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

Electrical 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
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 trigger point requirements
  • 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 the effect of temperature on mechanical properties of wiring insulation. The x-axis represents classes A, E, B, F, and H with temperatures 105°C, 120°C, 130°C, 155°C, and 180°C. The y-axis represents the mechanical property index. The graph shows that as temperature increases, the thermal margin decreases, while the permissible temperature and max ambient temperature increase.]
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
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.

$\Delta T = T_{\text{MAX}} - T_A$
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 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 Increase (H₂O)

Air Flow - CFM

0
0.2
0.4
0.6
0.8
1
1.2
0 200 400 600 800
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.
CUSTOMER NEEDS ANALYSIS

Determine ambient and electronics temperatures

Electrical Enclosure

A  AMBIENT TEMPERATURE
The maximum temperature outside the enclosure.

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

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

B > A  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

\[ \text{TOTAL HEAT LOAD} = \text{INTERNAL HEAT LOAD} + \text{HEAT TRANSFER LOAD} \]
**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

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 x 15 = 1725 W
Total Power = 2 x 1725 = 3450
Less Efficiency = 3450 x (1 - .90)
Total Heat Load = 345 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

**Kinetix 7000 Drive Power Specifications**

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AC input voltage</td>
<td>342...520V AC rms three-phase (380...480V vac)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC input frequency</td>
<td>47...63 Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bandwidth (Hz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity loop</td>
<td>500 Hz</td>
<td>1500 Hz</td>
<td>500 Hz</td>
<td>500 Hz</td>
<td>500 Hz</td>
<td>500 Hz</td>
<td>500 Hz</td>
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<tr>
<td>Current loop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PWM Frequency</td>
<td>44 Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main AC input current (Nom. (Arms))</td>
<td>36.7 A</td>
<td>47.7 A</td>
<td>59.6 A</td>
<td>90.1 A</td>
<td>117 A</td>
<td>169 A</td>
<td>233 A</td>
</tr>
<tr>
<td>DC input voltage</td>
<td>450...750V DC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></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 (24V DC, nom)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control power DC Input current (Nom.)</td>
<td>3.3 A</td>
<td>6.8 A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum input (rms)</td>
<td>3.3 A</td>
<td></td>
<td>6.8 A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous output current (rms)</td>
<td>40.0 A</td>
<td>52.9 A</td>
<td>65.0 A</td>
<td>98.0 A</td>
<td>125 A</td>
<td>180 A</td>
<td>248 A</td>
</tr>
<tr>
<td>Continuous output current (Dc-pk)</td>
<td>56.0 A</td>
<td>73.9 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 output current (rms)</td>
<td>68.0 A</td>
<td>80.0 A</td>
<td>104 A</td>
<td>154 A</td>
<td>193 A</td>
<td>250 A</td>
<td>384 A</td>
</tr>
<tr>
<td>3 s duration</td>
<td>51.0 A</td>
<td></td>
<td>80.0 A</td>
<td></td>
<td>154 A</td>
<td>241 A</td>
<td></td>
</tr>
<tr>
<td>60 s duration</td>
<td>60.0 A</td>
<td></td>
<td>80.0 A</td>
<td></td>
<td>154 A</td>
<td>241 A</td>
<td></td>
</tr>
<tr>
<td>Peak output current (Dc-pk)</td>
<td>96.0 A</td>
<td>112 A</td>
<td>147 A</td>
<td>217.0 A</td>
<td>236.5 A</td>
<td>441 A</td>
<td>526 A</td>
</tr>
<tr>
<td>3 s duration</td>
<td>72.0 A</td>
<td>94.4 A</td>
<td>129 A</td>
<td>217.0 A</td>
<td>236.5 A</td>
<td>441 A</td>
<td>526 A</td>
</tr>
<tr>
<td>60 s duration</td>
<td>60.0 A</td>
<td></td>
<td>80.0 A</td>
<td></td>
<td>154 A</td>
<td>241 A</td>
<td></td>
</tr>
<tr>
<td>Bus overvoltage</td>
<td>800V DC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus undervoltage</td>
<td>275...560V DC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></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 (Hp)</td>
<td>30 Hp</td>
<td>40 Hp</td>
<td>50 Hp</td>
<td>75 Hp</td>
<td>100 Hp</td>
<td>150 Hp</td>
<td>200 Hp</td>
</tr>
<tr>
<td>Maximum power cycles/minute</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>AC line</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 line</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%
# Finding the Efficiency of Components

