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Meeting High Altitude Requirements For Power Supplies: A Guide For Designers and Specifiers*

by Kevin Parmenter, Excelsys Technologies

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- Effects of altitude on power electronics
- Regulatory impacts
- An example power supply implementation by Excelsys Technologies.

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- Aircraft applications such as cabin entertainment, passenger seat power plugs in medical transports, and airborne instrumentation.
- These include both rotary and fixed wing aircraft.

Applications where altitude is a consideration include:

Drones, surveillance balloons, ROVs, surveillance aircraft, mapping aircraft .

Applications where altitude is a consideration include:

Broadcast towers, repeaters, transmitters, radar –weather and others.

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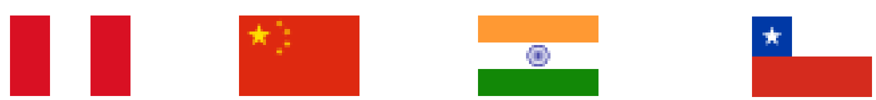
Applications where altitude is a consideration include:

Medical and industrial applications globally where geographic areas include high-altitude operation–Peru, China (GB 4943.1-2011), India, Chile and others.



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Why is altitude a factor and what are its effects?

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As altitude is increased, the air is less dense—cooling capacity of the air is decreased as altitude increases, making heat removal via air less effective.

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- Paschen's Law: Dielectric properties of the air change with altitude.
- The creepage and clearance of the power supply have to take this law into account.
- At higher altitude air is not as good an insulator—until you reach a vacuum.

Why is altitude a factor and what are its effects?

To maintain safety ratings for an approved medical and or industrial power supply the creepage and clearance must be taken into consideration.

Why is altitude a factor and what are its effects?

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- Paschen's curve describes electric discharge voltage as a function of atmospheric pressure and wiring/electrode separation defining the minimum voltage for breakdown in air to be 327 V.
- Voltages, steady state or repeated transients, higher than 327 V are referred to as high voltages .

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- Power supplies routinely handle 240 Vac and 380 Vdc voltages plus internally, as well as high-frequency, high-voltage ac energy.

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- Power supplies routinely handle 240 Vac and 380 Vdc voltages plus internally as well as high-frequency, high-voltage ac energy.
- Thus considerations for breakdown and processing high voltage must be considered for use in the end application.

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- Air at high altitude is less dense than air at sea level, reducing its convective capability and overall heat transfer capacity.

