HOW TO CALCULATE ENCLOSURE HEAT LOAD AND WHY YOU NEED TO COOL ELECTRONICS.
HARMFUL HEAT

Like people, industrial electronics can over-heat, causing malfunction and even complete failure. The good news is that electronic components can be kept cool to extend their life and prevent expensive operations downtime.
LEARNING OBJECTIVES

• Understanding why temperature variation can be a problem
• Understand the consequences of over-heated electronics
• Learn the benefits of cooling industrial electronics
• Identify the sources of damaging heat
• Learn how to size a cooling unit for your cabinet
WHY CAN TEMPERATURE VARIATION BE A PROBLEM?

Typical devices housed in an enclosure in an Automation Control System

- VARIABLE FREQUENCY DRIVE (VFD)
- SERVO DRIVE
- PROGRAMMABLE LOGIC CONTROLLER (PLC)
- STARTER KIT
- POWER SUPPLY
- INVERTER
- RELAYS
- TERMINAL BLOCKS
- INDICATOR LIGHTS
- TRANSFORMER*

* Typically outside the control panel, but can sometimes be included inside the enclosure
WHY CAN TEMPERATURE VARIATION BE A PROBLEM?

TEMPERATURE EXTREMES WILL CAUSE PROBLEMS

AT HIGH TEMPERATURES:
Drive performance is de-rated
I/C-based devices behave strangely-
funky output- voltage migration
(Properties of silicone materials
change with temp extremes)

AT LOW TEMPERATURES
Cooling below the dew point leads to
condensation - promotes corrosion
Batteries die
I/C-based devices behave strangely

6
WHY CAN TEMPERATURE VARIATION BE A PROBLEM?

All Metal-Oxide-Semiconductor electronic components are sensitive to temperature changes: Metal Oxide field effect transistors (MOSFET) are no different

• Electrical characteristics
  • Threshold voltage = Applied voltage to the gate
  • The higher the temperature, the higher the threshold voltage
  • May cause the transistor to drift out of design requirements
  • The higher the temperature, the longer it takes for the gate to open
  • The higher the temperature the greater the internal resistance – the gate may not open at all
  • Result: the gate does not open when it is designed to, which adversely affects other components on the circuit

• Life Expectancy
  • Properties of silicon oxide used in the components changes with temperature fluxuations
WHY CAN TEMPERATURE VARIATION BE A PROBLEM?

Mechanical properties of materials change with increasing temperatures

In Wiring Insulation

• Elasticity and strength are reduced
• Ductility increases temporarily
• Atomic Mobility increases

![Graph showing temperature variations for different classes of wiring insulation.](attachment:image.png)
TREND TOWARD MORE HEAT

As information processing becomes more powerful, the heat generated from electronics continues to increase.

“Semiconductor transistor density and performance double every 18-24 months.”

Moore’s Law
Named for Intel founder, Dr Gordon Moore

The need for more electronics cooling continues to grow
CPU Transistor Counts 1971-2008 & Moore’s Law

Curve shows ‘Moore’s Law’: transistor count doubling every two years.
WHY CAN TEMPERATURE VARIATION BE A PROBLEM?

Every 10 C / 18 F over room temperature cuts electronics life in half.

Using cooling can avoid early automation drive replacement.

Source: DEC Study
RUNNING HOT COMPONENTS IS A GAMBLE

Depending on the equipment, allowing electronic components to run hot can be a costly gamble.

Early replacement of industrial drives, hours of automation system downtime, and out-of-warranty conditions all become risks when cooling is not used.
CONSEQUENCES OF HOT ELECTRONICS

One hour of industrial operation downtime can cost big money

UP TO $500,000 PER HOUR!

Lost production + direct repair cost + lost opportunity cost = Cost of downtime

A little investment in cooling can save huge costs later
CONSEQUENCES OF HOT ELECTRONICS

Operating electronics over its specified temperature could void the manufacturer’s warranty.

Using cooling can prevent unpleasant and expensive surprises.
SOURCES OF DAMAGING HEAT

Typical efficiency of devices housed in an enclosure in an Automation Control System

- VARIABLE FREQUENCY DRIVE (VFD)
  - APPROX. 95 TO 98% EFFICIENT
- SERVO DRIVE
  - >85% EFFICIENT
- POWER SUPPLY
  - APPROX. 60 TO 83% EFFICIENT
- TRANSFORMER*
  - APPROX. 95-99% EFFICIENT

* Typically outside the control panel, but can sometimes be included inside the enclosure
SOURCES OF DAMAGING HEAT

Heat can also come from outside the electrical enclosure and radiate inside, further adding to the heat stress of the component.

