# Efficient Cooling of Enclosures Using Purge Manifold Technology

Technical White Paper

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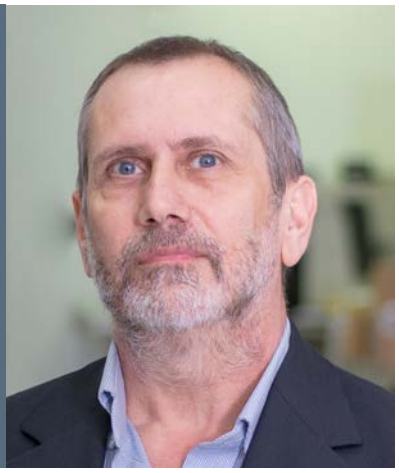



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Chris Romano is the Product Manager for Purge and Pressurization Systems / Level Control Devices at Pepperl+Fuchs, Inc. He is an expert on hazardous areas and purge + pressurization systems and holds a BSEE from Cleveland State University. Since joining Pepperl+Fuchs in 1984, Chris has held many positions throughout the company and taken on key roles in developing, production, marketing, field work, and training customers and internal personnel on hazardous area products. He began developing Pepperl+Fuchs' own line of pressurization and purging products in 1992. In his current role, Chris is involved with new product development and promotes purge and pressurization products to a global audience. He has presented training seminars and technical papers to organizations like ISA and NACE and served on the ISA 12 standards committee.



**The Co-Author: Geoff Callahan**

Geoff Callahan began his career in factory automation after earning a degree in Electrical Engineering. His time as a self-employed engineer allowed him to take on diverse design projects, eventually leading to product development work and a patent. He later joined a small company, but as the engineering team became too lean, he sought a more collaborative environment, ultimately joining Pepperl+Fuchs in 2014 as a Design Engineer. Since then, he has supported purge systems, transitioned to HMI, and now focuses once again on purge technology. Over the years, Geoff has developed strong expertise in certification and functional safety, an area he had not initially anticipated but now considers a valuable part of his career.



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# Efficient Cooling of Enclosures Using Purge Manifold Technology

## Introduction

**The Pepperl+Fuchs 6000, 6500, and 5500 Series purging and pressurization systems include an optional temperature input feature that allows the control units to monitor sensor temperatures and respond when they reach a user-defined set point. Often, this feature is used to trigger alarms for high temperatures within the pressurized enclosure. The system can be programmed to activate alarms, energize the purging valve for cooling, and/or shut down power to the enclosure. This capability is crucial for maintaining safety when using enclosures in hazardous areas.**

**Both the internal and external temperature of the enclosure must be evaluated to ensure compliance with T-code requirements for safely operating in areas with hazardous gases or dust. The Rapid Exchange® purge manifold system provides a means of expelling high-temperature air during peak conditions, thereby supporting effective enclosure cooling. To assess the cooling performance of the manifold under elevated temperatures, several parameters and formulas must be considered. This white paper will outline the key information required for such an evaluation.**

## Heat and Expected Life of Electrical Equipment

The Variable Frequency Drive (VFD) and Programmable Logic Controller (PLC) located inside the IP66-rated enclosure have a maximum operating temperature of 70 °C. During testing, the internal temperature of your enclosure never exceeds 65 °C, event at maximum ambient temperatures. This may seem acceptable; however, it is worth considering further.

The chart below depicts the expected lifespan of any hypothetical electronic device, illustrating the relationship between temperature and longevity using the "10 °C = 1/2 rule (10 °C rise in temperature ≈ 50 % reduction in expected lifetime)". Please note that this is an approximation; numerous other factors can influence the actual lifespan, potentially resulting in longer or shorter durations. However, the goal here is to demonstrate the effects of heat on electronics.

The previous example may be acceptable if the temperature of 55 °C is only experienced periodically and other variables, such as humidity or on/off cycling, do not come into play. However, if our units are being used for hazardous area protection, adding a simple temperature sensor could facilitate cooling measures to prevent reaching 55 °C, thereby extending the life of the equipment. For Original Equipment Manufacturers (OEMs), this could provide a significant marketing advantage. So, how can we implement this?

| Temperature | Expected Lifetime |
|---|---|
| **25 °C** | 200 years |
| **35 °C** | 100 years |
| **45 °C** | 50 years |
| **55 °C** | 25 years |
| **65 °C** | 12.5 years |

## The Different Types of Cooling

- **Natural Convection Cooling:** This method relies on the enclosure itself to radiate heat into the surrounding area, allowing for heat dissipation within the enclosure. It is effective when the ambient temperature outside the enclosure is cooler than the temperature inside. Factors such as size, color, material, and placement of the enclosure influence the heat transfer from the enclosure. Its cooling capability is quite limited.