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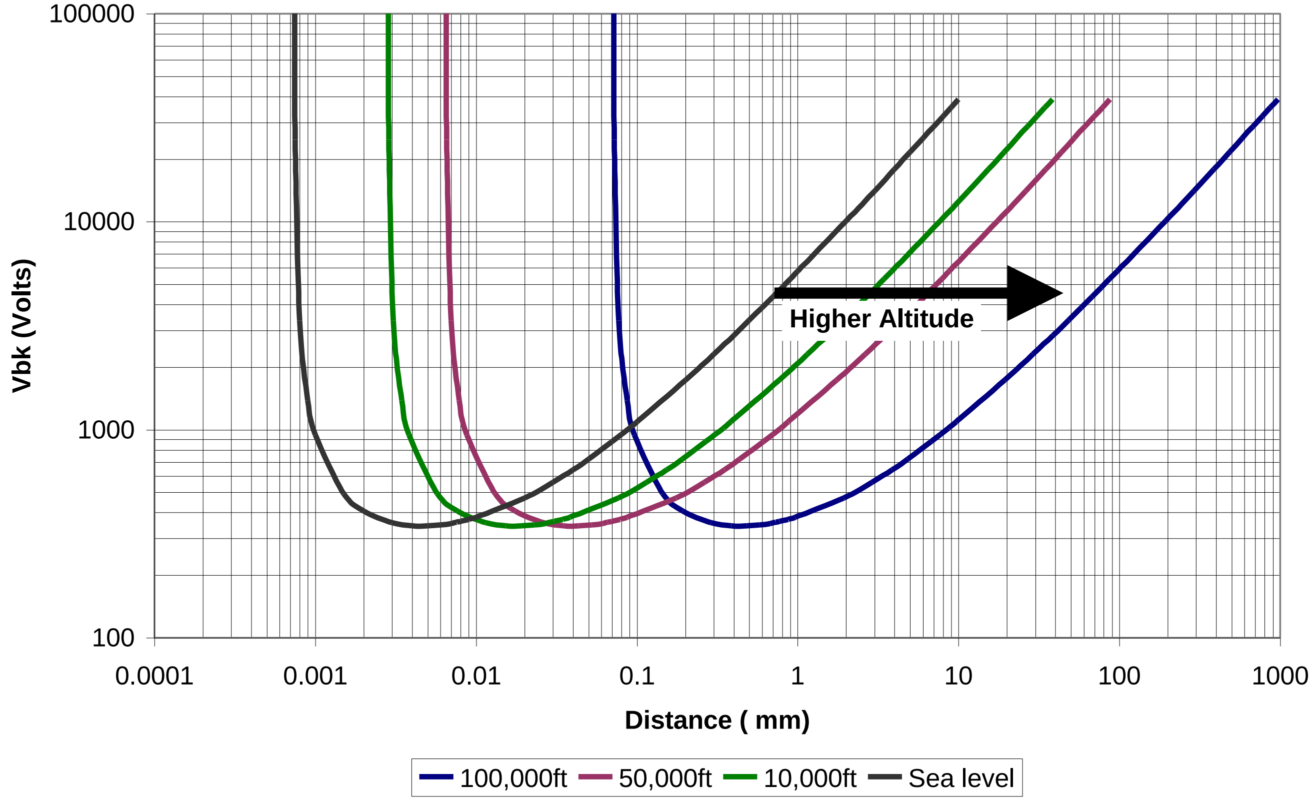
- Air at high altitude is less dense than air at sea level, reducing its convective capability and overall heat transfer capacity.

- Therefore, all electronics that rely on natural or forced convection to dissipate heat will experience greater air and component temperature rises for the same amount of power at high altitudes.

Why is altitude a factor and what are its effects?

- Thermal derating above 2000 m
  = 1°C per 305 m (1000 ft).

Paschen curves



Paschen curves illustrate the dependency of breakdown voltage on distance between conductors and altitude.