IRON FOUNDRY
MINING
Heat radiates into the control cabinet from outside

WELDING PROCESS
INTENSE LIGHTING
Applies extra heat load to the automation electronics inside

SOLAR HEAT GAIN
HOT WEATHER
Dark-painted enclosures collect more heat than light-colored cabinets

DRYING OVEN
BLAST FURNACE
Many factories around the world are hot environments and use automation equipment

Most of these conditions require industrial control cooling
Heat Load

The heat generated by the equipment or system and is usually given in Watts.

**Max System Temperature** $T_{\text{MAX}}$

The maximum internal system equipment temp allowable.

**Ambient Temperature** $T_A$

The Outside or Inlet Temperature to the equipment or system.

**Temperature Rise or $\Delta T$**

The difference between the Maximum Internal System Temp. and the Ambient Temperature.

$$\Delta T = T_{\text{MAX}} - T_A$$
TERMS AND ABBREVIATIONS

Solar load
This is the contribution to the heat load of the Sun on outdoor systems

Noise
Quoted in dB(A)
The higher the number the louder the fan.

Volumetric Flow Rate
Air flow performance of the fan in free air (i.e. fan blows in free space without static pressure) measured in CFM or m³/hr

Static Pressure
This is the amount of ambient air pressure. As air pressure increases fan performance declines.
In general, high static pressure in an application is caused by air flow obstructions and/or inadequate venting
TERMS AND ABBREVIATIONS

**Fan Curve**
This is the key performance characteristic for a particular fan.

**System Flow Resistance**
This curve represents the system or requirements resistance to the flow of air itself.

**Static Pressure (Inches H₂O)**

Graph showing air flow (CFM) vs. static pressure (Inches H₂O) for a fan.
CONVERSIONS/ASSUMPTIONS

1 Watt = 3.413 BTU/HR
1 HP = 746 Watts
1 HP = 2546 BTU/HR

If the efficiency of the drive is known, Watts lost to heat can be estimated if it is not supplied by the manufacturer.

50 HP drive = 37,300 Watts potential power consumption.
If 93% efficient, and operating at full capacity,
2,611 Watts lost to heat = 8,911 BTU/HR cooling required.
HEAT TRANSFER BASICS

• Thermal energy moves from high to low. (second law of Thermodynamics)

• A/C’s and HX’s create air movement over a cool surface which “pulls” heat out of the enclosure.

• A/C’s cooling source is refrigeration system therefore, capable of temp’s below ambient.

• Heat exchanger cooling source is ambient air therefore, can never create temp’s below ambient.

• Forced Convection (open loop)cooling source is ambient air therefore, can never create temp’s below ambient.
WAYS TO COOL INDUSTRIAL ENCLOSURES

There are 3 basic ways to cool industrial enclosures.

1. SEALED ENCLOSURE COOLING
   - Cooling that maintains the protective seal of the cabinet, typically with an air conditioner or heat exchanger.

2. FRESH AIR COOLING
   - Cooling that circulates fresh air through the cabinet to take damaging heat away.

3. CONDUCTIVE COOLING
   - Cooling that allows the heat to simply radiate through the cabinet.
Determine ambient and electronics temperatures

**A** AMBIENT TEMPERATURE
The maximum temperature outside the enclosure.

**B** ELECTRONICS TEMPERATURE
The rated or desired temperature for the electronics inside the enclosure.

**IF ELECTRONICS TEMPERATURE MUST BE LOWER THAN AMBIENT TEMPERATURE**
Then air conditioners, air-to-water heat exchangers, thermoelectric coolers or vortex coolers are selected.

**IF ELECTRONICS TEMPERATURE CAN BE HIGHER THAN AMBIENT TEMPERATURE**
Then filter fans, axial fans, fan trays or air-to-air heat exchangers are chosen.

Temperature differences dictate the type of cooling
WHERE ARE YOU GOING TO DEPLOY YOUR CABINET?
Capacity needs to match or exceed amount of total heat load generated by the electronic system.