## 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)(2)</td>
<td>25 W @ 0...60 °C (32...140 °F)</td>
</tr>
<tr>
<td>Power consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power dissipation</td>
<td>85.3 BTU/hr</td>
<td></td>
</tr>
<tr>
<td>Hold up time(1)</td>
<td>5 cycles @ 85V AC, 50/60 Hz</td>
<td>6 cycles @ 120V AC, 50/60 Hz</td>
</tr>
<tr>
<td></td>
<td>6 cycles @ 200V AC, 50/60 Hz</td>
<td>6 cycles @ 240V AC, 50/60 Hz</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(3)</td>
<td></td>
</tr>
<tr>
<td>Fusing</td>
<td>Non-replaceable fuse is soldered in place(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 Type tested @ 3500V DC for 60 s, power input-to-backplane</td>
<td></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>Left side of 1756 chassis (series B only)</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 ΔT in °F or °C

**Step B.** Find the heat transfer per ft.$^2$ or m$^2$ on the chart, using ΔT 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 ΔT and enclosure surface area to estimate heat transfer load.

**Surface Area (ft.$^2$):** \[
\text{SURFACE AREA} = \frac{2AB + 2BC + 2AC}{144}
\]

**Surface Area (m$^2$):** \[
\text{SURFACE AREA} = \frac{2AB + 2BC + 2AC}{1000000}
\]

**Total Heat Transfer Load:** \[
\text{Total Heat Transfer Load} = \text{Heat Transfer per ft.}^2 \text{ or m}^2 \times \text{Cabinet Surface Area}
\]
**STEP 2: DETERMINE HEAT TRANSFER LOAD**

**METHOD 1: SIMPLE CHART METHOD**

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):

\[ q = (T_o - T_i) \div [(1/ho) + (1/hi) + R] \]

Metric System (° C, millimeters and meters):

\[ q = (T_o - T_i) \div [(1/ho) + (1/hi) + R] \times 5.67 \]

\[ q = (125 - 75) \div [(1/6) + (1/2) + 4] \]
\[ q = (50) \div (.16 + .5 + 4) \]
\[ q = 50 \div 4.66 \]
\[ q = 10.7 \text{ BTU/hr./ft.2} \]

**Total Heat Transfer Load**

10.7 x 72 = 770 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 W

Definition of Variables—
q = Heat transfer load per unit of surface area
To = Maximum ambient temperature outside the enclosure
Ti = Maximum rated temperature of the electronics components
ho = 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

hi = 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
**STEP 3: DETERMINE TOTAL HEAT LOAD**

The internal heat load from one of the earlier examples was 3795 Watts. If the heat transfer load is 730 W.

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

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

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

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.
SPECIFYING FRESH AIR COOLING PRODUCTS

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 H₂O (English system)
    - Pascal (Metric system)

You will also use Static Pressure to choose Fresh Air Cooling
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

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

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

   \[ \text{Delta-T} = 10°C (18°F) \]

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

   **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 \( \Delta T \) 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**

5. **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 airflow.

- **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**
  - Light Airflow Restriction

- **SF13 473 CFM (803 m³/Hr) Filter Fan**
  - Light Airflow Restriction

- **Right-Sized**
  - At the 180 CFM (306 m³/Hr) target

- **Over-Sized**
  - Above 180 CFM (306 m³/Hr) target

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

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.

## SEALED ENCLOSURE COOLING

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR CONDITIONER</td>
<td>Keeps electronics cooler than temperatures outside the enclosure by using a refrigerant system</td>
</tr>
<tr>
<td>AIR-TO-AIR HEAT EXCHANGER</td>
<td>Quickly radiates heat away from the enclosure by circulating cool air through a metal core</td>
</tr>
<tr>
<td>VORTEX COOLER</td>
<td>Cools electronics lower than temperatures outside the enclosure using compressed air</td>
</tr>
<tr>
<td>AIR-TO-WATER HEAT EXCHANGER</td>
<td>Also keeps electronics cooler than temperatures outside the enclosure, but with chilled water</td>
</tr>
<tr>
<td>THERMOELECTRIC COOLER</td>
<td>A refrigerant-free form of air conditioning that relies on electrified ceramic chips. Also known as Peltier cooling</td>
</tr>
<tr>
<td>ENCLOSURE HEATER</td>
<td>Used to warm electronics rather than cool them. Also reduces condensation inside the electrical enclosure</td>
</tr>
</tbody>
</table>

## FRESH AIR COOLING

<table>
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<tr>
<th>Product</th>
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</tr>
</thead>
<tbody>
<tr>
<td>INDUSTRIAL FILTER FAN</td>
<td>Pushes cool air through the enclosure to remove heat from the electronics</td>
</tr>
<tr>
<td>COMPACT AXIAL FAN</td>
<td>Circulates cool air through or within the electrical enclosure</td>
</tr>
<tr>
<td>19” FAN TRAY AND BLOWER</td>
<td>Fits a standard 19” data rack, blowing fresh cool air through the electronics</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