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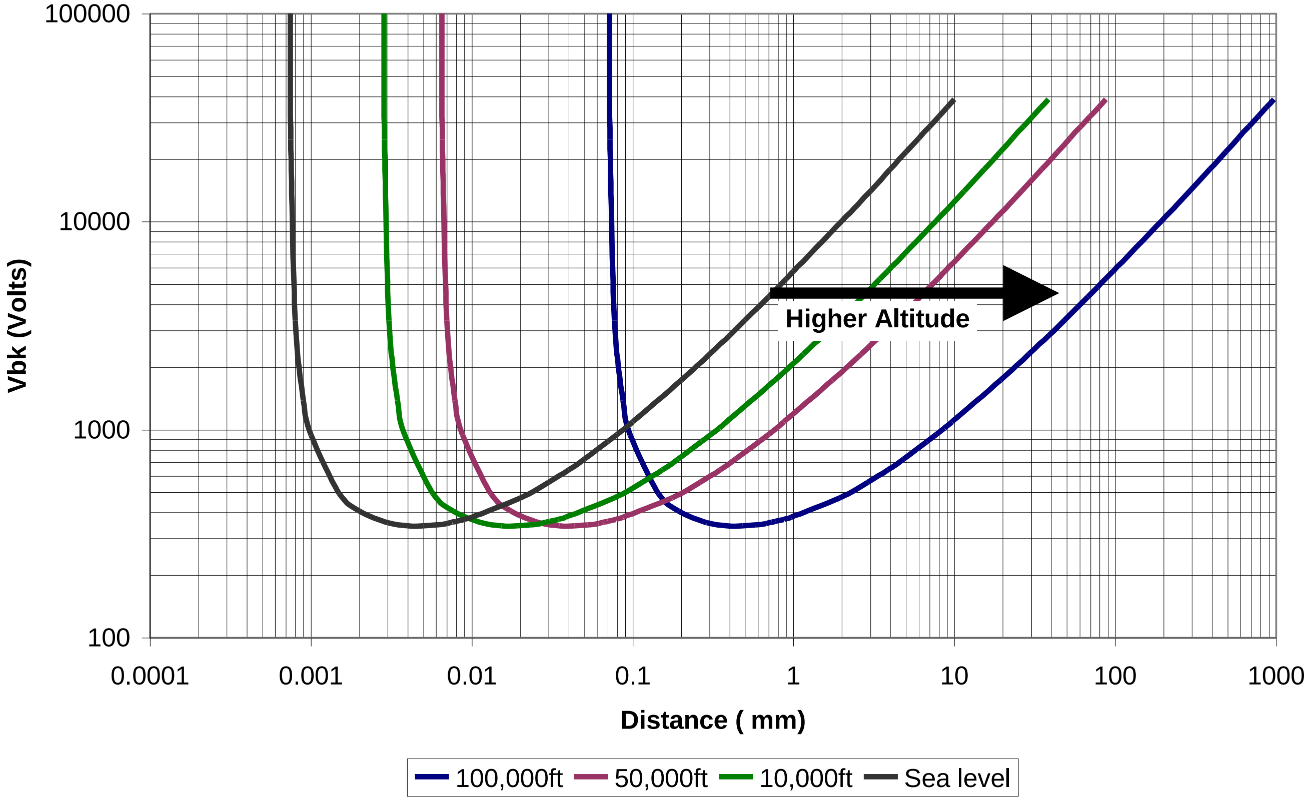
Paschen curves



Variation in breakdown voltage is approx. proportional to pressure and inversely proportional to temperature.

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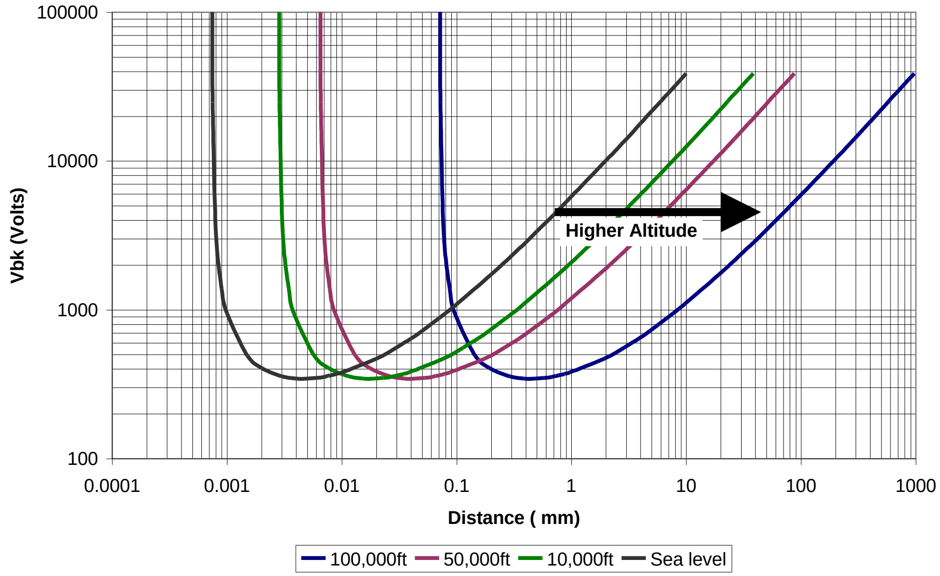
Paschen curves



Consider a 1-cm gap between conductors.

