Enclosure Cooling Basics

By Ravi Jain,

Director of Manufacturing

Bud Industries, Inc

An important and often overlooked aspect of electronic and electrical equipment performance is how well heat is transferred out of the equipment enclosure. Electronic equipment has a specific operating temperature range, and when put inside a cabinet rack or other enclosure, temperature rise becomes a major issue. Excessive waste heat generated by equipment within a cabinet is the single most important factor affecting equipment performance, reliability, and failure. Having an effective cooling strategy for the enclosure can help in adequately dealing with heat dissipation.

Heat Transfer. Heat transfer takes place in three ways: through radiation, conduction, and natural or forced convection. Heat transfer via radiation occurs through electromagnetic waves, an example being the sun's energy reaching the earth. Heat can also be transferred through conduction between objects in contact; for instance, a microprocessor chip can be cooled through direct contact with a heat sink. The heat sink itself can also be cooled through any of the three heat transfer processes. Most systems remove heat through a combination of these thermal mechanisms.

The key to equipment cooling is to remove heat from the cabinet while supplying cool air to the places that need it. Most often this is accomplished with natural and forced convection, but sometimes cooling via forced convection with chilled air (air conditioning) is also used. Cooling cost increases as one progresses from natural convection to forced convection to air conditioning.

Natural Convection. Natural convection cooling is adequate for most applications that generate a small amount of heat, provided the cabinet interior offers an unrestricted airflow path. The user must insure that the cabinet has sufficient venting at both the top and bottom to promote airflow and a chimney effect. The best way for natural airflow to circulate within a cabinet is when it is drawn from the bottom up through the top of the enclosure.

Ventilated covers and doors allow natural exhausting of hot air and help keep a cabinet rack cool inside. Some manufacturers provide ventilated tops with pre-punched holes for mounting an exhaust fan if one is needed.

Ventilation louvers on cabinet sides and doors promote easier air entry and exit to remove hot air from the interior via convection cooling. One problem associated with bringing air into an electronics enclosure is the entry of dust and unwanted particles. Louvers provide some degree of protection against dust entry while hiding the contents of the cabinet.

Forced Convection. Where natural convection is inadequate, forced convection via fans and blowers can be used. The main differences between fans and blowers are their flow and pressure characteristics. Fans provide airflow parallel to the fan blade axis and can deliver moderately high airflow rates. They are most suitable for low to moderate backpressure where little resistance to airflow is created by equipment inside the cabinet. Blowers normally deliver air in a direction perpendicular to the blower axis, producing flow volumes up to 300cfm or more against relatively high backpressures. A combination of a blower and exhaust fan

sometimes works best in densely packed cabinets.

Fan Features. There are several types of fans, the most common being propeller, tube-axial and vane-axial styles. Propeller fans are the simplest, consisting of only a motor and propeller. However, poor performance under flow resistance or backpressure, and the potential for air turbulence caused by tip vortices, makes them unsuitable for most electronic enclosures.

The tube-axial fan is the most common type used in electronic cooling systems. It is similar to a propeller fan except for a venturi tube placed around the propeller to reduce vortices. Tube-axial fans, typically used for general hot air removal as well as heat transfer from specific hot spots, often have ball bearings to provide long life. The vane-axial fan has vanes that trail behind the propeller in the airflow to straighten the swirling flow of accelerated air.

Exhaust fans can be mounted inside or outside the top of the cabinet. In some applications, exhaust fans are also mounted on the front, back, or sides of the cabinet.

Blower Features. When a cabinet is stuffed with equipment, exhaust fans alone may not be enough to remove heat due to high airflow resistance. For such conditions, blowers are used to draw cool ambient air into the cabin et. Blowers with squirrel cage air delivery assemblies are rather common.

A blower can be used at the bottom of the cabinet to create high internal pressure within the cabinet. Hot air can then be exhausted through the top of the cabinet through vents. Sometimes, adding an exhaust fan at the top can improve airflow. Most blowers are fitted with a filter at the air inlet side to prevent dust and lint from entering the cabinet. The high pressure created by the blower inside the cabinet also prevents entry of dust and lint through other openings.

Forced Convection Considerations. When selecting fans or blowers, pay attention to noise ratings. Blowers typically have noise ratings from 50 dB to 65 dB, while 30 dB to 55 dB is typical for tube-axial fans. Designers must ensure that forced air devices, whether fans or blowers, provide adequate airflow (typically measured in cubic feet per minute, or cfm) under actual backpressure conditions. Most air movement device manufacturers provide a performance chart that indicates airflow for various levels of backpressure.

Carefully positioning fans and blowers in the cabinet improves cooling efficiency. Mount blowers close to cold air inlets near the bottom of a cabinet and away from major heat sources, such as transformers and power supplies. If possible, heat-generating devices should be placed near the exhaust so that heat can be vented directly to the outside.

Cabinets and other enclosures filled with card cages, shelves, and drawers full of equipment may still have hot spots that are difficult to cool because of restricted airflow. So, in addition to a blower and an exhaust fan, fan trays are often used to direct airflow to these hot spots. A fan tray is basically a chassis with a bank of small tube-axial fans daisy-chained together and connected to a common power source. This chassis can be mounted directly below the sensitive equipment or hot spot.

Air Conditioning. For most cooling applications, a combination of natural convection, fans, and/or blowers will do the trick. For critical and thermally sensitive applications, and also for sealed cabinets, air condition-

ers or cabinet coolers are used to keep internal cabinet temperature at the desired level. A typical cabinet cooler has two heat exchangers. The interior fan draws hot air over the heat exchanger inside the cabinet and blows the cooled air back into the cabinet. The heat absorbed is transferred to an outside heat exchanger where it is cooled by the ambient air using another fan. An air conditioner uses compressed refrigerant in the cooling process.

Most air-conditioned cabinets are sealed with only inside air circulated inside the cabinet. This prevents moist air from entering the cabinet and causing condensation that could harm sensitive equipment. However, if cabinets are not properly sealed and interior components are kept at lower than ambient temperature, silica or other dehumidifying means would be needed to prevent condensation.

Basic Airflow Calculations. The amount of airflow that must be provided to achieve the desired cooling effect is related to the temperature rise, "T, caused by component heat generation. This can be expressed by the following equation:

Airflow (CFM) = (3,170 kW) / "TF or (1,760 kW) / "TC, where kW is the total heat generated in kilowatts by all components, and "TF or "TC represents the temperature rise over ambient air temperature in degrees F or degrees C respectively. Typical values for "T are 18F or 10C, plus 25 percent added as a safety margin (i.e., 23F or 12.5C). If the ambient temperature gets too high, it may be difficult or impossible to maintain a safe operating temperature for the equipment in the cabinet without air conditioning.