Total heat load comes from 2 sources:

Internal Heat Load
Electronics in enclosure

Heat Transfer Load
Ambient heat outside enclosure

TOTAL HEAT LOAD = INTERNAL HEAT LOAD + HEAT TRANSFER LOAD
STEP 1: DETERMINE INTERNAL HEAT LOAD

Internal heat load = waste heat generated inside enclosure expressed in Watts (W)

METHODS TO DETERMINE INTERNAL HEAT LOAD
1. Data from Each Electronics Component
2. Component Power – Component Efficiency
3. Incoming – Outgoing Power
4. Automated Equipment Horsepower

4 methods for determining internal heat load
STEP 1: DETERMINE INTERNAL HEAT LOAD

METHOD 1: DATA FROM COMPONENTS

Customer may know amount of heat their equipment is generating

GATHER HEAT LOAD DATA OF EACH ELECTRONIC COMPONENT
Ask your customer . . .
“How much heat is being generated from each electronic component in your enclosure?”

“SUPER COOL SALESMAN”

Gather heat load data for each electronic component
**STEP 1: DETERMINE INTERNAL HEAT LOAD**

**METHOD 2:**

\[
\text{INTERNAL HEAT LOAD} = \text{COMPONENT POWER (W)} - \text{COMPONENT EFFICIENCY}
\]

System uses **two** components that draw 115 VAC at 15 amps. Each has a rated efficiency of 90% (10% of each device becomes heat).

**Estimated internal heat load is:**

Device Power = 115 \times 15 = 1725 \text{ W}

Total Power = 2 \times 1725 = 3450

Less Efficiency = 3450 \times (1 - .90)

Total Heat Load = 345 \text{ W}

**Utilize component efficiency to estimate heat load**
STEP 1: DETERMINE INTERNAL HEAT LOAD

An enclosure has three input lines of 230 VAC at 11, 6 and 4 A. It has one output control line of 115 VAC at 9 A.

Estimated internal heat load is:

Incoming Power = (230 x 11) + (230 x 6) + (230 x 4) = 4830 W
Outgoing Power = 115 x 9 = 1035 W
Total Heat Load = 4830 – 1035 = 3795 W

Utilize power input and output to estimate heat load
STEP 1: DETERMINE INTERNAL HEAT LOAD

A cabinet has three 5-hp VFDs with 95% efficiency

Estimated internal heat load is:

VFD Watts = 5 hp x 745.6 x 3 = 11184
Adjusted Watts = 11184 x (1 - .95) = 559
Total Heat Load = 559 x 1.25 = 699 W

1.25 is an assumed “safety” margin for other minor heat producing components.

Utilize horsepower (hp) to estimate heat load
## Finding the Efficiency of Components

**Maximum Surrounding Air Temperature**
- Without derating: 0...50 °C (32...122 °F)
- Flange Mount: 0...50 °C (32...122 °F)
- IP66, NEMA/UL Type 4X/12: 0...40 °C (32...104 °F)

**Cooling Fan Operation**
- Frames A and C: Fan operates when power is applied.
- Frames B, D, and E: Fan operates when power is applied and in Run condition.

**Storage Temperature (all const.):**
- -40...70 °C (−40...158 °F)

**Atmosphere**
- Important: Drive must not be installed in an area where the ambient atmosphere contains volatile or corrosive gas, vapors or dust. If the drive is not going to be installed for a period of time, it must be stored in an area where it will not be exposed to a corrosive atmosphere.

**Relative Humidity:**
- 5...95% non-condensing

**Shock:**
- 15 g peak for 11 ms duration (±1.0 ms)

**Vibration:**
- 0.152 mm (0.006 in.) displacement, 1 g peak

### Electrical Specifications

<table>
<thead>
<tr>
<th>Category</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Tolerance:</td>
<td>-10% of minimum, +10% of maximum. See page C-17 for Full Power and Operating Range.</td>
</tr>
<tr>
<td>Frequency Tolerance:</td>
<td>47-63 Hz.</td>
</tr>
<tr>
<td>Input Phases:</td>
<td>Three-phase input provides full rating for all drives. Single-phase operation provides 50% of rated current.</td>
</tr>
<tr>
<td>Displacement Power Factor (all drives):</td>
<td>0.98 across speed range</td>
</tr>
<tr>
<td>Efficiency:</td>
<td>97.5% at rated amps, nominal line volts.</td>
</tr>
<tr>
<td>Maximum Short Circuit Rating:</td>
<td>200,000 Amps symmetrical.</td>
</tr>
<tr>
<td>Max. Short Circuit Current Rating:</td>
<td>Maximum short circuit current rating to match specified fuse/circuit breaker capability.</td>
</tr>
</tbody>
</table>
## Finding the Efficiency of Components

