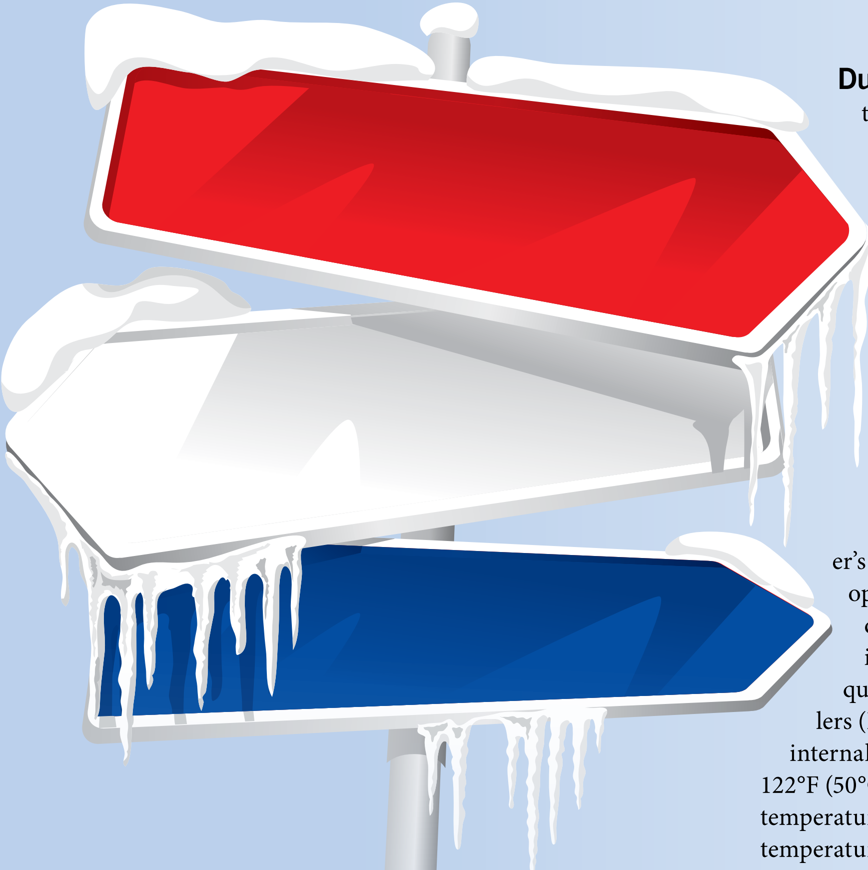


CHOICES IN PANEL COOLING

THE HARDWARE YOU SELECT MUST BE KEYED TO THE SPECIFIC INSTALLATION

BY DOUG WILSON

During the past few decades, the use of sophisticated, high-density electronics in automation and process control panels has become commonplace. As a result, thermal management for these electronic enclosures and its related cost have become important considerations in managing these assets. Choosing the appropriate and most cost-effective and energy-efficient cooling solution from the many types available requires knowledge of the individual strengths and weaknesses of the most commonly used designs, and the ability to match those attributes most effectively to the operational environment.

Knowledge of the panel equipment manufacturer's specifications regarding the maximum allowable operating temperature is the starting point in this decision process. Most modern plant electronics, including common devices such as variable-frequency drives (VFDs), programmable logic controllers (PLCs), transformers, and relays are designed for internal panel air temperatures between 104°F (40°C) and 122°F (50°C). Common sense dictates maintaining the panel temperature at or below the highest allowable operating temperature.

Leaving the panel open on unusually hot days provides ambient air temperature cooling and can resurrect an overheated device, but aside from the OSHA safety issues, this approach guarantees that dirt, oil, corrosive moisture, and other hazards will attack the electronics.