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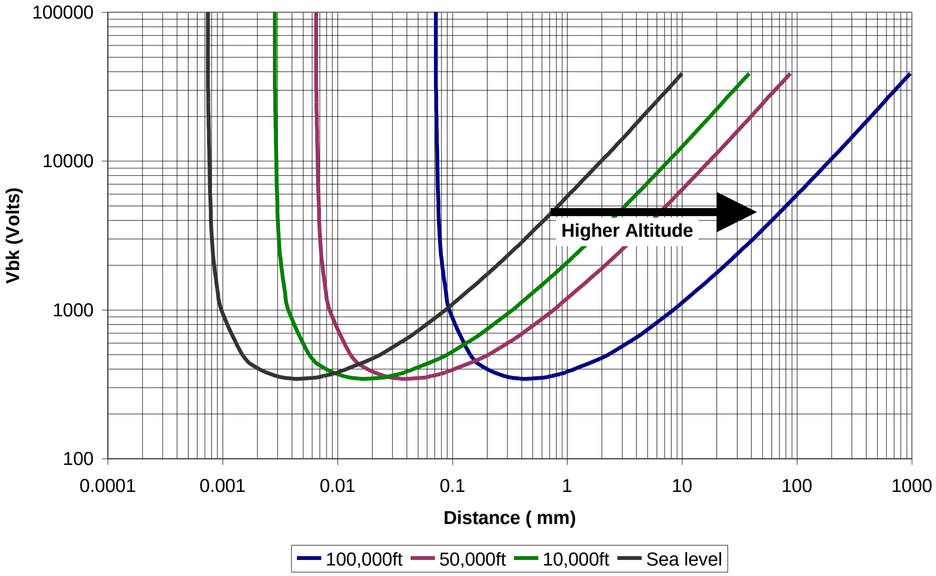
Paschen curves



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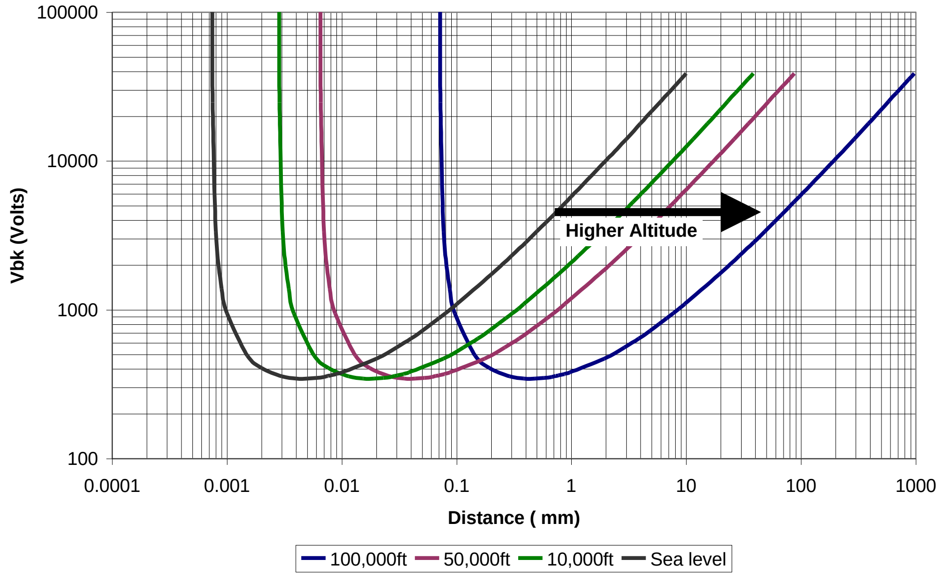