### Technical Specifications - Kinetix 7000 High Power Servo Drives

<table>
<thead>
<tr>
<th>Attribute</th>
<th>2099-BM04-S</th>
<th>2099-BM07-S</th>
<th>2099-BM08-S</th>
<th>2099-BM09-S</th>
<th>2099-BM10-S</th>
<th>2099-BM11-S</th>
<th>2099-BM12-S</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC input voltage</td>
<td>342...528V</td>
<td>340...528V</td>
<td>380...528V</td>
<td>380...528V</td>
<td>400...528V</td>
<td>400...528V</td>
<td>400...528V</td>
</tr>
<tr>
<td>AC input frequency</td>
<td>47...63Hz</td>
<td>47...63Hz</td>
<td>47...63Hz</td>
<td>47...63Hz</td>
<td>47...63Hz</td>
<td>47...63Hz</td>
<td>47...63Hz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity loop</td>
<td>1500 Hz</td>
<td>1500 Hz</td>
<td>1500 Hz</td>
<td>1500 Hz</td>
<td>1500 Hz</td>
<td>1500 Hz</td>
<td>1500 Hz</td>
</tr>
<tr>
<td>Current loop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC input voltage</td>
<td>450...750V</td>
<td>450...750V</td>
<td>450...750V</td>
<td>450...750V</td>
<td>450...750V</td>
<td>450...750V</td>
<td>450...750V</td>
</tr>
<tr>
<td>DC input current</td>
<td>42.9 A</td>
<td>55.7 A</td>
<td>69.7 A</td>
<td>105 A</td>
<td>137 A</td>
<td>204 A</td>
<td>281 A</td>
</tr>
<tr>
<td>Control power input Voltage</td>
<td>18...36V DC</td>
<td>18...36V DC</td>
<td>24V DC</td>
<td>24V DC</td>
<td>24V DC</td>
<td>24V DC</td>
<td>24V DC</td>
</tr>
<tr>
<td>Control power DC Input current</td>
<td>3.3 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
</tr>
<tr>
<td>Control power DC Input current (Nom)</td>
<td>3.3 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
</tr>
<tr>
<td>Control power DC Input current (Max)</td>
<td>3.3 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
</tr>
<tr>
<td>Control power DC Input current (Max Ims)</td>
<td>3.3 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
<td>3.6 A</td>
</tr>
<tr>
<td>Continuous current (nom)</td>
<td>40.0 A</td>
<td>52.0 A</td>
<td>65.0 A</td>
<td>96.0 A</td>
<td>125 A</td>
<td>180 A</td>
<td>248 A</td>
</tr>
<tr>
<td>Continuous current (max)</td>
<td>56.0 A</td>
<td>73.0 A</td>
<td>92.0 A</td>
<td>135 A</td>
<td>176 A</td>
<td>254 A</td>
<td>351 A</td>
</tr>
<tr>
<td>Continuous current (max Ims)</td>
<td>56.0 A</td>
<td>73.0 A</td>
<td>92.0 A</td>
<td>135 A</td>
<td>176 A</td>
<td>254 A</td>
<td>351 A</td>
</tr>
<tr>
<td>Peak current (nom)</td>
<td>68.0 A</td>
<td>80.0 A</td>
<td>104 A</td>
<td>154 A</td>
<td>194 A</td>
<td>234 A</td>
<td>325 A</td>
</tr>
<tr>
<td>Peak current (max)</td>
<td>68.0 A</td>
<td>80.0 A</td>
<td>104 A</td>
<td>154 A</td>
<td>194 A</td>
<td>234 A</td>
<td>325 A</td>
</tr>
<tr>
<td>Peak current (max Ims)</td>
<td>68.0 A</td>
<td>80.0 A</td>
<td>104 A</td>
<td>154 A</td>
<td>194 A</td>
<td>234 A</td>
<td>325 A</td>
</tr>
<tr>
<td>DC bus voltage</td>
<td>800V DC</td>
<td>800V DC</td>
<td>800V DC</td>
<td>800V DC</td>
<td>800V DC</td>
<td>800V DC</td>
<td>800V DC</td>
</tr>
<tr>
<td>DC bus voltage (over)</td>
<td>275...650V</td>
<td>275...650V</td>
<td>275...650V</td>
<td>275...650V</td>
<td>275...650V</td>
<td>275...650V</td>
<td>275...650V</td>
</tr>
<tr>
<td>Continuous power output, nom</td>
<td>22 kW</td>
<td>30 kW</td>
<td>37 kW</td>
<td>56 kW</td>
<td>75 kW</td>
<td>112 kW</td>
<td>149 kW</td>
</tr>
<tr>
<td>Continuous power output, max</td>
<td>30 kW</td>
<td>40 kW</td>
<td>50 kW</td>
<td>75 kW</td>
<td>100 kW</td>
<td>150 kW</td>
<td>200 kW</td>
</tr>
<tr>
<td>Maximum power cycles/minute</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC line</td>
<td>4 per minute (pre-charge provided by drive)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC bus</td>
<td>2 per minute (DC pre-charge provided by the regenerative power supply)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC bus dead time</td>
<td>3 minutes after removal of main AC power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Efficiency: 97.5%
## Table 1 - Technical Specifications - ControlLogix Standard AC Power Supplies

