Surge Protection Device (SPD)
Questions & Answers
(Commonly Asked Questions)

1. What are Surges (also called Transients, Impulses, Spikes)?

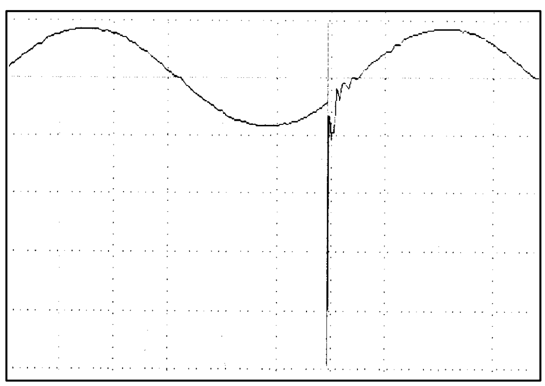
An electrical surge (transient voltage) is a random, high energy, short duration electrical disturbance. As shown in Figure 1, it has a very fast rise time (1-10 microseconds). Surges, by definition, are sub-cycle events and should not be confused with longer duration events such as swells or temporary over-voltages.

High-energy surges can disrupt, damage or destroy sensitive microprocessor based equipment. Microprocessor failure results from a breakdown in the insulation or dielectric capability of the electronics.

Approximately 80% of recorded surges are due to internal switching transients caused by turning on/off motors, transformers, photocopiers or other loads. The IEEE C62.41 surge standard has created the Category B3 ringwave and the B3/C1 combination wave to represent higher energy internal surges.

Externally generated surges due to induced lightning, grid switching or from adjacent buildings account for the remaining recorded surges. The Category C3 combination wave (20kV, 10kA) represents high-energy surges due to lightning. Refer to the CPS Technote #1 for more information on IEEE surge standards.

Figure 1: An externally created electrical surge caused by induced lightning.

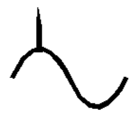


2. Why is there a need for Surge Protection Devices?

In the coming years, electronic devices will represent half of the electrical demand in the United States. Electronics, consist of microprocessors which rely on digital signals: fast on/off coded sequences. Distortion on the power or signal lines may disrupt the sensitive signal sequence. As electronic components become smaller and more powerful, they become more sensitive. The tremendous proliferation in the use of sensitive electronic equipment - sensitive by virtue of circuit density (microchips having literally thousands of transistors on a single chip) – is now incorporated into almost every new electrical device. Surge protection is now the standard technology for increasing the reliability and uptime of microprocessors.

Microprocessors can be “upset”, “degraded” or “damaged” by surge events. Depending on the magnitude of the surge, the system configuration and the sensitivity of the load. Figure 2 summarizes the results of a major survey conducted by Dranetz on the effects of surges on different microprocessor equipment.

Figure 2: Summary of major survey results on the effects of surges on different microprocessor equipment.

Impact to Electronic Loads	Impulse 4x 	Impulse 2x 	Repetitive Disturbanc (noise) 
Circuit Board Failure	Yes	Yes	
Data Transmission Errors	Yes	Yes	Yes
Memory Scramble	Yes	Yes	Yes
Hard Disk Crash	Yes		
SCR Failure	Yes		
Process Interrupt	Yes	Yes	Yes
Power Supply Failure	Yes		
Program Lock Up	Yes	Yes	Yes

Source: Dranetz Handbook for Power Quality

Other references for the recommendation of surge protection devices includes:

IEEE Emerald Book (std 1100)
IEEE C62.41
NEMA LS-1

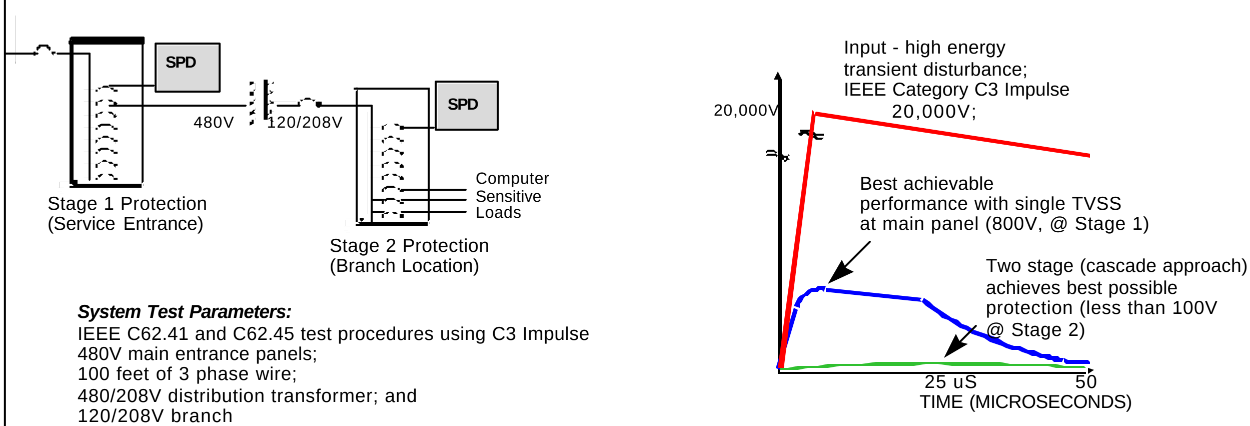
FIPS 94
Manufacturers (Allan Bradley, Motorola, other suppliers)
NFPA 780