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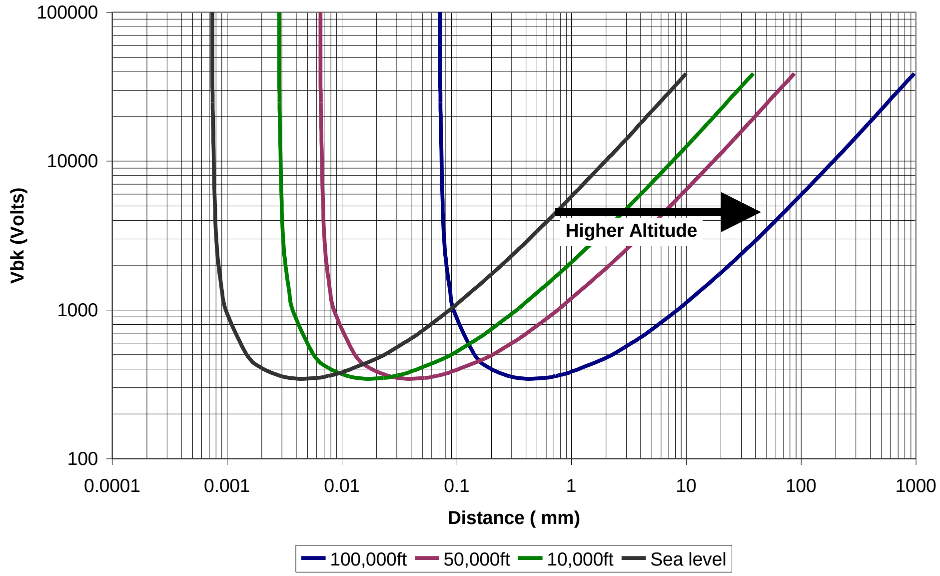

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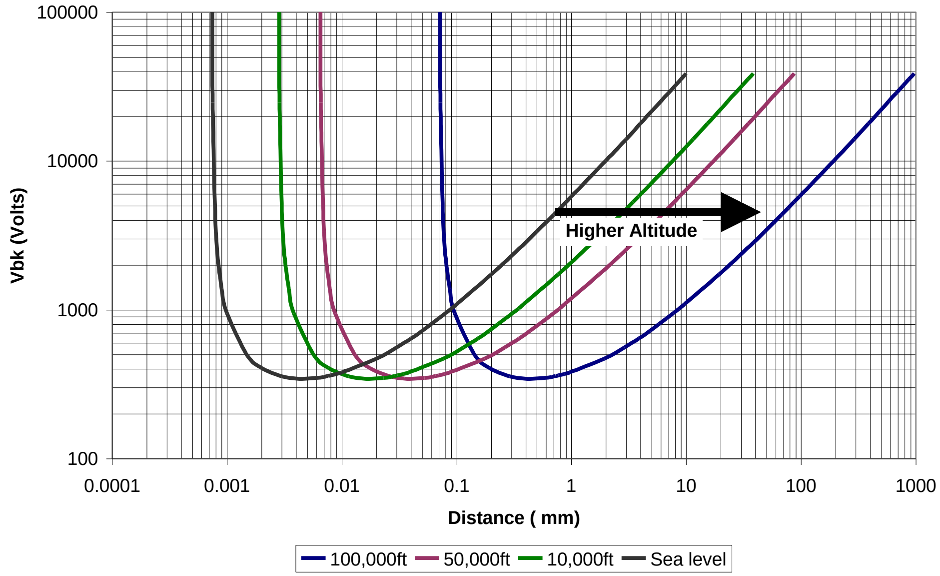
For this spacing, breakdown voltage will be:

- 30 kVdc at sea level
- 1.2 kV at 5000 ft

Paschen curves



Consider a 1-cm gap between conductors.

For this spacing, breakdown voltage will be:

- 30 kVdc at sea level
- 1.2 kV at 47,000 ft
- 300 V at 150,000 ft.

What are clearance and creepage?

- Clearance is the shortest distance through air between two conductors. This is the path where damage is caused by short duration maximum peak voltage.

What are clearance and creepage ?

- Clearance is the shortest distance through air between two conductors. This is the path where damage is caused by short duration maximum peak voltage.

- Creepage is the shortest distance between two conductive parts along the surface of any insulating material common to both parts. The breakdown of the creepage distance is a slow phenomenon based upon dc or RMS voltage.

What are clearance and creepage ?

- Clearance relates to flashover.

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- Clearance relates to flashover.
- Creepage relates to tracking.
- These separations must be increased at higher altitudes .

The creepage and clearance distances required to meet medical and industrial specifications at sea level must be increased to meet safety specifications and prevent breakdown at altitude.

