to ventilate the room. The resultant pressure differential was only 0.05 in. of water. Even this low positive pressure was sufficient to prevent infiltration when man doors between the motor room and the mill were opened. However, substantial infiltration might be expected in this situation if truck doors in outside walls were opened in even a slight wind.

Motorized or counterbalanced pressure relief dampers are recommended to control the degree of positive pressure. They should be sized on the assumption that at least 30 percent of the total ventilation make-up air will be relieved through them. It is frequently most practical to design the relief dampers so that they vent to a neighboring mill bay. In winter, this helps provide tempered make-up air to these areas. During summer operation, the pressurization air escapes through neighboring roof ventilators.

FIGURE VI

AIR VOLUME REQUIREMENTS FOR ROOM PRESSURIZATION



Allowable Leakage Area

$$A \text{ ft.}^2 = \frac{Q \text{ CFM}}{k \text{ (constant)}}$$

EXAMPLE: Assume desired degree of Room Pressurization is 0.25 in. w.g. and airflow into room is 8000 CFM. From this curve k = 1625

Then max. allowable leakage

$$\text{Area A} = \frac{8000}{1625} = 4.9 \text{ Ft.}^2$$

This curve presents a method of determining max. allowable leakage area (A) in a Room if some min. static pressure (P_1) is to be maintained in the Room and with a predetermined air flow (Q).

If actual Room opening is less than "A" as derived from this formula, a Pressure Relief Damper should be used to limit max. Room pressure.

This curve can also be used to determine Q or P_1.

CONCEPTUAL SYSTEM DESIGN

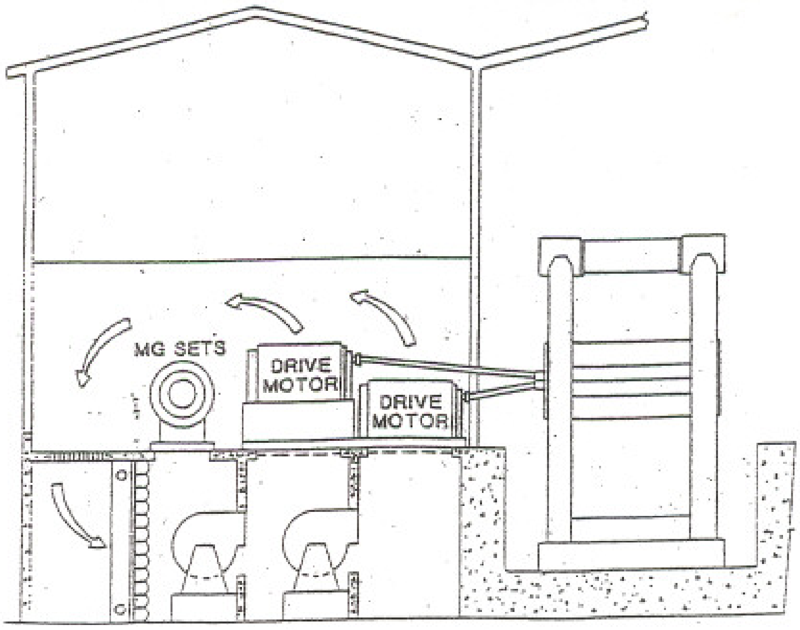
Rolling Mill Motor Rooms - The rolling mill motor room is generally the largest of the electrical equipment enclosures in the metals industry requiring ventilation. Many design procedures applied to motor rooms can also be applied to other electrical rooms. Generally, motor room ventilation systems in use today can be divided into three categories: "Recirculating Systems", "Once-Through Up-Flow Systems", and "Once-Through Down-Flow Systems".

Recirculation Systems are more frequently found in older installations and many are currently being replaced throughout the industry. In a typical recirculating system, air is drawn down or blown up through the drive motors and other force ventilated equipment by metering fans and then through air-to-water heat exchangers and particulate filters. The cooling medium is frequently river water, lake water or water from cooling towers.

Theoretically, when the air-to-water heat exchangers are functioning at peak efficiency, the warm air leaving the electrical gear can be cooled to near entering air temperature and the cycle is repeated.

The design of the recirculating system described above originated in the earlier part of this century. Although well conceived on paper, recirculation systems are difficult to maintain at peak efficiency. River water temperatures have risen steadily; thus the efficiency of the coolers which use river water must be derated. Heat exchangers are also frequently plagued by corrosion, silt build-up, and "biological attack", all of which have a negative effect on performance. Water passages inside the heat exchangers are dark and warm thus providing an ideal breeding ground for freshwater clams and mussels that cause clogging. Recirculating systems generally are designed to bring in only a small amount of make-up air and do not have the capability to maintain adequate positive room pressurization, thus infiltration of dirt and corrosives can be a problem. Because of these problems, many recirculating motor ventilation systems operating today deliver higher than desired air temperatures and many have been taken out of service.

