SURGEX® Buyer's Guide to Surge Protection

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1. Introduction

After buying a new piece of equipment you can usually tell whether it is performing to your expectations within a reasonable period of time. However, the same is not true of power conditioners and surge protectors. Like most equipment, power conditioners and surge protectors have specifications and claims but, in order to verify these, you need specialized equipment. Another concern is: if you pay more for a power conditioner do you get a better or a more reliable product? Do you get better protection from a $300 product than from a $100 product?
These are very important questions, and the purpose of this Buyer's Guide is to help you answer these questions. Fortunately for all of us, the Federal Government had similar concerns, and commissioned Underwriters Labs (UL) to develop a method of testing and certifying surge protectors so that the effectiveness and reliability of the device could be determined and categorized before it was purchased. The result of this effort was the development of UL surge protector Endurance Testing and Certification – a means of testing and labeling surge protectors so that buyers would have a guarantee of how well a particular device would perform under certain conditions. This Buyer's Guide explains the following:

- **The types of surges and transients that are typically found within buildings**
- **Why power conditioning and surge protection are so important**
- **What a power conditioner must do in order to protect equipment**
- **The different types of surge protectors currently available and how they work**
- **Testing and certification of surge protectors**
- **How to decide what type of surge protector to buy**

2. Why Surge Protection Is So Important

Most people are aware of the fact that electrical and, in particular, electronic equipment can be damaged or destroyed by lightning. This is a dramatic and probably the most extreme example of surge damage, and equipment definitely needs to be protected from lightning damage, but surges and transients can also be produced by equipment located inside a building.
Surges and voltage transients are defined as abnormally high pulses of voltage that substantially exceed the normal operating voltage of a circuit. They are generally random in nature and may last anywhere from tens of nanoseconds (a billionth of a second) to around one millisecond (a thousandth of a second). Advances in semiconductor processing technology, producing devices with smaller and smaller geometries, have also limited the ability of these devices to absorb transient energy. As such devices are designed into electronic equipment, the overall susceptibility of the system increases. With billions of dollars' worth of equipment now being lost each year to the effects of electronic overstress, effective power conditioning is absolutely necessary as a part of system design.

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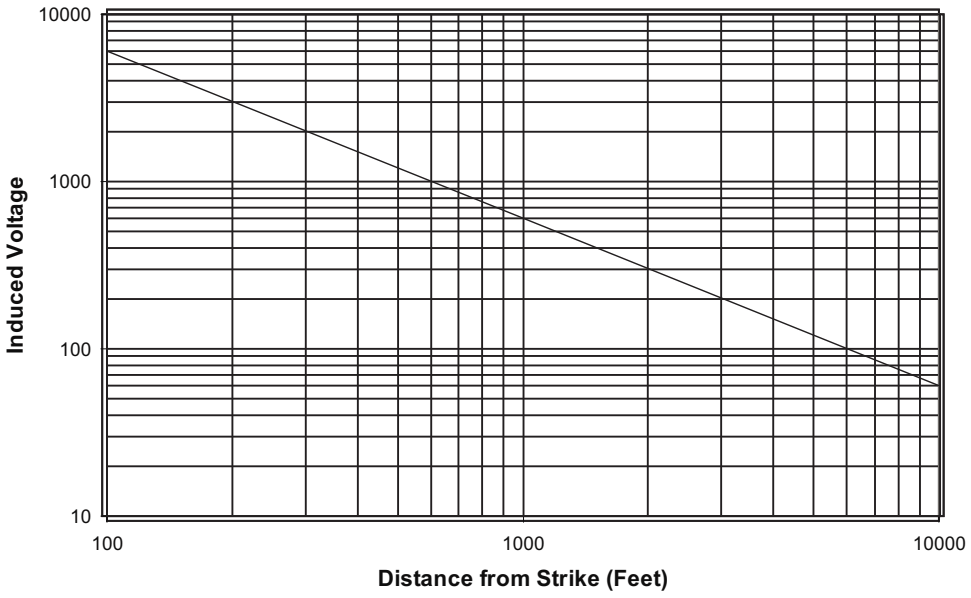
Lightning Surges

There is absolutely no way to protect equipment in a part of a building that gets a direct hit by lightning. Usually, however, when a building or a utility pole gets hit, the equipment itself does not receive the direct discharge; the equipment receives a surge conducted through the building wiring. Research has shown[1] that because of arc-over at the service entrance and within the building wiring, the maximum voltage that reaches a 120V outlet is 6000V. It has also been determined by the same research that the maximum current is 3000A. So, although lightning itself has millions of volts, we don't get millions of volts jumping out of the 120V outlet. We also now have an idea of what a surge protector must be able to reliably handle in order to protect equipment from lightning damage.