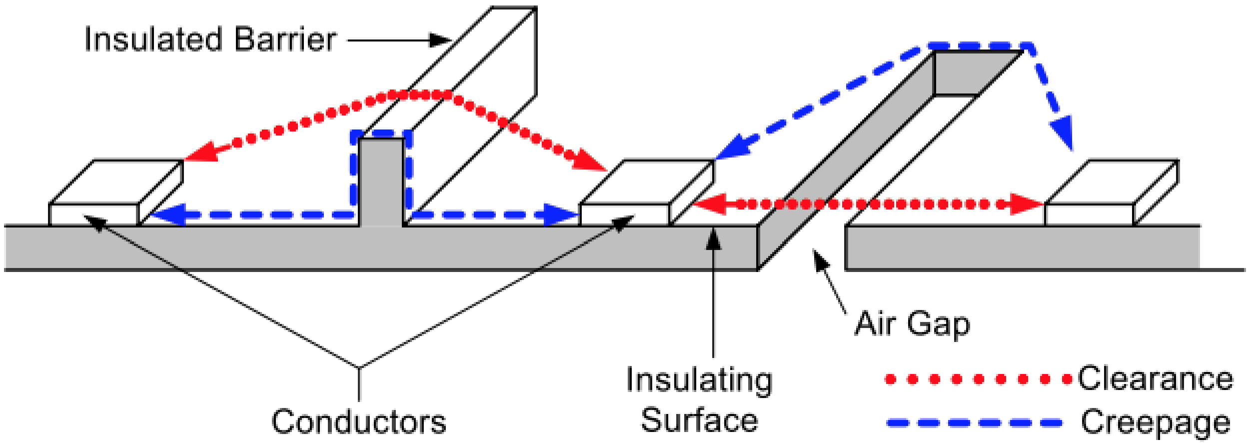

Fig. 5. Definitions of Creepage and Clearance.

As altitude increases greater distances are needed.

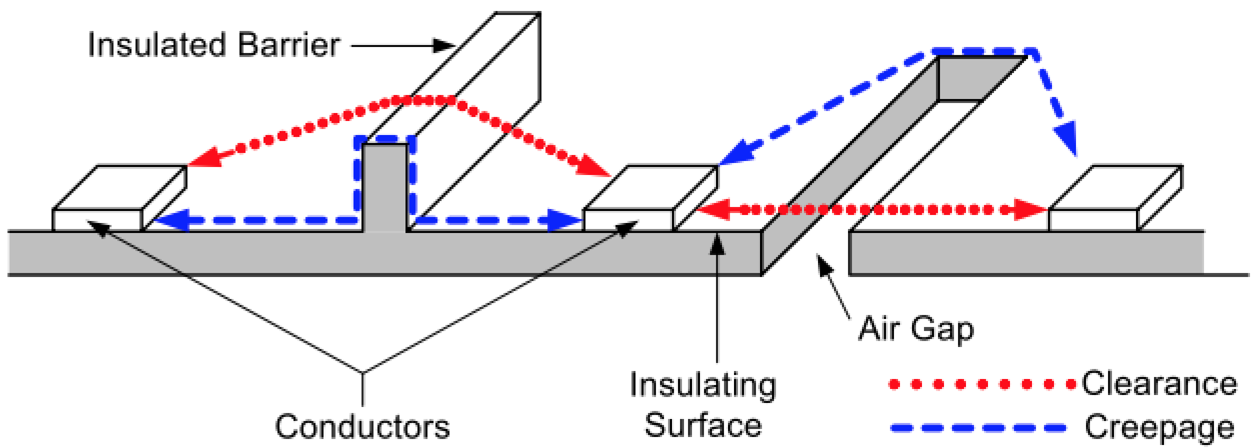

Fig. 5. Definitions of Creepage and Clearance.

What does an altitude specification mean for a power supply?

Does it simply mean the power supply will work at X altitude?