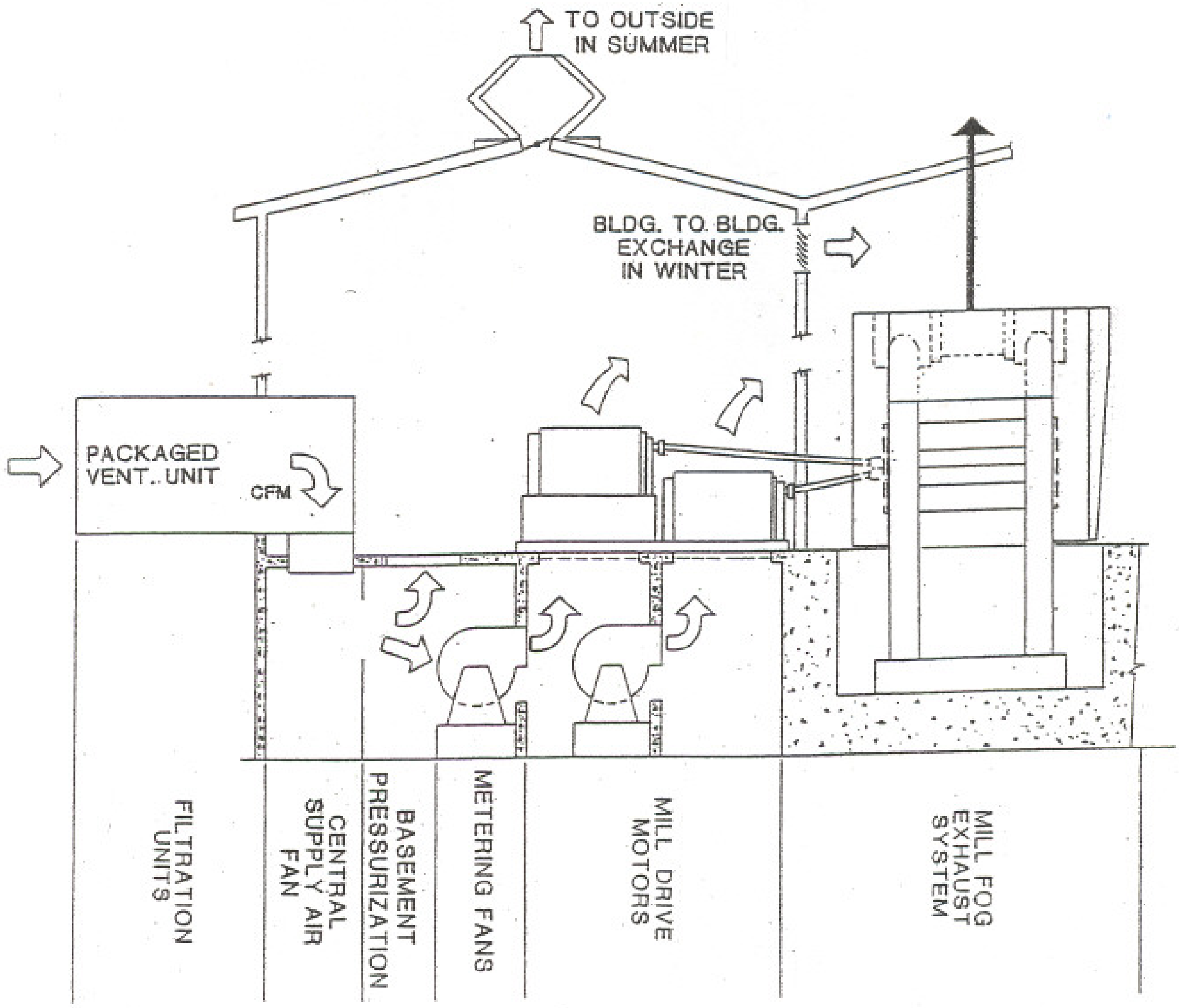
FIGURE VII
RECIRCULATING MOTOR VENTILATION SYSTEM



"Once-Through Up-Flow" Ventilation Systems typically utilize "packaged" supply air filtration units to deliver air directly to the Motor Room Basement. Air is delivered to the force ventilated equipment by metering fans. During summer months the air is vented to the outside by gravity roof vents equipped with motorized dampers. In winter, the dampers are closed and the warm, relatively clean air is vented to the mill bay as make-up air. In winter months, steam heat, gas heat, or recirculating air dampers are used in the main supply air units to temper the air to a minimum supply temperature. One principal advantage of this system design is that the motor room is kept under positive pressure and migration of dirt and corrosives from other areas is reduced. If the system is large enough to create concerns about carbon dust from commutator brushes, motor ventilation air can be ducted directly outside.