<table>
<thead>
<tr>
<th>Attribute</th>
<th>1756-PA72/C</th>
<th>1756-PA75/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>85…265V AC</td>
<td></td>
</tr>
<tr>
<td>Input voltage, nom</td>
<td>120V/240V AC</td>
<td></td>
</tr>
<tr>
<td>Input frequency range</td>
<td>47…63 Hz</td>
<td></td>
</tr>
<tr>
<td>Input power, max</td>
<td>100VA/100 W</td>
<td></td>
</tr>
<tr>
<td>Output power, max</td>
<td>75 W @ 0…60 °C (32…140 °F)(^{\text{2}})</td>
<td>25 W @ 0…60 °C (32…140 °F)</td>
</tr>
<tr>
<td>Power consumption</td>
<td>25 W @ 0…60 °C (32…140 °F)</td>
<td>85.3 BTU/hr</td>
</tr>
<tr>
<td>Power dissipation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold up time(^{\text{1}})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inrush current, max</td>
<td>20 A</td>
<td></td>
</tr>
<tr>
<td>Current capacity at 1.2V DC</td>
<td>1.5 A</td>
<td></td>
</tr>
<tr>
<td>Current capacity at 3.3V DC</td>
<td>4 A</td>
<td></td>
</tr>
<tr>
<td>Current capacity at 5.1V DC</td>
<td>10 A</td>
<td>13 A</td>
</tr>
<tr>
<td>Current capacity at 24V DC</td>
<td>2.8 A</td>
<td></td>
</tr>
<tr>
<td>Overcurrent protection, max</td>
<td>User-supplied 15 A(^{\text{3}})</td>
<td></td>
</tr>
<tr>
<td>Fusing</td>
<td>Non-replaceable fuse is soldered in place(^{\text{4}})</td>
<td></td>
</tr>
<tr>
<td>Transformer load, max</td>
<td>100VA</td>
<td></td>
</tr>
<tr>
<td>Isolation voltage</td>
<td>250V (continuous), reinforced insulation type</td>
<td>Type tested @ 3500V DC for 60 s, power input-to-backplane</td>
</tr>
<tr>
<td>Weight, approx.</td>
<td>0.95 kg (2.10 lb)</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td>140 x 112 x 145 mm (5.51 x 4.41 x 5.71 in.)</td>
<td>Left side of 1756 chassis (series B only)</td>
</tr>
<tr>
<td>Module location</td>
<td>Left side of 1756 chassis</td>
<td></td>
</tr>
</tbody>
</table>
STEP 2: DETERMINE HEAT TRANSFER LOAD

Heat transfer load = ambient heat outside enclosure conducting itself through enclosure walls

METHODS TO DETERMINE HEAT TRANSFER LOAD
1. Simple Chart Method
2. Equation Method

REMEMBER
▶ The higher the ambient temperature and/or the presence of solar heat gain on the enclosure, the more cooling capacity is required.
Step 2: Determine Heat Transfer Load

Method 1: Simple Chart Method

Reasonably accurate for most indoor industrial systems

Step A. Determine $\Delta T$ in °F or °C

Step B. Find the heat transfer per ft.$^2$ or m$^2$ on the chart, using $\Delta T$ and the proper enclosure material curve.

