How to Dissipate Excess Heat - Understanding ΔT and CFM

$$\text{Watts} = .316 \times \text{CFM} \times \Delta T$$

or

$$\text{CFM} = \text{Watts} / (.316 \times \Delta T)$$

or

$$\Delta T = (.315 \times \text{CFM}) / \text{Watts}$$

Factors in this equation will need to be de-rated for high elevations.

When it comes to cooling a data center, one equation is key
Cooling network equipment requires both cold intake air and airflow (CFM). These two factors work directly to dissipate, or carry away, the heat that network equipment produces. While increasing either factor will increase the amount of heat that is dissipated, there are limits to both. Air that is too cold results in thermal expansion and condensation issues. Airflow that is too high results in acoustic and physical limitations. A cooling system that relies on too much of only one of these factors usually results in higher capital and operating costs. Finding an ideal balance between cold air and airflow allows optimal heat dissipation, protecting network equipment from the consequences of overheating.

ΔT

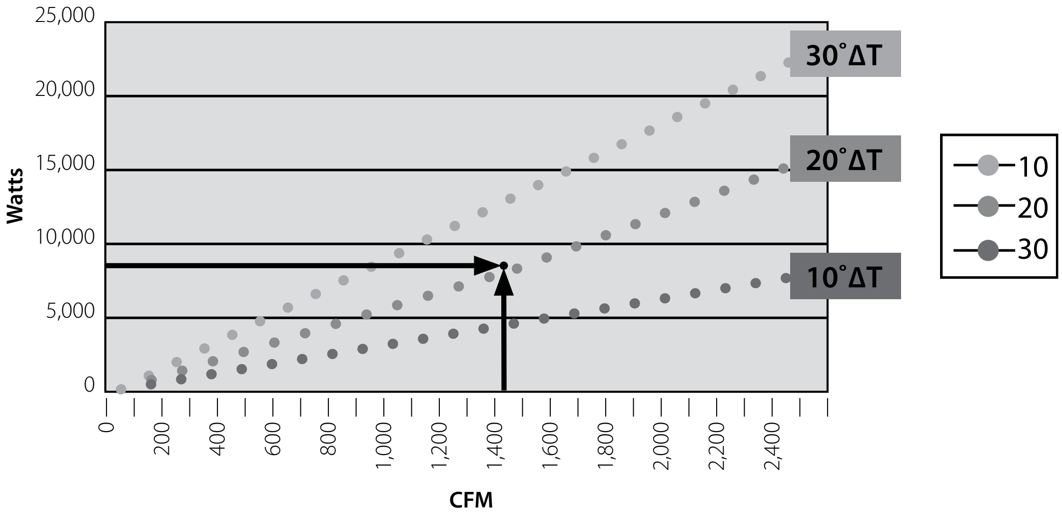
In the above equations, ΔT, measured in degrees Fahrenheit, refers to the difference between the intake air and exhaust air, or the amount of heat that is carried away by the stream of air exiting the heat load. A greater temperature difference signifies more heat being removed. While it is difficult to constantly deliver the coldest air to all equipment—in particular, equipment installed in upper rack units—data centers that maintain a range between 10 and 30 F ΔT carry a high level of confidence that equipment will dissipate the amount of heat that it produces, staying within its thermal limits.

- The area between 10 and 30 degrees ΔT represents capable cooling in a typical well-designed data center.
- Knowing two of the three quantities allows operators to solve for the third—in this equation, knowing either watts or CFM solves for ΔT.

For example, 9000 W in a data center with a ΔT of 20 degrees requires 1425 CFM.

More than 30 degrees ΔT can cause humidity and condensation issues.