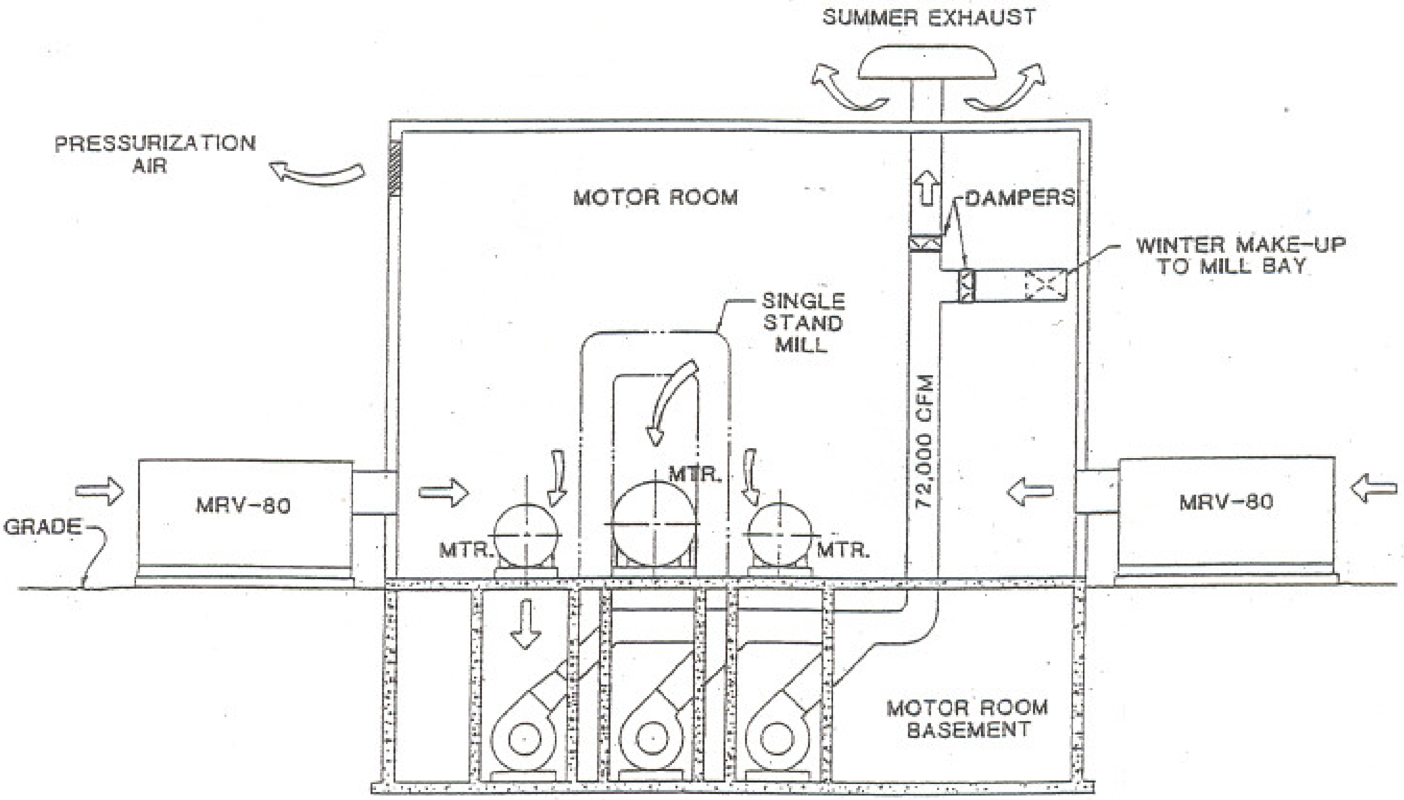
The up-flow system design is frequently used in retrofit installations where the motor room is "land locked" with the only source for outside air being an electrical tunnel or similar opening to the basement, or where the original system utilizes up-flow metering fans that are to be retained.

FIGURE VIII
"ONCE-THROUGH UP-FLOW" VENTILATION SYSTEM



"Once-Through Down-Flow" Ventilation Systems are considered by many to be state-of-the-art. These systems utilize "packaged" supply air filtration units to deliver air directly to the motor room. In summer, the supply air can be evaporatively cooled. In winter, it is tempered with steam or gas heat or by using recirculating dampers. Air is drawn down through metering fans then exhausted directly to the outside in the summer and used as warm makeup air for the mill bay in the winter. This design has the advantages of positive motor room pressurization and winter-time heat recovery like the "Up-Flow System". However, the "Down-Flow System" has the additional benefit of providing the lowest possible temperature at the motor room floor level. A properly designed "Down-Flow System" will result in no more than a 10°F temperature rise over outdoor ambient conditions on a 1% basis in occupied areas. Supply air should be taken from the cleanest possible source to help reduce the level of acids and other contaminants delivered to the motor room.

FIGURE IX
"ONCE-THROUGH DOWN-FLOW" VENTILATION SYSTEM



CONCLUSION

During the early phases of a project it is important to develop a conceptual ventilation design and to assign real estate and funds accordingly. Although usually considered secondary in importance to production equipment, poorly designed ventilation systems can result in costly process down time and poor working conditions. Fortunately the trend in the industry is toward more end-user involvement in ventilation design, and thus the subject is now being given the attention it deserves.

SPECIAL THANKS

SPECIAL THANKS ARE GIVEN TO RICHARD A. ROOS, TECHNICAL CONSULTANT-BUSCH INTERNATIONAL, WHOSE INPUT WAS A VALUABLE ADDITION TO THIS PAPER