Heat vs. Hot Air

A Liebert White Paper

SUMMARY
The Liebert Series 600 UPS operates reliably in a wide range of environments, including extremes of altitude and temperature. This paper gives a general explanation of how heat and altitude affect UPS operation. Also included are tables showing how to compensate for high altitude (more than 4,000 feet above sea level) in specifying power systems.

Does the Series 600 need to be kept in an air-conditioned room? Can it tolerate ambient operating temperatures up to 40° Centigrade? Can the Series 600 be used at sites higher than 4,000 feet above sea level (ASL)?

The answers: No, Yes, Yes.

Our printed specifications show that the Series 600 produces full rated output in the environmental envelope considered normal for our industry: between 0 and 40°C and altitudes up to 4,000 feet ASL. No mention of air conditioning. No warnings about altitude sickness at places like Denver, the mile-high city.

Nevertheless, we still encounter some misconceptions out in the field. One misconception is that our UPS requires air conditioning and that a rotary UPS will work in a normal, vented room without air conditioning. As “proof,” one customer cited Section 5.2 in our Operations and Maintenance Manual where we specify 25°C as the *recommended* operating temperature. Apparently ignored is the very next line, “Maximum Operating Temperature: 40°C (design temperature).”

Those of you familiar with the product know that it is installed in facilities as varied as our customers. Some buildings are air conditioned, some are not. Some installations are above 4,000 feet, some are not. The only two constant factors: the UPS is indoors, and the UPS is reliable.

Is Heat the Enemy?
It’s no secret that high temperatures put stress on electronic components of all types. In their Reliability and Quality Handbook[1], Motorola describes how they test devices at elevated temperatures in order to accelerate failures. They use this formula to express the relationship between temperature and failure rates:

Failure rate = A exp (ϕ/kT)

where:

A = Constant
ϕ = activation energy
k = Boltzman’s constant, 8.62×10^{-5}
T = Temperature in degrees Kelvin (°C + 273.15)

In their Fixed Resistors Data Handbook[2], Phillips Components says, “The stability of a chip resistor during endurance tests is mainly determined by the hot-spot temperature and the resistive materials used.” They define hot-spot temperature as expected temperature rise plus ambient temperature. This means that a lower ambient temperature leads to lower hot-spot temperatures and better reliability. Conversely, lower ambient temperatures permit the designer to specify a higher packing density and resulting higher temperature rise and still obtain the same expected reliability.

The bottom line is that failures increase at higher temperature, regardless of the manufacturer or type of components involved. However, intelligent design and attention to details can neutralize the influence of ambient temperature and produce a solid, reliable product.

The Liebert Approach
From the earliest conceptual stages, our product designers work to improve efficiency and eliminate the possibility of malfunctions due to excessive heat build-up in the unit. Here are a few examples:

- Our overall design approach is conservative. We design with greater margins for safety than required by typical industry practices.
- Since electrolytic capacitors tend to be the most heat-sensitive devices in the UPS, we have them custom built to our specifications by major manufacturers.
- All system control logic boards are located in their own air stream, just behind the front panel of the UPS, protected by a heat shield from the magnetics and other heat-generating devices. The logic boards remain at (or very near) room ambient temperature.
- Prototype units are fitted with thermocouples at all critical design points, tested at design temperature and monitored for any unexpected or inconsistent heat buildup.
- All systems have redundant cooling fans. Furthermore, the system control logic constantly monitors fan performance and triggers an alarm if a fan should fail.

Keeping Our Cool
Having said all this, how do we recommend cooling the Series 600? Common sense should guide us here. The UPS does not need to be cooled. However, it does produce heat, which is dissipated into the room. We recommend some type of ventilation to remove this heat so that the temperature of air coming into the UPS front grille stays at or below 40°C. The heat transfer mechanism could be forced air circulation, or it could be air conditioning; either should work. There will be some incremental improvement in product reliability if ambient temperature is kept in the 25-30°C range.

System batteries are another matter. Battery manufacturers generally specify performance at 77°F (25°C), and derate their products significantly for applications with higher expected ambient temperatures. Battery rooms -- especially those with flooded cells in open racks -- need room ventilation to meet local and NFPA codes and to prevent hydrogen gas buildup. Furthermore, higher battery room temperatures can cause excessive electrolyte loss and reduced battery life. Since all UPS manufacturers use the same basic pool of battery manufacturers, this should not be a competitive issue.

How High is Up?
Air is less dense -- and a less-efficient heat-transfer medium -- at higher altitudes. This is a matter of physics, not UPS topology. The Series 600 will meet all performance specifications, without derating, at 40°C ambient operating temperature up to 4,000 feet ASL.

The Series 600 can be used in 40°C ambient temperatures at higher altitudes, with a modest derating of kVA/kW. The table below shows the percent of nominal kVA/kW that can be specified at higher altitudes.

For example, at 6,500 feet ASL, we use a 5% derating of kVA and kW as a rule of thumb. For 40°C operation at 10,000 feet ASL, use a derating of 10%.

Altitude (Meters ASL)	Altitude (Feet ASL)	Rating (% of Nominal)
1500	4,922	97.5

2000	6,562	95.0
2500	8,203	92.5
3000	9,843	90.0
3500	11,484	87.5
4000	13,124	85.0
4500	14,765	82.5
5000	16,405	80.0

If the UPS will be in a facility with *a lower ambient temperature* than 40°C, it can provide *full rated output* at higher elevations than 4,000 feet. The table below shows representative values for this situation.

For example, if ambient temperature does not exceed 35°C (95°F), the UPS will provide full output up to 9,000 feet ASL. At 30°C (87°F), get full output to approximately 14,000 feet ASL.

Altitude (Meters ASL)	Altitude (Feet ASL)	Ambient Deg. F	Ambient Deg. C
1500	4,922	102.3	39.1
2000	6,562	99.3	37.4
2500	8,203	96.4	35.8
3000	9,843	93.4	34.1
3500	11,484	90.4	32.4
4000	13,124	87.4	30.8
4500	14,765	84.4	29.1
5000	16,405	84.4	27.5

These tables do not represent the outside limits of Series 600 operation. They are merely convenient guides to give a general idea of the performance trade-offs that are possible in system design. For specific situations, your best bet is to call your local Liebert Sales Representative or Applications Engineering at the Irvine facility for a complete specification analysis.

Responding to the Critics
Nothing in the design of a static UPS makes it more susceptible to heat than a rotary UPS. Conversely, every rotary UPS currently on the market contains all the elements of a static UPS -- rectifier/charger, control circuits, inverter, and storage batteries -- *plus* all of its own unique parts, many of them moving.

The electronic parts do not suddenly become more resistant to heat just because they are part of a rotary UPS. The field-proven Series 600 is still the best UPS on the market.

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[1]Reliability and Quality Handbook, Motorola Semiconductor Products Sector, 1992.
[2]Fixed Resistors Data Handbook, Phillips Components, 1995.

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