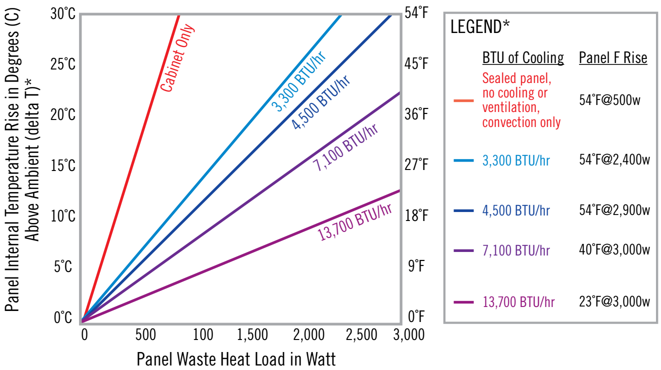
Halfway measures, such as cutting holes in the panel and installing filters and fans (Figure 1), can work in clean environments, but few industrial settings are so contaminant-free as to make this a practical approach. In addition, it won't work for outdoor installations. And, if the filter is dense enough to prevent the entry of contaminating dirt and moisture, it will clog and be a preventive maintenance concern, or lead to overheating if not maintained properly.

THE DILEMMA

Your choice is between dirt and moisture contamination slowly eating away at open, vented, or filtered control panels, or sudden death from heat damage if they're kept sealed and clean. You must do battle with one or the other, contamination or heat. To help make the correct choice, consider the most popular enclosure cooling technologies, along with some general cost considerations and characteristics to keep in mind in evaluating their fit for your requirements.

Thermoelectric devices are typically used only in very small cabinets because of the high cost-to-cooling ratio. On one hand, they're small and versatile. On the other hand, these solid-state air conditioners provide effective cooling at a cost of one watt of power to remove one watt of heat.

UNDERSTANDING PANEL TEMPERATURE INCREASES



*Results based on a freestanding metal uninsulated panel (72 x 36 x 24 inches)

If the heat load within a control enclosure is beyond the cabinet's capacity for natural convection cooling, heat buildup will cause problems or even complete failure. This chart shows temperature differential over ambient conditions as a function of waste heat generation for different cooling capacities.

Uninsulated NEMA 12 and higher metal panels dissipate heat via natural convection, which occurs primarily along vertical walls, not from the top as intuition might lead you to expect. Therefore, a simple cooling solution for low heat loads is to place equipment in oversized panels that maximize vertical height over width and depth as much as possible.

As the chart indicates, in ideal conditions a 72-in. x 36-in. x 24-in. freestanding uninsulated metal panel with no sources of high heat such as transformers or ovens attached or nearby can dissipate nearly 500 W of waste heat with only a 15°C/27°F rise in panel temperature above ambient via unassisted, natural convection cooling.

Those ideal conditions require that the ambient temperature never rise above 77°F (25°C) to maintain a conservative 104°F (40°C) panel or no greater than 95°F (35°C) for an allowable 122°F (50°C) panel air temperature. But few environments are that ideal, and most heat loads are far larger than 500 W.

If the required internal panel temperature is below the peak ambient the panel will experience, then a below-ambient cooling solution, such as air-to-water heat exchangers, compressed air, or air conditioning is a must. If there's a sufficient ΔT between the panel requirement and the ambient air temperature, a heat pipe-based heat exchanger often is the most cost-effective solution.

Compressed air coolers rely on plant air to produce a cyclone effect that cools the inside of the cabinet. The "per panel" cost of the actual cooling device is low compared to most other solutions, and the design provides effective below-ambient cooling. But, consider the high cost of compressed air and whether that air is sufficiently dry and oil-free. Like the fan-and-filter method, short-term gains often are offset by long-term maintenance issues and hidden energy costs.

Hank Van Ormer of Air Power USA Inc., a recognized expert on the subject of compressed air technology, states "Just how expensive is compressed air? It takes about 8 hp of electrical energy to produce 1 hp worth of work with compressed air. Do you think your electric power is expensive? Your air power is eight times more!"

Air conditioners are frequently used in panel cooling. When electronics first made their way into the plant, air conditioners were mandatory because the low thermal thresholds of early electronics required that the devices inside be refrigerated below ambient conditions. But modern panel components are made to withstand higher heat loads without harm or performance de-rating than in the past. When below ambient cooling is required, air conditioners are often the only below-ambient cooling option available. Modern panel air conditioners are competitively priced, smaller than previous designs, and come in a variety of sizes, NEMA ratings, and thermal ratings. But with so many moving parts and thus failure points, air conditioning units are more expensive to maintain and consume far more energy than most other options.