Watts = .316 x CFM x ΔT (˚F)



Thermal Management

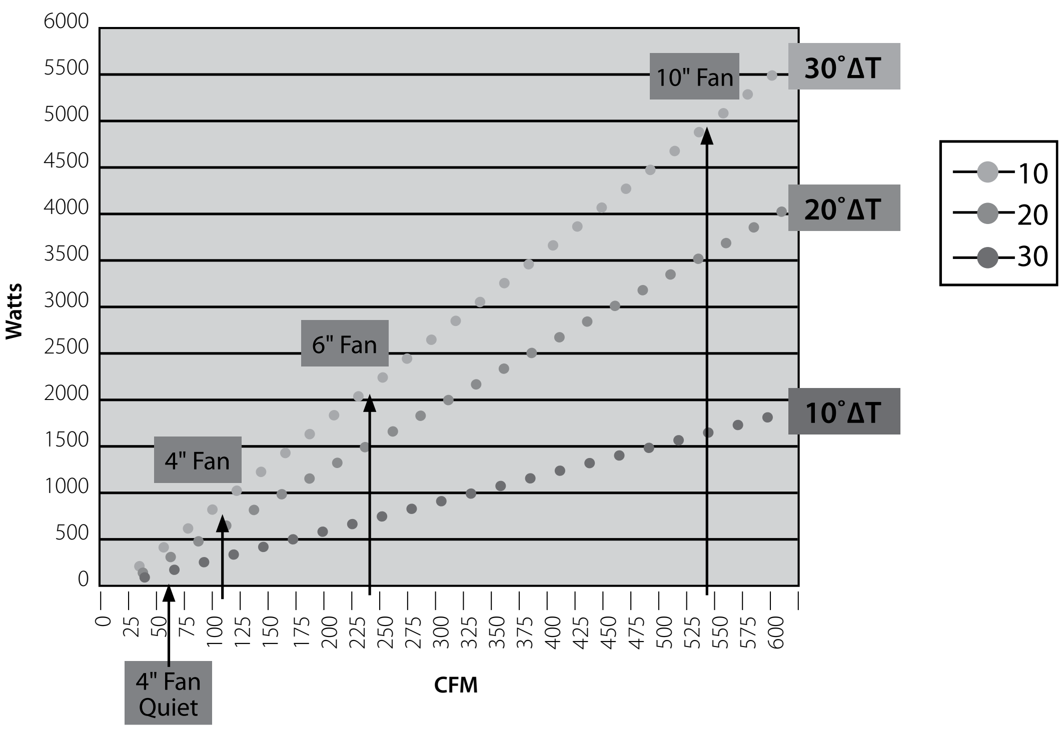
CFM

Another way to increase the amount of heat dissipated or removed from network equipment is by increasing the airflow, expressed in cubic feet per minute (CFM). An increase of CFM—the amount of airflow across a given area in a given time—results in increased heat removal. CFM can be achieved through the use of fans. The larger the fan, the more CFM it provides. An increase in RPM (the speed at which the fan circulates) as well as the size or quantity of fan blades results in a higher CFM, but as these factors increase, so do several others that can be detrimental to the equipment in data centers. For example, acoustic noise is one consequence of high levels of CFM. Additionally, at very high CFM, physical forces also come into play that can cause damage to electrical equipment. Plus the higher the CFM, the higher the upfront capital costs, as well as ongoing operational expenses.

- Most data centers operate between 10 and 20 ΔT. Using this and the CFM of the fan, the necessary quantity of cooling (watts) can be determined.
- The same equation also works for equipment outside the data center. Again, the intake air can only be so cold and at a certain CFM before other issues arise.
- The bigger the fan, the more airflow that moves across equipment. The amount of airflow and the temperature of the air determine the amount of heat dissipation that can occur.
- $CFM_{in} = CFM_{out}$ on all passive systems.
- Total CFM_{in} = the sum of all equipment (servers) mounted in the cabinet.

An increase in fan size will increase acoustic noise at the same motor RPM.

4", 6", & 10" Cooling Fan Performance



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Solar Heat Gain

When evaluating the thermal management needs of outdoor electrical enclosures, solar heat gain must be considered. Variables that affect the enclosure's internal temperature rise include the amount of solar exposure, enclosure color and material type, highest sustained atmospheric temperature, heat build-up from internal components and heat reflectance from the surrounding environment.