Step C. Multiply the heat transfer per ft.$^2$ or m$^2$ by the total surface area of the enclosure that will conduct heat. (Remember to exclude surfaces such as a side mounted to a wall.)

Use $\Delta T$ and enclosure surface area to estimate heat transfer load.

Surface Area (ft.$^2$) = \[2AB (in.) + 2BC (in.) + 2AC (in.)\] ÷ 144

Surface Area (m$^2$) = \[2AB (mm) + 2BC (mm) + 2AC (mm)] ÷ 1000000

Total Heat Transfer Load = Heat Transfer per ft.$^2$ or m$^2$ x Cabinet Surface Area
STEP 2: DETERMINE HEAT TRANSFER LOAD

A painted steel enclosure has 80 ft.$^2$ of surface area and will be located in a maximum ambient temperature of 95 degrees F. The rated temperature of the electronics is 75 degrees F.

**Estimated internal heat transfer load is:**

\[
\Delta T = 95 - 75 = 20 \text{ F}
\]

Heat Transfer = 4 W/ft.$^2$ (from chart)

Total Heat Transfer Load = 80 x 4 = 320 W

If system will be deployed outdoors, solar heat gain will need to be added. We recommend utilizing the online Product Selection Tool in these instances.
**STEP 2: DETERMINE HEAT TRANSFER LOAD**

**METHOD 2: EQUATION METHOD**

The governing equations for heat transfer load are:

English System (° F, inches and feet):

\[
q = \frac{(T_o - T_i)}{\left(\frac{1}{h_o} + \frac{1}{h_i} + R\right)}
\]

Metric System (° C, millimeters and meters):

\[
q = \frac{(T_o - T_i)}{\left(\frac{1}{h_o} + \frac{1}{h_i} + R\right) \times 5.67}
\]

\[
q = \frac{(125 - 75)}{\left[\frac{1}{6} + \frac{1}{2} + 4\right]}
\]

\[
q = \frac{(50)}{\left[\frac{1}{16} + \frac{1}{5} + 4\right]}
\]

\[
q = 50 \div 4.66
\]

\[
q = 10.7 \text{ BTU/hr./ft.}^2
\]

**Total Heat Transfer Load**

\[
10.7 \times 72 = 770 \text{ BTU/hr. or } 770 \div 3.413 = 226 \text{ W}
\]

Since the cabinet is outdoors, and assuming it is painted ANSI 61 gray and located in the sun, extra solar load needs to be added to the outcome above which is 504 Watts (7 W per ft.2 x 72 ft.2).

**Total Heat Transfer Load with Extra from Solar Heat Gain**

\[
226 + 504 = 730 \text{ W}
\]

Definition of Variables—

- \(q\): Heat transfer load per unit of surface area
- \(T_o\): Maximum ambient temperature outside the enclosure
- \(T_i\): Maximum rated temperature of the electronics components
- \(h_o\): Convective heat transfer coefficient outside the cabinet
  - Still air: \(h = 1.6\)
  - Relatively calm day: \(h = 2.5\)
  - Windy day (approx. 15 mph): \(h = 6.0\)
- \(h_i\): Convective heat transfer coefficient inside the cabinet
  - Still air: \(h = 1.6\)
  - Moderate air movement: \(h = 2.0\)
  - Blower (approx. 8 ft.3/sec.): \(h = 3.0\)
- \(R\): Value of insulation lining the interior of the enclosure walls
  - No insulation: \(R = 0.0\)
  - 1/2 in. or 12 mm: \(R = 2.0\)
  - 1 in. or 25 mm: \(R = 4.0\)
  - 1-1/2 in. or 38 mm: \(R = 6.0\)
  - 2 in. or 51 mm: \(R = 8.0\)
The internal heat load from one of the earlier examples was 3795 Watts. If the heat transfer load is 730 W.

\[
\text{Total Heat Load} = 3795 + 730 = 4525 \text{ W}
\]