- **Closed Loop Cooling:** This approach utilizes a device to cool the equipment within the enclosure, relying on the atmosphere inside the enclosure rather than the ambient outside temperature, which can be equal to or greater than the internal temperature.

  - **Air Conditioner:** An air conditioner functions by removing heat from within the enclosure and transferring it to the outside environment. This process involves refrigerants that absorb and release heat. Air conditioners are highly effective, especially when the outside ambient temperature is higher than the temperature inside the enclosure.

  - **Thermoelectrical Coolers:** Similar to air conditioners, thermoelectric coolers use an array of semiconductors to create cold and warm sides on plates instead of refrigerants. They can also be used when the outside ambient temperature exceeds the inside temperature.

  - **Heat Exchangers:** This type operates like an air conditioner, using refrigerants but without moving parts. Heat exchangers rely on the outside atmosphere being cooler than the temperature inside the enclosure. They can also function effectively when the outside ambient temperature is higher than the inside temperature.

- **Vortex Coolers:** Vortex coolers use compressed air through an assembly that separates the air into hot and cold streams. The hot air is expelled to the outside, while the cool air is injected into the enclosure.

- **Forced Convection Cooling:** In this method, cooler air from the outside or another source is introduced into the enclosure and expelled through a vent. This approach is suitable in conditions where the external ambient temperature is cooler than the temperature inside the enclosure.

Pepperl+Fuchs manifolds operate using the forced convection cooling method, along with natural convection from the enclosure.

## Forced Convection Cooling with the Pepperl+Fuchs 5500-MAN, 6000-MAN, or 6500-MAN Automatic Manifolds

When using the 5500, 6000, or 6500 control units, along with their respective purging and pressurization manifolds and temperature sensors, these control units can be configured by the user to energize the purging valve of the manifold when the temperature sensor reaches a user-defined setpoint. This feature allows a high flow rate of compressed purge gas to be introduced into the enclosure, which then exhausts through the EPV pressure relief vent, creating a forced convection cooling system. It is important to note that this system only functions effectively when the temperature of the outside atmosphere and the compressed purging gas is lower than the maximum allowed temperature inside the enclosure.

## The Cooling Effect of Our Manifold Is Based on the Following Parameters:

- **Purging Gas:** Typically, air or nitrogen is used.
- **Temperature Difference:** Consider the maximum outside temperature and the desired maximum allowable inside temperature to determine the temperature difference (ΔT in °F) for worst-case scenarios.
- **Internal Heat Load:** Evaluate the heat generated by electrical equipment operating at peak values within the enclosure.
- **Enclosure Dimensions:** Measure the total square footage of exposed area (in $ft^2$) to the surrounding atmosphere, which will help determine the heat load transfer for natural convection cooling of the enclosure.
- **Maximum Allowable Pressure**: Determine the maximum pressure for the enclosure when the purging valve is open. Each enclosure protection vent (EPV) has a specific enclosure pressure that needs to be accommodated for necessary cooling flow.
- **Heat Transfer Coefficient (k):** This value is expressed in BTU / (h × $ft^2$ × °F) and is critical for understanding the enclosure's thermal performance.
- **Purging Gas Temperature:** If the temperature of the purging gas is unknown, assume it to be equal to the maximum ambient temperature.
- **Maximum Flow and Backpressure:** Consider the flow rate and backpressure during the flow through the enclosure protection vent.

For calculation purposes, we will treat the cooling effects of air and nitrogen as equivalent, since their specific heat and mass flow rates are very similar. Consequently, the amount of heat absorbed by each medium is nearly the same.

### Determining the Required Cooling (Qr)

To determine the required cooling flow rate, two distinct components of the total head load must be evaluated. First, we will calculate the internal heat load generated by the equipment within the enclosure **(Qi)**. Second, we will evaluate the heat load transfer due to natural convection from the enclosure to the outside atmosphere **(Qn)**.
The formula for the required flow rate for cooling **(Qr)** in watts **(W)** is as follows: **Qr = Qi + Qn**

### Determining the Heat Load Transfer (Qn) from Natural Convection

We can calculate **(Qn)** using the following formula: **Qn = k × A × ΔT × 0.293 = W**

**Where:**
**(k) =** heat transfer coefficient **BTU / (h × $ft^2$ × °F),** which indicates the rate at which an enclosure conducts heat. The **(k)** value depends on the type of enclosure material, as shown on right .

| Enclosure Material | k (BTU/ (h × $ft^2$ × °F)) |
|---|---|
| **Painted carbon steel** | 0.97 |
| **Stainless steel** | 0.83 |
| **Aluminum** | 2.1 |
| **Non-metal** | 0.62 |

**A =** surface area of the enclosure exposed to the outside atmosphere (in square feet). It can be calculated using the following formula:
**A = 2 (h×w) + 2 (h×d) + 2 (w×d)**

**Note:** If one side of the enclosure is against a wall or another surface, the (k) factor may differ and is usually lower. For conservative calculations, we will exclude these surfaces from the formula, as the ambient temperature must remain less than the maximum internal allowed temperature for forced convection to function effectively.