As a design objective, the IEEE Emerald Book (and the CBEMA curve) recommends reducing 20,000 Volt induced lightning surge disturbances down to two times nominal voltage (< 330 Volts peak). To achieve this level of performance, surge suppressors were developed. Since the mid-1980s, surge protection devices mounted at switchboards, panelboards and MCCs have become the preferred choice for protecting all loads within a facility.

3. Where do I need a SPD? Why do I need to implement a two stage approach?

As recommended by IEEE (Emerald Book 1992) SPDs should be coordinated in a staged or cascaded approach. The starting point is at the service entrance. (Service entrance protection is also required by NFPA 780). The first surge diversion occurs at the service entrance, then any residual voltage can be dealt with by a second SPD at the power panel of the computer room, or other critical load (See Figure 3). This two-stage approach will reduce 20,000 Volt induced lightning surges well under 330 Volts peak as recommended by IEEE and CBEMA. (See Tech Note CPS-3 for more information).

Figure 3: Facility Wide Protection Solutions
IEEE Emerald Book recommends a cascaded (or 2 stage) approach



System Test Parameters:
IEEE C62.41 and C62.45 test procedures using C3 Impulse
480V main entrance panels;
100 feet of 3 phase wire;
480/208V distribution transformer; and
120/208V branch

☐ Clipper Power System

4. Is there a difference between a TVSS and a SPD?

No, Underwriters Laboratories (UL) uses the term Transient Voltage Surge Suppressor (TVSS), while NEMA, IEC, and IEEE use Surge Protection Device (SPD). An SPD/TVSS is a device that attenuates (reduces in magnitude) transient voltages.

5. How does a SPD work? - The design goal is to divert as much of the transient disturbance away from the load as possible. This is accomplished by shunting the energy to ground through a low impedance path (i.e. the surge suppressor).

Metal Oxide Varistors (MOVs) are the most reliable and proven technology to reduce transient voltages. Under normal conditions the MOV is a high impedance component. When subjected to a voltage surge (i.e. voltage is over 125% of the nominal system voltage), the MOV will quickly become a low impedance path to divert surges away from loads. The MOV reaction time is nanoseconds – 1000 times faster than the incoming surge.

In AC power applications, over 95% of SPDs use Metal Oxide Varistors (MOVs) because of their high-energy capability and reliable clamping performance. For added performance and SPD life expectancy, a filter element is used in conjunction with the MOVs.

Silicon Avalanche Diodes (SADs) are frequently used in dataline or communication surge protectors. They are not recommended for use in high exposure AC applications due to their limited energy capabilities.

Selenium cells were once used in surge applications but are now an outdated technology. They were used in the 1920's but were replaced in the 1960's by the more efficient silicon and MOVs. One TVSS company continues to use selenium enhanced surge protection as a marketing ploy to create confusion with engineers. Selenium cells are metallic rectifiers (diodes) having a maximum reverse voltage of 25 VDC. Many selenium plates are stacked together to create sufficient voltage breakdown for use in AC power circuits. When mounted in parallel with MOV components, selenium offers no performance, cost or application advantages. In fact they are expensive and add considerable space (which makes installation more difficult). There are no patents on selenium cells.

6. What criteria are important when specifying a suppressor? - A specification should focus on the essential performance, installation and safety requirements. A number of surge specifications contain misleading criteria that does follow NEMA LS-1 or other recommended performance standards.

