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COOLING FOR ELECTRONIC PROCESS CONTROL SYSTEMS IN HOSTILE FACTORY ENVIRONMENTS

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Many plant shutdowns result from malfunction of electronic control components due to the effects of heat, dust, corrosive agents or moisture. Failure to seal electronic equipment against the ingress of these elements, and then provide adequate cooling can have disastrous effects, including the necessity for replacement of expensive components or sub-assemblies, not to mention the cost of loss of production due to the shutdown.

Most electronic control systems generate a substantial amount of heat during operation. This heat factor is intensified as electronic controls are made more compact, perform more functions, and are placed in confined enclosures.

Additional problems are encountered when the electronic process control system is located on-line in an industrial setting, rather than in a clean computer room. The factory environment can be hostile to the point that performance and effective life of the electronic components are materially reduced, or the control system fails completely.

Ambient temperature may be excessively high, as found in a steel mill.

Moisture-laden air and airborne particulate matter will adversely affect electronic controls.

Corrosive environments must be dealt with in the manufacture of chemicals and paper.

The above examples may be regarded as environments hostile to the operation of electronic equipment. A hostile environment may be defined more particularly as one possessing one or more of the following properties:

- ***temperature greater than 35 to 40 degrees Celsius;*** high temperatures can give rise to malfunction of sensitive electronic components and reduction of the effective life of such components. Studies have shown that failure rates of electronic control systems are likely to double for every 10 degrees C rise in the temperature of the air surrounding the controls.
- ***containing dust or other contaminants;*** dust collects electrostatically against points of high electric potential, and eventually the build-up of sticky dust causes a short-circuit between these points as vapours and smoke condense on the dust.
- ***containing corrosive agents such as acids or alkalis;*** such agents can corrode pins, contacts or circuit board tracks, ultimately leading to the necessity for replacement of expensive components or indeed entire circuit boards. It is worthy of note that salt-

laden seaside environments are corrosive.

- ***containing high levels of moisture (relative humidity);*** where the temperature of components or enclosure surfaces is below the "dew-point" of humid air within the enclosure, condensation can occur, giving rise to the potential for short circuiting. Additionally, moisture within the air can act as a vehicle for distribution of dust and corrosive agents.

The most common method employed for cooling of electronic or electrical components, ***forced-air cooling***, is satisfactory in the absence of all of the hostile conditions discussed above. Forced-air cooling involves intake of ambient air into the equipment enclosure at low level by an air-moving device (fan or blower), forcing the air over components or heat sinks, and discharging the warmer air at high level.

Care must be exercised in selection of a fan or blower of air volume flow rate to provide sufficient cooling of the components within the enclosure; the internal enclosure temperature will always be above the surrounding ambient temperature with forced-air cooling, and the maximum enclosure temperature must be maintained below the maximum temperature allowable by the electronic equipment manufacturer.

The intake air of a forced-air cooling system is usually filtered, however the filter media used are generally not of sufficient dust-removal efficiency to remove smaller dust particles or smoke. Filters clog rapidly in industrial environments, and must be cleaned or replaced often, as clogging reduces the air volume flow rate through the enclosure, thereby increasing the temperature rise of the air passing through the enclosure. A forced-air cooling system designed to maintain maximum enclosure temperature below maximum electronic equipment operating temperature may soon allow the enclosure temperature to rise above specification, with inadequate filter cleaning.

The obvious method of isolating electronic controls from hostile elements (with the exception of high temperature) is to seal the equipment enclosure airtight. This will have the effect of preventing entry to the enclosure of hostile air, however in the absence of a cooling system, enclosure temperature will rise above ambient temperature.

In some cases, a relatively large enclosure surface area, combined with relatively low heat output from the enclosed electronic equipment, results in enclosure temperature stabilising only a few degrees above the surrounding ambient temperature, and below recommended maximum operating temperature.

In many cases however, a cooling system employing a ***closed-loop*** design, for example an ***air-to-air heat exchanger*** or an ***airconditioner***, will be required to remove heat from the enclosure. With the closed-loop design, clean air is continuously drawn from the enclosure, cooled and then recirculated to the enclosure; only clean air comes into contact with the electronic components. A second, separate airstream is drawn into the cooling unit from outside the enclosure, as the medium to which the enclosure heat is rejected, and then discharged to ambient. This air does not contact the clean enclosure air, ensuring that contaminants are locked out.

A ***closed-loop heat exchanger*** will provide heat rejection from a sealed enclosure, with the resulting air temperature above ambient air temperature. A typical design temperature rise of 5 to 10 degrees C is considered, depending on the ambient temperature surrounding the enclosure. This temperature rise will be limited by the performance of the heat exchanger, at a temperature significantly lower than without the heat exchanger.

Heat exchangers for electronic enclosures usually incorporate either a refrigerant-filled heat exchanger core, which provides efficient transfer of the heat from the enclosure air circulation system to the separate cooler ambient airstream, or a convoluted aluminium core, in which heat from the inside enclosure air is conducted through the core walls to the ambient air flow on the other side and discharged into the atmosphere.

Heat exchangers are rated in terms of an ***Efficiency Rating***, expressed in Watts per degree C (or degree F), which governs the temperature rise afforded by the heat exchanger. For example, assuming no rejection of heat through the walls of the enclosure (which is typically not realistic), a heat exchanger of efficiency rating of 20 Watts per degree C will limit the temperature rise within an enclosure with electronic equipment generating 200 Watts of heat, to 10 degrees C, or 5 degrees C for 100 Watts of heat, etc. The existence of heat convection/conduction through the walls of the enclosure due to the difference between enclosure and ambient temperatures will limit the temperature rise further. Closed-loop heat exchangers are typically available with efficiency ratings up to 100 Watts/K.