All parts of the USA receive a significant frequency of lightning strikes in a year[2], but there are variables. Being on a hill, for example, increases the risk of a lightning strike as does being in a part of the country like Tampa, Florida. Thus, it is not just the energy of a surge that has to be considered, but the frequency of surges.

Direct lightning strikes are the most devastating, but lightning is not only hazardous to equipment when the strike is very close. The intense electric and magnetic fields surrounding a typical 20,000 amp strike will induce a voltage of around 2000V at a distance of 300 feet in just 3 feet of wire, and will still induce hundreds of volts at a distance of ½ mile! This is the reason equipment failures occur during a storm when there is apparently no evidence of a strike in the immediate vicinity. Even if the AC power is protected by an adequate surge protector, induced surges can still be produced on interconnecting cables. The only way to prevent this is to run cable in steel conduit. The accompanying graph shows the typical relationship of induced voltage to distance.

Induced Voltage from a Lightning Strike



Inductive Surges

When a piece of equipment that contains an inductive element such as a motor, transformer or coil is switched off, a "back-emf" is produced. This back-emf, which is caused by the collapse of the magnetic field, is the result of one of the most basic laws of electricity, Faraday's Law of Induction. The voltage thus produced can be many times the original voltage applied to the inductive element before it was switched off, although the duration of these surges (or transients) is very short. Electric cattle fences and automotive ignition used to use this principle – a coil is repeatedly energized (by a 12V battery) and then the current is shut off. The resulting back-emf is many times the original energizing voltage, in this case 12V.
Such inductively produced transients may not be as energetic as a lightning strike, but similarly damage and degrade electronic equipment when they find their way onto the circuit board. Inductively produced transients, which travel throughout building wiring, are commonly produced by air conditioning and refrigerator motors cycling on and off, and by other equipment containing inductive elements.
It is plainly desirable to protect equipment from lightning surges and from inductive transients produced within a building. This is especially true if the equipment is very costly or is in an application which absolutely must remain operational. Protecting equipment with quality power conditioning not only prevents catastrophic failures but also improves the reliability of electronic equipment by preventing degradation and premature failure of integrated circuits.

3. The Types of Surge Protector

All surge protectors can be put into two main categories based on the way they operate. Most surge protectors operate by shunting energy, but SurgeX operates in series with the electric service. The following two diagrams show the differences between an MOV (Metal-Oxide Varistor) based shunt type surge protector and SurgeX.

Shunt Protection

Almost all shunt surge protectors rely on MOVs connected in such a way as to shunt surge energy to ground. An MOV is a type of semiconductor device which "turns on" when the voltage across it exceeds a certain value. MOVs are about the size of a quarter, and cost about a quarter. When a surge appears at the terminals of an MOV its resistance drops as the voltage across it exceeds the threshold and it conducts the surge current, diverting the surge to the neutral wire and/or the ground wire. Shunt protection is therefore diversion technology – the surge is diverted from the hot wire to the neutral wire and/or the ground wire.