Two of the most cost-effective, reliable, and energy-efficient cooling methods are air-to-air and air-to-water heat exchangers (Figure 2). Where appropriate, the heat exchanger delivers the best value and ROI because of its low

A TRADE-OFF TO CONSIDER

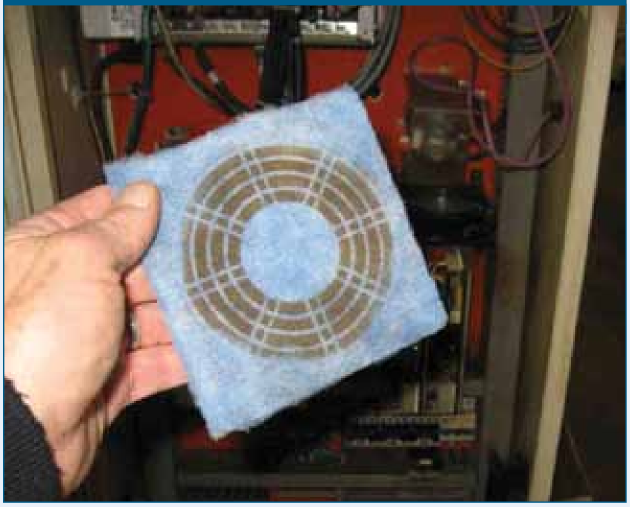


Figure 1. Fans and filters might have a low first cost, but keeping them clean can turn them into a maintenance headache.

DETERMINING THE PANEL HEAT LOAD

Whatever panel cooling solution you choose, the critical factor for a successful installation is assessing the panel's waste heat load correctly. This loss, caused by the inefficiency of the electrical devices inside can be calculated with some accuracy or, more reliably, it can be measured by placing thermometers inside the panel to capture real-world operational readings. Both approaches have their shortcomings, however. Here are a few tips to achieve the best accuracy.

Calculating the waste heat load is critical when designing new panel installations, but it's a somewhat inexact approach. With either measured load (in watts) or temperature readings, you can determine your cooling requirements. Predicting how devices might interact, how airflow might affect natural convection cooling and other variables means it's best to base your estimate on the worst case

Better to error on the high side and overcool than on the low side and discover the panel overheats. The best source is the manufacturer's data on the device, which typically can be found online. Lacking that information, here are a few methods to estimate waste heat from common sources.

Modern variable frequency drives typically operate with 93% to 97% efficiency. Based on 1 hp being equivalent to 746 W, you can determine the best and worst case heat load by doing the math. For example, a 3-hp VFD would produce 3 x 746 W = 2,238 W x 0.07 = 157 W of waste heat inside a panel.

Waste heat from transformers is harder to estimate accurately, and can be a high source of heat. Power factor isn't going to have any effect on heat generation, except to cause more current to flow and increase the kVA load on the transformer. According to Cutler-Hammer, a 75-kVA, 150°F-rise, dry-type transformer has an efficiency of 97.2% at 1/4 load and 96.7% at full load. So, figure 3% loss at 75 kVA, which would represent 2,250 W. For greater precision, you need to know the amp load on the transformer and separate out the core losses (which are constant) and the winding losses (which vary as the square of the current).

The direct-sun solar load on an outdoor installation can represent 30 watts of heat penetrating the panel per sq. ft. of sun-exposed surface area.

Generally speaking, a PLC is a negligible source of heat, but as with the VFD calculation, base your estimate on an approximate 5% heat loss. Thus, if a PLC is rated at 1,000 W and has an efficiency of 95%, then heat loss is 50 W.

Measuring the waste heat load is a real-world operating measurement and is reliable, but offers its own set of challenges. Often, it's impossible to measure a fully-loaded, operating panel with no cooling or ventilation in place (there's a risk of failure from overheating during the measurement process).