Where the enclosure temperature is to be maintained at or below ambient air temperature, or where the enclosure heat load is too high for application of heat exchangers, a ***closed-loop airconditioner*** is necessary. An airconditioner will also be necessary where the enclosure relative humidity is to be reduced below the ambient relative humidity.

These airconditioners incorporate a refrigeration system, and the clean enclosure air is recirculated continuously through a cooling coil, which both cools and dehumidifies the enclosure air. The enclosure heat is rejected to a separate stream of ambient/outside air (isolated from the clean enclosure air), which is forced through the refrigeration system's condenser coil, and discharged to atmosphere. In some cases, where ambient temperature is too high for operation of an air-cooled condenser coil, or where the level of airborne contaminants is too high, a water-cooled condenser is used to reject the heat from the refrigeration system.

Airconditioners employed for cooling of electronic enclosures in hostile environments should possess several special features:

- ***closed-loop design*** to isolate electronics from the surrounding hostile environment.
- ***capable of operation at high ambient temperatures;*** it is not unusual for factory electronic enclosures to be located in areas where the ambient temperature exceeds 50 degrees C.
- ***should incorporate powerful fans or blowers;*** to ensure good air distribution through the enclosure despite close-packed components, and to keep supply air temperature relatively high to prevent thermal shock of sensitive electronic components.
- ***should incorporate condenser air filter;*** to remove dust from the ambient air stream prior to passing through the condenser coil, thereby minimising fouling of this coil.
- ***should be capable of controlling enclosure air temperature without necessarily cycling the refrigeration compressor on/off;*** compressor cycling may give rise to power "spiking" on compressor start-up, which may potentially send erroneous signals to the electronic equipment. This spiking can be minimised by use of a suppressor in the airconditioner. In addition, compressor life is extended with reduction in on/off cycling. A "hot gas bypass" control valve in the refrigeration system of the airconditioner will provide some degree of cooling capacity control without the necessity to cycle the compressor.
- ***should be inherently reliable;*** failure of the airconditioner may also lead to failure of or the necessity to reduce the duty of the process control system. The design life of the airconditioner should be at least 20,000 hours, and the quality control procedures

implemented in its manufacture should be commensurate with those of the control equipment it is to protect.

These features are not available on standard domestic or commercial airconditioning equipment, and only equipment designed specifically for the applications under consideration should be used.

Closed-loop airconditioners for electronic enclosures are rated in terms of ***Cooling Capacity***, expressed in Watts, and typically range in capacity from 290 Watts to 3000 Watts. Airconditioner cooling capacity may be selected to maintain the enclosure temperature below, equal to, or even slightly above ambient temperature. Typically, an airconditioner might be selected to maintain enclosure temperature at 30 to 35 degrees C with ambient temperature up to 55 degrees C.

The temperature stability afforded by an airconditioner is one of its greatest advantages, as constant enclosure air temperature may be maintained under all conditions, summer or winter, and the designer can be assured that his electronic equipment is operating below the maximum allowable temperature at all times.

Airconditioners and heat exchangers for electronic enclosures are available in a wide range of configurations, suitable for locating on the side, door, top, or within the enclosure (either rack-mounted or "cassette" style).

The success of an electronic enclosure cooling system is reliant upon the matching of the cooling equipment to the enclosure heat load generated by the electronic equipment, and the transmission of heat into or out of the enclosure by virtue of the difference in temperature between the enclosure and the ambient air.

In all electronic enclosure cooling applications, regardless of whether cooling is by enclosure surface area convection, forced-air cooling, closed-loop heat exchanger or closed-loop airconditioner, the following minimum information is required to allow accurate selection of cooling equipment appropriate to the application:

- ***heat load*** generated by the electronic equipment within the enclosure.
- maximum allowable ***operating temperature*** and ***relative humidity*** for the electronic equipment.
- maximum likely ***ambient temperature and relative humidity*** to which the enclosure is exposed.
- ***construction*** of the enclosure.
- identification of any ***hostile elements*** (acids, etc.) within the ambient air surrounding the location of the enclosure.
- existence of any ***radiative heat sources*** incident on the enclosure (solar radiation, nearby furnaces, etc.). Such heat sources will add to the heat load from the electronic equipment within the enclosure, and appropriate allowances will need to be made in design of the cooling system. Enclosure colour will also become important, in that a darker enclosure colour will absorb more heat from a radiative source than a lighter colour.

Of the above factors, the electronic equipment heat load is usually the most significant, and some care should be taken in estimation of this quantity.

In many cases, manufacturer's data is available in relation to heat output of equipment contained within the enclosure, and this data should be sought wherever possible.

Other methods of estimation of enclosure heat load, in reducing order of accuracy, include evaluation of control power supply rating; tong-testing of net power consumption within the enclosure (power in minus power out); estimation of heat dissipation of discrete components within the enclosure (calculated from known efficiencies of the components); observation of the temperature rise of the enclosure air above ambient air temperature, most accurate for a fully sealed enclosure (for an enclosure incorporating a forced-air cooling system, the air volume flow rate characteristics of the fan or blower must be known). In any event, one must take care to include the heat output from only the components within the enclosure in the evaluation.

If doubt exists, the advice of a professional experienced in selection of cooling equipment for electronic enclosures should be sought.

From a system designer's point of view, enclosures should be made as "airtight" as possible to prevent ingress of hostile elements, and care should be taken in estimation of internal enclosure heat dissipation, to allow optimum selection of cooling equipment.

The importance of selection of a cooling system to suit a given electronic control system, taking into account the environment in which the control system will be installed, must not be underestimated; some care in the design phase, or in the modification phase in the case of retrofit applications, is highly likely to mean the difference between uninterrupted plant operation and operation dogged with expensive shutdowns.