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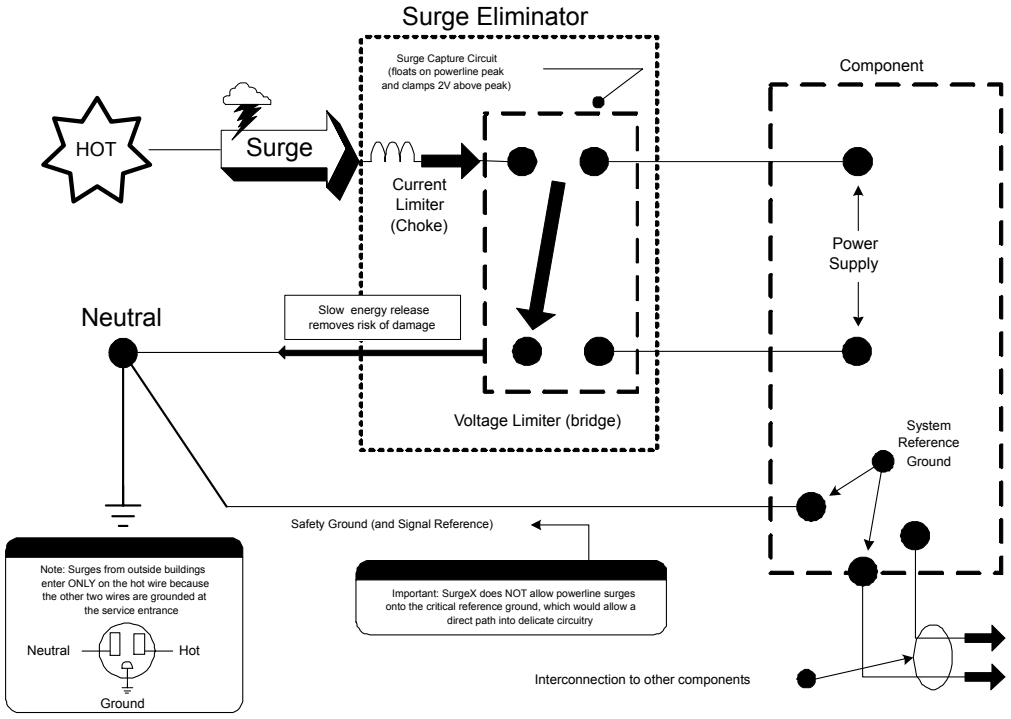
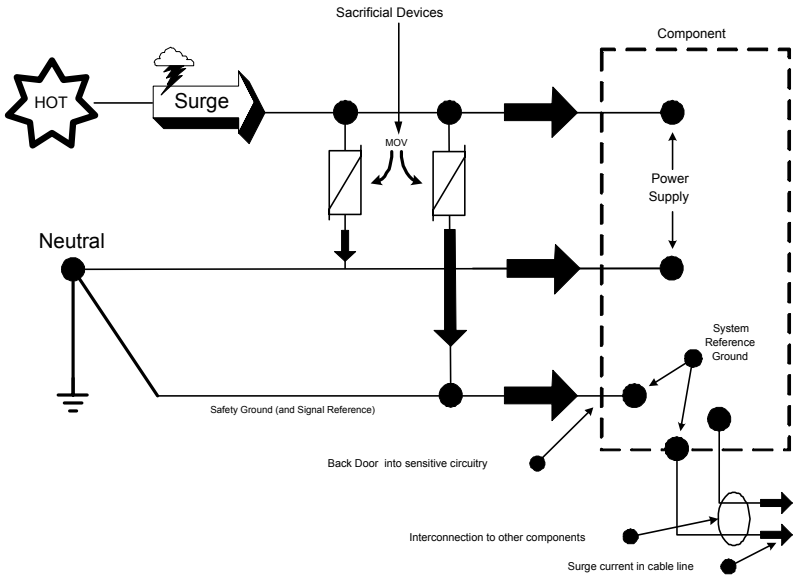
How SURGEX® Protection Works



How Ordinary Surge Protectors Work



CERTIFIED A-1-1 SURGE PROTECTION TECHNOLOGY

NO MOVs

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MOV-based surge protectors have been in use since the 1970's and have always had serious limitations that compromise their effectiveness and reliability. Of prime concern is the fact that MOVs have a lifetime "joule" rating. The joule is an engineering term for energy (energy can be measured in joules). The joule rating for an MOV means that when a particular MOV has received the specified maximum amount of energy, **it no longer works!** This could be the result of one or two large surges or several small surges. Therefore, when MOVs are used in surge protectors, a strict replacement schedule is necessary. It is like being without a gas gauge in your car – you never know when you are going to run out of gas, so you have to keep putting more gas in your car just in case! Lack of replacement can have very serious results – MOVs have been known to cause fires[3].