In cool weather, it's possible to perform this measurement because overheating generally is only a problem in hot summer months. Then the approach is simple and highly reliable. Place a few thermometers inside the panel, distributed top to bottom and not directly on or too near any heat sources. Run the panel at full load for 10 min. or more. Simultaneously, get an ambient air temperature within a few feet of the panel.

Now, you have the ΔT, the rise in panel temperature above ambient. If the highest panel reading is 91°F and the ambient is 72°F, your 19°F ΔT indicates that on hot summer days, when the facility ambient hits 85°F or more, your panel is now at 104°F and possibly heading for VFD failure. Bottom line, the ΔT is a constant and tells you exactly at what room temperature you're going to experience problems.

initial cost, negligible power consumption, and long life. These designs have become increasingly popular in new panel installations and retrofits of older panels, primarily as a replacement for air conditioners.

Air-to-water heat exchangers cost pennies on the dollar per BTU/hr compared to all other methods. They are the most environmentally-friendly solution as well. Air-to-water heat exchangers are closed designs, completely reliant on water temperature for cooling effectiveness. With no exposed fans or fins to require filtering in dirty environments, they're nearly zero maintenance devices. They're also a natural fit for hazardous locations; with a purged panel, you can use standard muffin fans instead of the costly explosion-proof fans.

Air-to-water units also can address large heat loads using even non-chilled, ground-temperature water in the 65°F (18°C) range. The clean but heated outlet water often can be reused in another process, taking advantage of the heat energy it carries with it. The main drawback to air-to-water

ISOLATED FROM THE ENVIRONMENT

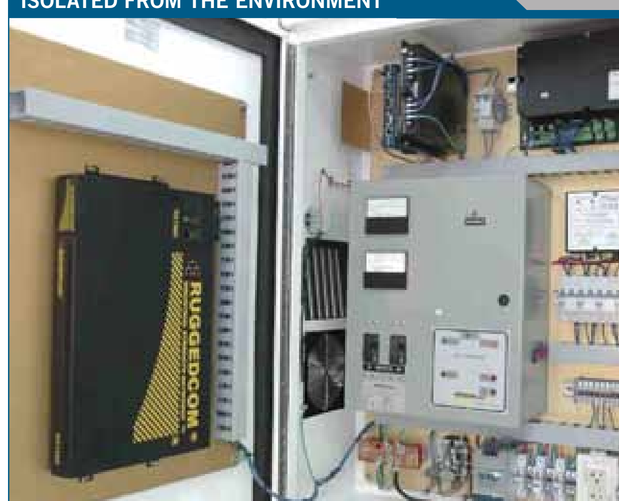


Figure 2. Cooling a panel with an air-to-air heat exchanger avoids corrosion and dirt buildup that can wreck electronics.

units is that few facilities have easy access to a suitable water supply and, for many, overcoming the fear of having water flowing near their expensive electronics is high.

The heat pipe-based, air-to-air heat exchanger exploits a basic physics principle, the latent heat of vaporization. This solution has grown in popularity during the past decade. These have high thermal transfer capabilities but low electrical energy consumption. They can perform at their full rated capacity for more than 15 years, with the only failure point and replacement cost being the inexpensive muffin fans they employ. According to Van Ormer, “Open blow, refrigeration, and compressed air cooling may be replaced with heat pipe heat exchangers with a potential energy savings of 3.5 kW to 4 kW each on an average cabinet. The initial cost, in the low $1,000 range, is offset by power savings of $1,000 to $2,000 per year each.”

Add in the effects of energy rebates and other incentives to become a greener operation, and these savings grow significantly. The Achilles heel of this approach is its reliance on ambient air temperature. In high-ambient conditions, when the panel-to-ambient temperature differential is insufficient for effective cooling, one of the below-ambient solutions becomes a necessity.

Whatever your requirements, be sure to investigate the long-term energy and maintenance costs as well as initial purchase price when evaluating your panel cooling alternatives. The initial cost is known, but you should assume that operating and energy costs will only continue to climb. Give them serious consideration when making a decision.

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