The following are considered essential performance/safety/installation criteria for a specification:

1. Surge Current Per Phase - 250kA/phase for Service Entrance, 120kA/phase for Panelboards or other locations.
2. Let Through Voltage – specify the performance voltage rating based on the three standard IEEE test waveforms (IEEE C62.41 Category C3 and B3 combination waves; and BE ringwave). Specify the required ratings for applicable nominal voltages (i.e. 208 vs. 480). This data should be requested as part of the project submittal process.
3. Effective Filter - noise attenuation at 100 kHz based on the MIL-STD-220 insertion loss test. The attenuation should exceed 45 dB (L-N modes). Specify that insertion loss bode plots are provided as submittals.
4. Integrated Installation - factory installed as part of the distribution equipment. Check to ensure the installation minimizes lead length.
5. Internal Fusing - safety and overcurrent protection. 200 kAIC internal fusing system.
6. Reliability Monitor and Diagnostic System - foolproof status indication for each phase. A popular option is to include Form C contacts for remote monitoring.
7. Independent Testing – to ensure a reliable construction and design, specify that all manufacturers submit results from an independent test lab verifying the device can achieve the published surge current ratings (on a per mode and per phase basis).

For more information on specification recommendations or a copy of sample specification, contact Cutler-Hammer.

7. What is surge current capacity? - Defined by NEMA LS-1 as:

The maximum 8/20 us surge current pulse the SPD device is capable of surviving on a single impulse basis without suffering either performance or degradation of more than 10 percent deviation of clamping voltage. Listed by mode, since number and type of components in any SPD may vary by mode.

The industry standard is to publish surge current "per phase" by summing modes L-N + L-G in a Wye system and L-L + L-G in Delta systems.

Surge current capacity is used to indicate the protection capability of a particular SPD design, and should be used on a per phase and per mode basis when specifying a SPD for a given application.

Beware: Manufacturers are not required to have their units independently tested to their published surge current capacity rating. Most published ratings are theoretical, and calculated by summing the individual MOV capabilities. Manufacturer "A" may claim a rating of 100 kA, but due to the poor construction integrity, the unit is unable to share current equally to each MOV. Without equal current sharing, the published surge current rating cannot be met. Specifiers should request that manufacturers submit independent test reports from lightning labs confirming the published surge ratings.

All Clipper units have been independently tested to meet or exceed their published surge current capacities.

8. What surge current capacity is required?

Surge current capacity is dependent on the application and the amount of required protection. What is the geographic location of the facility and the exposure to transients? How critical is the equipment to the organization (impact of downtime, repair costs)?

Based on available research, the maximum amplitude of a lightning related surge on the facility service entrance is 20kV, 10kA combination wave (refer to IEEE C62.41). Above this amount, the voltage will exceed BIL ratings causing arcing in the conductors or distribution system.

Cutler-Hammer recommends 250 kA per phase for service entrance applications (large facilities in high exposure locations), and not more than 120 kA per phase at branch panel locations.

If IEEE and other research specifies the maximum surge to be 10 kA, why do many suppliers, including Cutler-Hammer, suggest up to a 250 kA per phase device be installed? The answer is reliability, or, more appropriately, life expectancy. By increasing the kA rating of the suppressor, you are not increasing performance, but instead the life expectancy of the suppressor.