Because of the fire hazard associated with MOVs, UL changed the UL 1449 safety testing to Second Edition which was effective February 1998. UL 1449 Second Edition mandates that surge protectors must include a device that disconnects the surge protector from the power before the MOVs overheat. Manufacturers of MOV based surge protectors complied by incorporating a thermal fuse into the surge protector. This reduces the risk of fire being caused by an MOV based surge protector, but introduces another problem: when an MOV overheats and the internal fuse blows, either the equipment connected to the surge protector is shut down with no warning or the surge protector becomes totally ineffective.

However, the overwhelming weakness of shunt protection is that it does not handle or contain transients and surges in any way, the energy is simply diverted to the neutral wire and/or the ground wire. This is a serious problem because diverting surges to ground can cause damage to interconnected equipment. This is because the safety ground is also the system ground in audio, video and computer systems. The surges travel along the interconnecting cables and capacitively couple onto the signal wires! All wires including building wiring and interconnect wiring have impedance which will generate a substantial voltage when the thousands of amps of surge current are suddenly dumped onto such wiring. This is Ohm's Law. One of the worst case examples of this problem is that of interconnected computers[4], because computers are often interconnected by long datacomm cables, and plugged into 120V outlets at very different parts of a building.

The important points to remember for shunt type protectors are:

- **Cheap and simple to produce**
- **Limited lifetime**
- **Contaminate system ground**
- **MOVs are disconnected by a thermal fuse if they overheat**

SurgeX Protection

SurgeX protection was originally developed to meet the more demanding requirements of industry. SurgeX protection operates in series with the hot wire and works by blocking and containing transients and surges rather than by diverting them to ground. This has the dual advantages that the surge protector does not have to handle thousands of amps of surge current and, most importantly, system ground is not contaminated.

The accompanying diagram shows how SurgeX surge protection works. The first line of defense in the SurgeX system, and key to SurgeX protection, is the massive surge reactor which is in

series with the hot wire. It is the weight of the surge reactor that makes SurgeX products weigh much more than other power conditioners. The surge reactor filters out small transients, slows down larger surges (both are extremely fast), and limits the surge current. All current which passes to equipment connected to a SurgeX product passes through this filter. The second part of the SurgeX system is an electronic circuit which tracks, clamps and contains the residual surge energy after it has been slowed down by the surge reactor. This energy is then released slowly to the neutral wire, not the ground wire. In this way, the safety ground is never contaminated, and interconnected equipment is not put at risk when a surge comes in on the power lines feeding the equipment.

SurgeX contains no sacrificial components (such as MOVs) and can withstand thousands of the largest surges normally found on 120V wiring (6000V, 3000A). The SurgeX system also has superior clamping because it tracks the power wave and utilizes active clamping. This combination of passive and active technologies is extremely effective and SurgeX has been used in the most demanding industrial and commercial environments with exemplary performance. It has protected equipment when there have been direct lightning hits on buildings[5], and has also protected equipment from data errors caused by transients produced inside factories[6]. Furthermore, the same technology used inside all SurgeX products meets the highest level of Endurance Testing that is available – the buyer's absolute guarantee of performance. And, SurgeX products comply with UL 1449 Second Edition safety testing without using any fuses or other devices that can suddenly shut down equipment without warning or leave you without protection.

The important points to remember for SurgeX power conditioning are:

- **Unlimited lifetime**
- **No sacrificial components**
- **Unsurpassed voltage clamping**
- **Safety and system ground are not contaminated**

4. UL 1449 Adjunct Testing

Caution: Do not confuse the endurance (adjunct) testing discussed in this document with the safety testing that UL are usually associated with. UL 1449 certification does not automatically mean that a product also passes the adjunct endurance testing (which is *optional*), it only means that the product has passed safety requirements.

Beginning with meetings in 1992 and culminating with a new standard at the end of 1995, the Federal Government commissioned Underwriters Labs (UL) to develop testing specifically to determine the effectiveness and reliability of surge protectors. UL was chosen for this task because they had the necessary experience, and already had a safety standard in place for surge protectors (UL 1449). The additional testing procedure for endurance was added to UL 1449 as "adjunct" testing[7]. During 1996, the Federal Government followed up with a CID (Commercial Item Description) based on the UL 1449 adjunct testing[8]. Many Federal Government orders now require surge protectors to meet this CID.