To convert Watts into BTU/hr. multiply by 3.413

\[
4525 \text{ W} = 15444 \text{ BTU/hr.}
\]
AIR CONDITIONER SPEC EXAMPLE

Estimated internal heat load:
Device Power = 115V x 17Amp = 1955 W
Total Power = 6 x 1955W = 11730W
Less Efficiency = 11730W x (1 - .90)
Total Heat Load = 1173 W

Online Product Selection Tool:
Total heat load = 1733 W
BTU/Hr. = 1733 x 3.413 = 5914
CUSTOMER NEEDS ANALYSIS

Identify the customer’s remaining requirements

UTILITIES AT THE INSTALLATION
- Electricity only
- Chilled circulated water
- Compressed air

ENCLOSURE COOLING LOCATION
- Side of the enclosure
- Top of the enclosure
- 19” data rack
- Back panel / inside the enclosure

POWER INPUT
- 115 VAC 50/60 Hz
- 230 VAC 50/60 Hz
- 230 VAC 50 Hz
- 460 VAC 50/60 Hz single-phase
- 460 VAC 50/60 Hz three-phase
- 24 VDC
- 48 VDC

AGENCY CERTIFICATION
- UL / cUL
- UR
- CSA
- CE
- GOST
- Telcordia GR-487 capable

Leads you to the final cooling product and options
SPECIFYING FRESH AIR COOLING PRODUCTS

What is air flow?

- Air flow is the volume of air moved by a Fresh Air Cooling product such as a filter fan, impeller, 19” fan tray or blower
- It’s like gallons or liters per minute of water
- The more that an electronics system puts out heat, the more air flow is needed to cool it
- Air flow is measured in terms of:
  - CFM (English system)
  - M³/Hr (Metric system)

As you select a Fresh Air Cooling product, you will use Air Flow
What is static pressure?

- Static Pressure is the air flow restriction caused by electronic components.
- Here are three examples:

- Static pressure is measured in terms of:
  - Inches of H$_2$O (English system)
  - Pascal (Metric system)
SPECIFYING FRESH AIR COOLING PRODUCTS

Use these 5 simple steps to specify an Open Loop Product.

1. **Determine Delta-T** — The difference in maximum desired temperature for the electronics and maximum temperature outside the enclosure

   ![Diagram showing electronics vs. ambient temperature difference (ΔT)]

   \[
   \text{Delta-T} = \text{Maximum Temperature Desired for the Electronics} - \text{Maximum Expected Ambient Temperature}
   \]

   **Example** —
   \[
   \text{Delta-T} = 35^\circ C (95^\circ F) \text{ Maximum Electronics Temperature} - 25^\circ C (77^\circ F) \text{ Maximum Ambient Temperature}
   \]

   \[
   \text{Delta-T} = 10^\circ C (18^\circ F)
   \]

2. **Determine Heat Load** — The amount of heat to be removed from the enclosure

   **Electronics Heat Load**

   **Heat Load Definition**
   \[
   \text{Heat Load} = \text{Total Watts Drawn by the Electronics System} - \text{System Efficiency}
   \]

   **Example** —
   \[
   \text{Heat Load} = 10000 \text{ Watts Drawn by the Electronics System} - 90\% \text{ System Efficiency}
   \]

   \[
   \text{Heat Load} = 1000 \text{ Watts}
   \]

1000 Watts of heat at a ΔT of 10°C need to be removed
SPECIFYING FRESH AIR COOLING PRODUCTS

3. **Determine Free Air Flow** — Using Delta-T (Step 1) and Heat Load (Step 2)

Consult the manufacturers catalog for performance curves
Estimate Air Flow Restriction — Determine approximate system impedance based on the amount of electronics in the cabinet using your judgment

Levels of Air Flow Restriction
(Need to confirm with actual prototype testing)

Many Industrial cabinets are lightly packed with electronics
SPECIFYING FRESH AIR COOLING PRODUCTS

**Select Your Open Loop solution**— Pick the Power Input and Protection Level. Then overlay a judgmental airflow restriction curve on the performance curves of your fan options, picking the one with the closest air flow.

**ST13 303 CFM (515 M³/Hr) Filter Fan**

- **Under-Sized**
  - Below 180 CFM (306 M³/Hr) target

**SF13 376 CFM (638 M³/Hr) Filter Fan**

- **Right-Sized**
  - At the 180 CFM (306 M³/Hr) target

**SF13 473 CFM (803 M³/Hr) Filter Fan**

- **Over-Sized**
  - Above 180 CFM (306 M³/Hr) target

Designers should confirm the filter fan model with a system test.
SPECIFYING FRESH AIR COOLING PRODUCTS

Air mover cooling is based on air flow and static pressure.