**ΔT** = the temperature difference, calculated as the maximum external temperature minus the maximum allowable internal temperature. This value must be negative and expressed in degree Celsius (°C). The formula for calculating ΔT is as follows:

**ΔT = 0.293 W / BTU / hr. = conversion from BTU / hr. to watts**

**Determining the Internal Heat Load (Qi)**

Qi refers to the internal heat generated by the components within the enclosure. This is a combination of all the equipment that can generate heat under max load for worst case value. The equipment data sheet should have these values or contact the manufacturer of these devices for required information.

**Determining the Required Flow Rate for Cooling**

Once the required cooling (Qr) is determined, the following formula for the flow rate requirement is used.

***Flow rate required for cooling in CFM: Flow = −(3.17 CFM × °F / W) × Qr / ΔT**

➔ By following these guidelines, you can accurately determine the required cooling for your enclosure.

## Division 1 Installation Example

A customer has a Type 4 stainless steel enclosure with dimensions 24 in × 24 in × 12 in (2 ft × 2 ft × 1 ft) mounted to the wall. Inside the enclosure, there are eleven (11) Pepperl+Fuchs power supplies, model PS1000-A6-24.20.R. The enclosure needs to be installed in a Division 1 area, therefore purging and pressurization will be the type of protection used. We need to determine if cooling is required, and if so, how much airflow will be required.

**Ambient Conditions:**

- Purge gas: Compressed air
- Maximum external temperature: 30 °C
- Maximum allowable internal temperature: 60 °C
- Temperature of the purging gas: Maximum of 30 °C
- Maximum flow through the EPV vent: 30 CFM at 4.5 in water column (w.c.)
- Maximum allowable pressure for the enclosure: 6 in w.c.
- The internal heat load from eleven (11) PS1000 power supplies, calculated as follows:
  ➔ Qi = 11 × 31.7 watts = 349 W (operating at 120 V AC)
- The heat load from natural convection is calculated using the following formula:
  ➔ Qn = k × A × ΔT × 0.293
- **Where:**
  - **k:** Heat transfer coefficient for stainless steel enclosure is 0.83 BTU / (h × $ft^2$ × °F)
  - **A:** Surface area = 2 (2×2) + 2 (2×1) + 2 (2×1) = 16 sq.ft
  - **ΔT:** Temperature difference = 30 °C − 60 °C = −30 °C
  - **Qn:** k × A × ΔT × 0.293 = 0.83 × 16 × (−30 °C) × 0.293 = −117 W

**To calculate the required cooling, we use the following formula:**

**Qr = Qi + Qn = 349 W + (−117 W) = 232 W**

**Next, we will determine the necessary flow rate for cooling using the following formula:**

**CFM = −(3.17 × 232 / −30) = 25 CFM**

**Verification:**
At 25 CFM, the vent backpressure for this system will be approximately 3.5 in w.c. (see datasheet), which is below the maximum enclosure pressure.

The cooling effectiveness of using the purge gas source with our purging systems is dependent on the ambient conditions. However, it can effectively help control the enclosure temperature and extend the lifespan of the equipment within the enclosure.

**Note:**
The flow rate for cooling formula, CFM = −(3.17 CFM × °F / W) × Qr / ΔT, is derived from the principles of thermodynamics and fluid mechanics used in HVAC (Heating, Ventilation, and Air Conditioning) systems. The constant 3.17 is used to convert the energy provided in watts to an equivalent airflow rate in cubic feet per minute. This formula relates power (in watts) to the air temperature differential, illustrating how much air must be moved to achieve a desired heating or cooling effect.

**Conversions:**

**$1\ ft^3 = 1728\ in^3$**
**$1\ ft^2 = 92{,}900\ mm^2$**
**Flow = −(3.17 CFM × °F / W) × Qr / ΔT = −(1.76 CFM × °C / W) × Qr / ΔT**
**1 W = 3.41 BTU / h**
**°C = (°F −32) × 5 / 9**

## References:


- https://www.automationdirect.com/ebooks/enclosures-handbook
- https://joliettech.com/blog/calculating-forced-air-cooling-for-control-panels-a-simple-formula-for-longer-lasting-controls/
- ChatGPT


## 5500 Components



5500 control unit



EPV-5500 vent



5500-MAN manifold

## 6000 Components



6000 control unit and manifold



EPV-6000 vent

## 6500 Components



6500 control unit



EPV-6500 vent



6500-MAN manifold

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Printed in USA · Part No. 70198937 09/25

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