Exposure to Solar Radiation

Over much of the United States, the approximate peak values of solar radiation striking the Earth's surface is 97 W/ft.^{2} and the ambient air temperature can reach 104 F. Altitude, humidity and air pollution have an impact on these values, even more so than the location's latitude. In the high, dry climates of the southwest, solar radiation values of 111 W/ft.^{2} and air temperatures greater than 104 F can be reached.

The extreme conditions the enclosure will be exposed to should be identified. If the internal enclosure temperature is greater than the outdoor (ambient) temperature, wind will provide greater heat transfer and thus cool the enclosure. But, because the presence of wind cannot be guaranteed, it is usually not taken into account when establishing a worst-case evaluation.

Effect of Surrounding Location

Reflection of solar energy from the foreground and surrounding surfaces can impact the total amount of radiant exposure by as much as 30 percent.

Effect of Enclosure Color and Finish

The percent of solar energy absorbed by the enclosure depends on surface color, finish and texture. Absorption values of the finish will increase with age.

Standardized Test Evaluation

Telcordia NEBS™ GR-487 provides a test procedure for evaluating the solar load on electrical/electronic enclosures. The test is run with the internal electronics on, in an environmentally controlled room, and three sides of the enclosure are illuminated uniformly with controlled banks of lights to a measured surface radiant value of 70 W/ft.^{2} The temperature rise inside the enclosure above ambient is added to 115 F (46 C). This temperature total must not exceed the lowest-rated component within the enclosure.

Evaluation of Solar Heat Gain

To evaluate the heat load on an enclosure, you must take into account:

- Total surface area of the enclosure
- Color of the enclosure
- Internal heat load
- Maximum allowable internal temperature
- Maximum ambient temperature
- Solar load

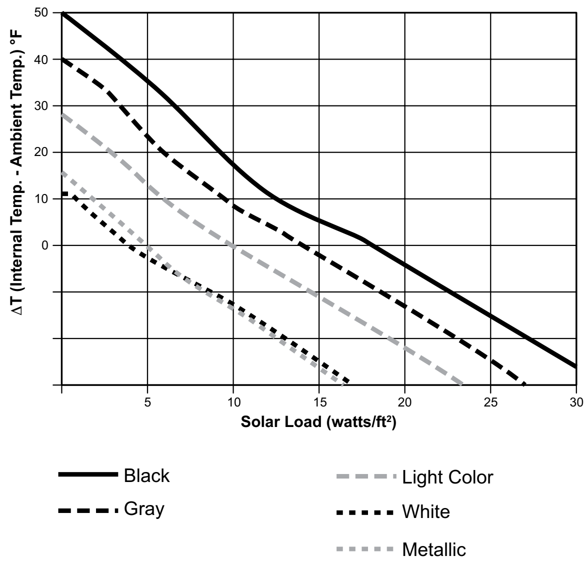
Examples:

1. What amount of heat energy must be removed from a 24 x 20 x 12 (surface area = 14 ft.^{2}) ANSI 61 gray enclosure located outdoors without any heat dissipated internally, to maintain the enclosure temperature equal to the ambient (temperature rise = 0 degrees)? From the chart below, at 0 F temperature rise we find the solar load is approximately 14 W/ft.^{2} (14 ft.^{2} x 14 W/ft.^{2} = 196 W). This is the heat energy that must be removed to maintain the enclosure temperature at ambient.

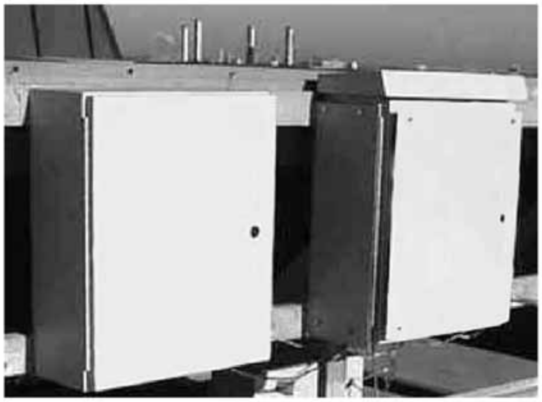
2. If the same enclosure has internal equipment dissipating 200 W of heat, what is the amount of heat energy that must be removed to maintain the enclosure at a temperature rise of 20 F above the ambient temperature? From the chart below, at 20 F temperature rise we find the solar load is approximately 6 W/ft.^{2} (14 ft.^{2} x 6 W/ft.^{2} = 84 W). All of the internally dissipated heat of 200 W must also be removed. 84 W + 200 W = 284 W. This is the total amount of heat energy that must be removed to maintain the enclosure at 20 F above the ambient temperature.