The UL endurance testing consists of Grades A, B and C, Classes 1, 2 and 3, and Modes 1 and 2. The Grade determines the level of surge voltage and current applied during testing, Grade A

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being the highest and consisting of 1000 surges of 6000V and 3000A. The Class specifies the letthrough voltage, Class 1 being the best, not to exceed 330V. The Mode specifies whether ground is contaminated, Mode 1 specifying that ground is not contaminated.

ALL SURGEX PRODUCTS MEET GRADE A, CLASS 1, MODE 1:

- **SURVIVED 1000 SURGES OF 6000V, 3000A – NO FAILURES OR DEGRADATION**
- **LET-THROUGH VOLTAGE DID NOT EXCEED 330V**
- **GROUND WAS NOT CONTAMINATED**

It is important to realize the difference between "let-through" voltage and "clamping" voltage. Clamping voltage often means the voltage at which the surge suppressor begins to work, not the suppressed voltage under actual worst-case test conditions. Further information on UL 1449 is available from many sources, some of which are listed in the references at the end of this document. However, the important points for the prospective purchaser of surge protection equipment to keep in mind are:

- **Grade A guarantees protection from the worst surges normally found within a building during a lightning strike (as defined by IEEE/ANSI C62.41-1991).**
- **Class 1 provides the best quality surge suppression.**
- **Mode 1 guarantees that the system ground is not contaminated.**
- **UL 1449 safety testing does not test for endurance.**
- **UL 1449 endurance testing is optional. Manufacturers are not required to submit their products for endurance testing, but those who do can offer their customers a true guarantee of performance to a nationally recognized standard.**
- **There is no reason why manufacturers of quality products should not submit their surge protectors for endurance testing.**
- **A product that does not have an endurance rating has no guarantee of performance.**

5. How to Choose a Surge Protector

Due to the random nature of surges, it is almost impossible to predict surges and transients that may occur at a given location There is equipment available that will measure and record powerline disturbances, but that one destructive surge that suddenly destroys thousands of dollars worth of equipment may occur this summer or may not occur for several years. An isokeraunic chart can give a guide to typical lightning activity and risk in a certain part of the country, but no-one can say exactly when a particular area will get hit. The only sure way of protecting equipment from that "killer" surge is to install an A-1-1 power conditioner that is designed and certified to handle multiple 6000V, 3000A surges as specified in IEEE/ANSI C62.41-1991. The actual type of equipment to be protected can also guide the decision making process. MOV based shunt protection does not clamp as effectively as SurgeX protection, and does not limit the extremely fast rise-times of transients. Computer modeling has shown[9] that, due to the way in which they operate, MOV based products are particularly ineffective at protecting switching power supplies. The modeling shows the extreme nature of this problem to the extent that the power supply is "protecting" the MOV! Any equipment that contains a switching power supply should therefore not be plugged into a shunt surge protector. In fact, a networked computer

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should not be plugged into a shunt surge protector for two reasons: because it contains a switching power supply, and because ground will be contaminated by the surge protector. (The datacomm cables offer a path to ground for surges via a server or other computers).
A top quality surge protector will also be a true power conditioner and block smaller transients and filter out electromagnetic interference (EMI) and radio frequency interference (RFI). SurgeX products contain a custom designed EMI/RFI filter that provides effective filtering under all powerline conditions. SurgeX is a true power conditioner as well as being the most reliable surge protector available.

Remember–Ask your supplier for the endurance rating before buying a surge protector!

References:
1 IEEE 587, IEEE/ANSI C62.41-1991 (Also explained in NFE Surge Suppression Report)
2 Chart of Isokeraunic Levels for the USA (Available from NFE)
3 Fires are Blamed on MOVs – Electronic Buyers' News, April 13, 1992
4 Surge Suppression Report (Available from NFE)
5 Lightning Testimonials (Available from NFE)
6 Letter from Klipsch (Available from NFE)
7 What Changes to UL 1449 Standard for Safety, Transient Voltage Surge Suppressors May Mean to you (Available from NFE)
8 CID Titled "Surge Suppressor, Transient Voltage" available from Defense General Supply Center, (804) 279-5440
9 Surge Suppressors: How Efficient Are They? (Available from NFE) 5/28/02

5/28/2002

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