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- *The correct specification answers the question, "does it meet the desired regulatory requirements for creepage and clearance with margin at the altitude specification (i.e. IEC 60601)?"*

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- *The correct specification answers the question, "does it meet the desired regulatory requirements for creepage and clearance with margin at the altitude specification (i.e. IEC 60601)?"*

- *And does it still meet the safety requirements of a medical – industrial power supply at that altitude?*

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Design methodologies

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- This will require a clearance limit 1.48 times that of IEC/UL 60950-1 unless your equipment is marked as suitable for use only up to 2000 m.
- IPC-2221B requirements (guidelines for PCB layout) are typically used with a multiplier as a design guide.

Temperature deratings at altitude

Temperature rise multipliers for high altitudes			
Altitude	Multiplier		
m(ft)	Fan-Cooled (General)	Fan-Cooled (High Power)	Naturally Cooled – conduction
0	1	1	1
1,500 (5,000)	1.2	1.16	1.1
3,000 (10,000)	1.45	1.35	1.21
4,500 (15,000)	1.77	1.58	1.33
6,000 (20,000)	2.18	1.86	1.48

Temperature deratings …

If you need fans, it's worse.

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- IEC 60601 for medical – with multiplier
- IEC 60950 going to 62368-1 with multiplier

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- IPC-2221B requirements are typically used with a multiplier—usually 1.48 X.

Excelsys' CoolX600 implementation

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- This new modular power supply has been designed to exceed regulatory safety requirements at 5000 m for creepage and clearance.

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Excelsys' CoolX600 implementation:

- This new modular power supply has been designed to exceed regulatory safety requirements at 5000 m for creepage and clearance.

- It not only works at that altitude, it also meets medical and industrial standards with margin at a 5000-m altitude.

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Excelsys' CoolX600 implementation:

This product has no fan so the thermal derating needed at altitude is less.

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Excelsys' CoolX600 implementation:

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Benefits of this reduced derating include:

- More freedom to the system designer
- Less over-specification of the power supply
- Cost savings.

Excelsys' CoolX600 implementation:

- This product features extra efficiency so it does not dissipate the heat in the first place, and heat removal is easier.

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Excelsys' CoolX600 implementation:

- This product features extra efficiency so it does not dissipate the heat in the first place, and heat removal is easier.

- As a result, it can work at greater altitudes with higher flexibility and freedom and higher reliability.

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For more information on the CoolX600 power supply see:

"Modular Power Supplies Offer Fanless Operation, User Configurability And Extensive Feature Set ," How2Power Today, August 2016 issue.

For more information on Paschen’s Law:

- http://www.teledynereynolds.com/product/1singlepin/other/pdfs/page42.pdf
- http://www.fxsolver.com/browse/formulas/Paschen's+Law
- https://en.wikipedia.org/wiki/Paschen%27s_law.

About The Author

Kevin Parmenter has over 20 years of experience in the electronics and semiconductor industries. Kevin is currently vice president of applications engineering in the U.S.A. for Excelsys Technologies. Previously, Kevin has served as director of Advanced Technical Marketing for Digital Power Products at Exar, and led global product applications engineering and new product definition for Freescale Semiconductors AMPD - Analog, Mixed Signal and Power Division based in Tempe, Arizona.

About The Author

Prior to that, Kevin worked for Fairchild Semiconductor in the Americas as senior director of field applications engineering and held various technical and management positions with increasing responsibility at ON Semiconductor and in the Motorola Semiconductor Products Sector. Kevin also led an applications engineering team for the start-up Primarion where he worked on high-speed electro-optical communications and digital power supply semiconductors.

About The Author

Kevin serves on the board of directors of the PSMA (Power Sources Manufacturers Association) and was the general chair of APEC 2009 (the IEEE Applied Power Electronics Conference.) Kevin also has design engineering experience in medical and military electronics. He holds a BSEE and BS in Business Administration, is a member of the IEEE, and holds an Amateur Extra class FCC license (call sign KG5Q) as well as an FCC Commercial Radiotelephone License.

About The Author

Kevin is a special contributor to How2Power.com who frequently writes technical articles on power supply topics and reports on numerous conferences and tradeshows.

See Kevin's other articles in How2Power Today.