3. What is the expected temperature rise above the ambient temperature due to solar heat gain for an enclosure with ANSI 61 gray finish? From the chart below, the temperature rise due to solar heat load can be found by locating the intersection of the data curve for the given finish and the 0 Solar Generated Heat Load axis. For ANSI 61 Gray, the temperature rise due to solar heat is about 40 F.

Solar Load Based on Color and Temperature Rise



The Benefits of Shielding Enclosures



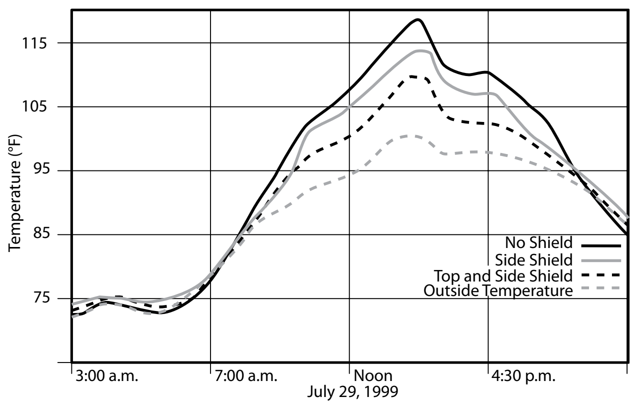
Hoffman's research on the effects of solar radiation on enclosures has shown the positive benefits of utilizing shielding to decrease temperature rise. Shielding has been found to be an effective, low-cost method of reducing solar heat gain in outdoor electrical/electronic applications.

A test to compare the shielding effect on internal temperature rise was performed on similar enclosures exposed to the sun. The enclosures are the same color (RAL 7035 light gray) and material. The enclosure on the left is unshielded; the enclosure on the right is shielded on top and applicable sides.

Solar Heat Gain

The results of the test show the enclosure with top and side shields to have approximately a 46 percent reduction in temperature compared to the unshielded enclosure. The reduction in temperature is approximately 25 percent with the solar top shield only. Hoffman offers top shields as an accessory for Hoffman COMLINE® Wall-Mount Enclosures. Hoffman can provide side shields as a customer-ordered modification.

Shielding E ec tiveness



Enclosure Type	Temperature (F)	Temperature (C)	Percent Temperature Reduction
Unshielded	119	48	—
Top shield only	114	46	25
Top and side shields	110	43	46

Standards Organization Summary and Directory Overview

What's in a Rating?
As a way of standardizing enclosure performance, organizations like NEMA, UL, CSA, IEC and VDE use rating systems to identify an enclosure's ability to resist external environmental influences. Resistance to everything from dripping liquid to hose-down to total submersion is defined by the ratings systems. While these ratings are all intended to provide information to help you make a safer, more-informed product choice, there are differences among them.

North American Standards Organizations
In North America, NEMA, UL and CSA are the commonly recognized standards organizations. Their ratings are based on similar application descriptions and expected performance. UL and CSA both require enclosure testing by qualified evaluators in their certified labs. They also send site inspectors to make sure a manufacturer adheres to prescribed manufacturing methods and material specifications. NEMA, on the other hand, does not require independent testing and leaves compliance completely up to the manufacturer.

North American enclosure rating systems also include a 4X rating that indicates corrosion resistance. This rating is based on the enclosure's ability to withstand prolonged exposure to salt water spray.

While a 4X rating is a good indicator that an enclosure can resist corrosion, it does not provide information on how a specific corrosive agent will affect a given enclosure material. It is best to conduct a full analysis of the specific application and environment to determine the best enclosure choice.