- Fans - High Volume Low Pressure
- MI’s - High Volume Medium Pressure
- Centrifugal Blower - High Volume High Pressure
- Radial Blower - Low Volume High Pressure

Impellers overcome more air restriction than filter fans
SPECIFYING FRESH AIR COOLING PRODUCTS

The capability of each Fresh Air Cooling option varies considerably.

• General vs. concentrated air flow
• Amount of air volume
• Ability to overcome air flow restrictions caused by electronic components
• Component price
• Power input (AC or DC volt)
• Ability to protect the electronics from dust and water

You will need to carefully consider your Fresh Air Cooling options
Filter fans often cool Industrial enclosures because the electronics are “lightly packed”, and the factory is climate controlled.

Industrial Filter Fan Design Options

**Push Design**

A typical application. Pressurizes cabinet to help keep out dust.

**Push Design with Dual Exhaust**

An extra exhaust grille is added to improve air flow and cooling.

**Pull Design**

Pull design is less desirable because dust can be sucked inside the cabinet.

**Push / Pull Design**

Push / pull is used to increase air flow through more tightly packed cabinets.

**Roof Mount Design**

Roof mount filter fans save space inside the cabinet.

Filter fans are typically installed using a “Push Design”
SPECIFYING FRESH AIR COOLING PRODUCTS

How to Specify an Open Loop Cooling Solution

- Determining Factors
  - Maximum ambient temperature
  - Maximum enclosure temperature
  - Maximum rise in temperature ($\Delta T$)
  - Heat to be dissipated (heat load)
  - Hot spots in the cabinet
  - Air mover type (fan tray, blower, etc.)
  - Air flow (CFM or M3/HR)
  - Enclosure system air resistance
  - Static pressure (air flow drive)

- Negative or positive cabinet pressure
- Air filtration
- Maximum sound levels (dB)
- Power source (AC or DC)
- Voltage range (of power source)
- Optional controls & alarms
- Power consumption
- Reliability (estimated life)
- Budget
## TYPES OF ENCLOSURE TEMPERATURE REGULATORS

A variety of sealed enclosure and fresh air cooling products exist.

<table>
<thead>
<tr>
<th>SEALED ENCLOSURE COOLING</th>
<th>FRESH AIR COOLING</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR CONDITIONER</td>
<td>INDUSTRIAL FILTER FAN</td>
</tr>
<tr>
<td>Keeps electronics cooler than temperatures outside the enclosure by using a refrigerant system</td>
<td>Pushes cool air through the enclosure to remove heat from the electronics</td>
</tr>
<tr>
<td>AIR-TO-AIR HEAT EXCHANGER</td>
<td>COMPACT AXIAL FAN</td>
</tr>
<tr>
<td>Quickly radiates heat away from the enclosure by circulating cool air through a metal core</td>
<td>Circulates cool air through or within the electrical enclosure</td>
</tr>
<tr>
<td>VORTEX COOLER</td>
<td>19” FAN TRAY AND BLOWER</td>
</tr>
<tr>
<td>Cools electronics lower than temperatures outside the enclosure using compressed air</td>
<td>Fits a standard 19” data rack, blowing fresh cool air through the electronics</td>
</tr>
<tr>
<td>AIR-TO-WATER HEAT EXCHANGER</td>
<td>ENCLOSURE HEATER</td>
</tr>
<tr>
<td>Also keeps electronics cooler than temperatures outside the enclosure, but with chilled water</td>
<td>Used to warm electronics rather than cool them. Also reduces condensation inside the electrical enclosure</td>
</tr>
<tr>
<td>THERMOELECTRIC COOLER</td>
<td></td>
</tr>
<tr>
<td>A refrigerant-free form of air conditioning that relies on electrified ceramic chips. Also known as Peltier cooling</td>
<td></td>
</tr>
</tbody>
</table>

McLean makes every one of these products available today
SUMMARY

• Understanding why temperature variation can be a problem
• Understand the consequences of over-heated electronics
• Learn the benefits of cooling industrial electronics
• Identify the sources of damaging heat
• Learn how to size a cooling unit for your cabinet