International Standards Organizations
Like NEMA, IEC does not require independent testing and leaves compliance completely up to the manufacturer. Nevertheless, there are differences in how enclosure performance is interpreted. For example, UL and CSA test requirements specify that an enclosure fails the water-tight test if even a single drop of water enters the enclosure. In the IEC standards for each level of ingress protection (IP), a certain amount of water is allowed to enter the enclosure.

IEC 60529 IP ratings do not specify construction requirements or degrees of protection against corrosive atmospheres, risk of explosion or conditions such as moisture or corrosive vapors. NEMA Type ratings, on the other hand, do specify construction and performance requirements for most environmental conditions. For this reason, and because the tests and evaluations for other characteristics are not identical, the IEC enclosure classification designations cannot be exactly equated with NEMA enclosure Type numbers.

CE

For industrial control equipment, the CE Mark is not intended to be applied to empty enclosures because such enclosures are inactive components of a final assembly. The responsibility of ensuring compliance with all applicable EU directives and harmonized standards belongs with the final equipment manufacturer.

Enclosure Type Rating vs. IP Rating

Electrical enclosures are rated by Type (NEMA 250 / UL 50, 50E), and/or IP rating (IEC 60529) based upon the degree of protection provided. Type ratings and IP ratings have only the following in common:

1. A degree of protection for persons from hazardous components inside the enclosure
2. A degree of protection for equipment inside the enclosure from ingress of solid foreign objects, including dust
3. A degree of protection for equipment inside the enclosure from ingress of water

NEMA 250 and UL 50, 50E Type rating documentation defines additional requirements that a Type-rated enclosure must meet. These include:

- Mechanical impact on enclosure walls
- Gasket aging and oil resistance
- Corrosion resistance
- Door and cover latching requirements
- Sheet metal gauge construction requirements (UL 50 only)

Electrical enclosures that carry only an IP rating have not been designed or tested to the additional Type-rating requirements. For this reason, and because the tests and evaluations for other characteristics are not identical, the IP ratings cannot be exactly equated with NEMA enclosure Types.

Electrical enclosures manufactured by Hoffman are tested for and carry both Type and IP ratings.

Fluid Statics and Dynamic Comparison of Ingress Water Tests

Test Type	Flow Rate (gal./min.)	Flow Rate (l/min.)	Nozzle Diameter in./mm	Nozzle Area (in.^{2})	Nozzle Velocity (ft./sec.)	Equivalent Head (ft.)	Equivalent Pressure (psi)	Mass Flow (lb./sec.)	Power (hp)	Total Force on Vertical Plate (lb.)
Type 3	45.00	170	1.0000 25.4	0.7854	18.38	5.25	2.274	6.256	0.060	3.5716
Type 4	65.00	246	1.000 25.4	0.7854	26.55	10.85	4.744	9.037	0.180	7.4516
IPX5	3.30	12.5	0.2480 6.3	0.0483	21.93	7.46	3.235	0.459	0.006	0.3126
IPX6	26.42	100	0.4921 12.5	0.1902	44.55	30.82	13.357	3.672	0.206	5.0815

NEMA, UL and CSA Ratings

Enclosure Type Descriptions for Non-Hazardous Locations

	Enclosure Type	NEMA	UL	CSA
Indoor	Type 1	Enclosures are intended for indoor use primarily to provide a degree of protection against contact with the enclosed equipment or locations where unusual service conditions do not exist.	Indoor use primarily to provide protection against contact with the enclosed equipment and against a limited amount of falling dirt.	General purpose enclosure. Protects against accidental contact with live parts.
Indoor	Type 12	Enclosures are intended for indoor use primarily to provide a degree of protection against dust, falling dirt and dripping noncorrosive liquids.	Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water and external condensation of noncorrosive liquids.	Indoor use; provides a degree of protection against circulating dust, lint, fibers and flyings; dripping and light splashing of non-corrosive liquids; not provided with knockouts.
Indoor	Type 12K	Enclosures with knockouts are intended for indoor use primarily to provide a degree of protection against dust, falling dirt and dripping noncorrosive liquids.	Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water and external condensation of noncorrosive liquids.	Indoor use: provides a degree of protection against circulating dust, lint, fibers and flyings; dripping and light splashing of noncorrosive liquids; not provided with knockouts.
Indoor	Type 13	Enclosures are intended for indoor use primarily to provide a degree of protection against dust, spraying of water, oil and noncorrosive coolant.	Indoor use to provide a degree of protection against lint, dust seepage, external condensation and spraying of water, oil and noncorrosive liquids.	Indoor use; provides a degree of protection against circulating dust, lint, fibers and flyings; seepage and spraying of non-corrosive liquids, including oils and coolants.
Outdoor	Type 3	Enclosures are intended for outdoor use primarily to provide a degree of protection against windblown dust, rain and sleet; undamaged by the formation of ice on the enclosure.	Outdoor use to provide a degree of protection against windblown dust and windblown rain; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain, snow and windblown dust; undamaged by the external formation of ice on the enclosure.
Outdoor	Type 3R	Enclosures are intended for outdoor use primarily to provide a degree of protection against falling rain and sleet; undamaged by the formation of ice on the enclosure.	Outdoor use to provide a degree of protection against falling rain; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain and snow; undamaged by the external formation of ice on the enclosure.
Outdoor	Type 3RX	Enclosures are intended for outdoor use primarily to provide a degree of protection against corrosion, falling rain and sleet; undamaged by the formation of ice on the enclosure.	Not specifically defined.	Not specifically defined.
Outdoor	Type 4	Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water and hose directed water; undamaged by the formation of ice on the enclosure.	Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water and hose-directed water; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain, snow, windblown dust, splashing and hose-directed water; undamaged by the external formation of ice on the enclosure.
Outdoor	Type 4X	Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water and hose-directed water; undamaged by the formation of ice on the enclosure.	Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water and hose-directed water; undamaged by the formation of ice on the enclosure; resists corrosion.	Indoor or outdoor use; provides a degree of protection against rain, snow, windblown dust, splashing and hose-directed water; undamaged by the external formation of ice on the enclosure; resists corrosion.
Outdoor	Type 6	Enclosures are intended for use indoors or outdoors where occasional submersion is encountered; limited depth; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use to provide a degree of protection against entry of water during temporary submersion at a limited depth; undamaged by the external formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against the entry of water during temporary submersion at a limited depth. Undamaged by the external formation of ice on the enclosure; resists corrosion.

Standards

IP Rating Descriptions

Example Rating

If 1st IP number is...	and the 2nd ip number is...	Then the IP rating is
2	3	IP 2 3
(protection against solid objects)	(protection against liquids)	An enclosure with this designation provides protection against touch with a finger, penetration of solid objects greater than 12mm, and spraying water.

First Numeral (Solid Objects and Dust)

IP	Protection of Persons	Protection of Equipment
0	No Protection	No Protection
1	Protected against contact with large areas of the body (back of hand)	Protected against objects over 50 mm in diameter
2	Protected against contact with fingers	Protected against solid objects over 12 mm in diameter
3	Protected against tools and wires over 2.5 mm in diameter	Protected against solid objects over 2.5 mm in diameter
4	Protected against tools and wires over 1 mm in diameter	Protected against solid objects over 1 mm in diameter
5	Protected against tools and wires over 1 mm in diameter	Protected against dust (limited ingress, no harmful deposit)
6	Protected against tools and wires over 1 mm in diameter	Totally protected against dust

Second Numeral (Liquid)

IP	Protection of Equipment
0	No Protection
1	Protected against vertically falling drops of water, e.g. condensation
2	Protected against direct sprays of water up to 15 degrees from vertical
3	Protected against sprays to 60 degrees from vertical
4	Protected against water sprayed from all directions (limited ingress permitted)
5	Protected against low-pressure jets of water from all directions (limited ingress permitted)
6	Protected against strong jets of water
7	Protected against the effects of immersion between 15 cm and 1 m
8	Protected against long periods of immersion under pressure

Standards

Notes