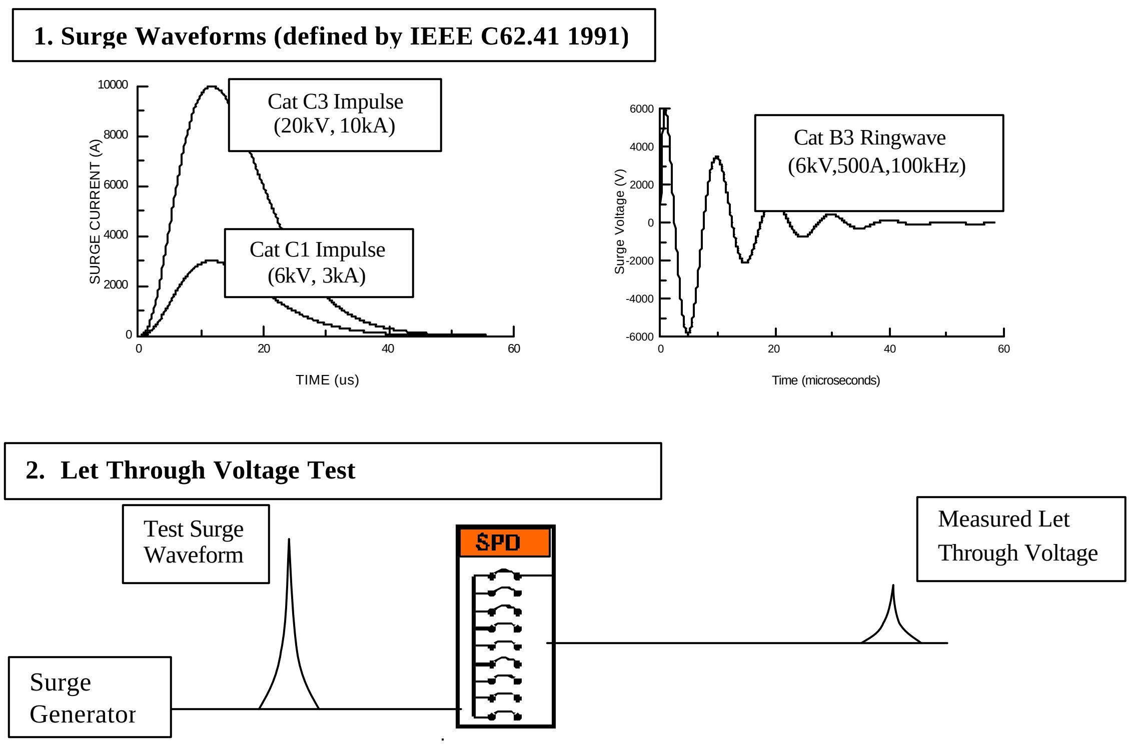
A service entrance suppressor will experience thousands of surges of various magnitudes. Based on statistical data we can determine the life expectancy of a suppressor. A properly constructed suppressor having a 250 kA per phase surge current rating will have a life expectancy greater than 25 years in high exposure locations.

Beware: Some manufacturers recommend installing SPDs having surge current ratings over 250 kA per phase. In fact, some are promoting ratings up to 600 or 700 kA per phase. This level of capacity is ridiculous and offers no benefits to customers. A 400 kA per phase device would have approximately 500 year life expectancy for medium exposure location - well beyond reasonable design parameters. (Cutler-Hammer is forced to build higher rated units to meet competitor specifications, however, we strongly recommend that consultants question suppliers who promote excessive ratings for commercial reasons.)

Today's SPDs will not fail due to lightning surges. Based on two decades of experience, the failure rate of a SPD is extremely low (<0.1%). Should a suppressor fail, it is likely the result of excessive temporary overvoltage (TOV) due to a fault on the utility power line i.e., the nominal 120 Volt AC line exceeds 180 Volts (for many cycles). TOV will damage surge protectors and other electronic loads. Should this rare event occur, call your utility to investigate the problem. (For more information on TOV problems in international environments, refer to the IEEE article written by Cutler-Hammer for the 1997 INTELEC conference, Australia).

9. What is Let Through Voltage (Clamping Voltage)?

Figure 4: Example of Let Through Voltages and different IEEE defined surge waveforms.



Let through voltage is the amount of voltage that is not suppressed by the SPD and passes through to the load. Figure 4 is an example of let through voltage.

Let through voltage is a performance measurement of a surge suppressor's ability to attenuate a defined surge. IEEE C62.41 has specified test waveforms for service entrance and branch locations. A surge manufacturer should be able to provide let through voltage tests under the key waveforms (i.e. Category C3 and C1 combination wave forms; Category B3 Ringwave).

Beware: As part of the requirements of UL 1449 (TVSS Listing), let through voltage tests are conducted. Recently the UL 1449 standards were changed. The new UL1449 (2^{nd} Edition, 1988) conducts a 500 Amp let through voltage test. This test does not provide any performance data and is not a key specification criteria.

Clamping voltage is often confused with let through voltage. Clamping voltage refers to the operating characteristic of a metal oxide varistor (MOV) component and is not useful for comparing the performance of a SPD. The clamping voltage is the voltage when 1 mA of current passes through an MOV. Clamping voltage does not include the effects of internal wiring, fusing, mounting lugs, or installation lead length.

Let through voltage is a more applicable test for SPDs and refers to the amount of voltage that is not suppressed by a SPD when tested to an IEEE defined surge waveform and test setup (refer to CPS Technote 1 for standard test waveforms).

10. Why is installation important? What affect does it have on an SPD's performance?

Installation lead length (wiring) reduces the performance of any surge suppressor. As a rule of thumb, assume that **each inch** of installation lead length will add between 15 to 25 volts per inch of wiring. Because surges occur at high frequencies (approximately 100 kHz), the lead length from the bus bar to the suppression elements creates impedance in the surge path.

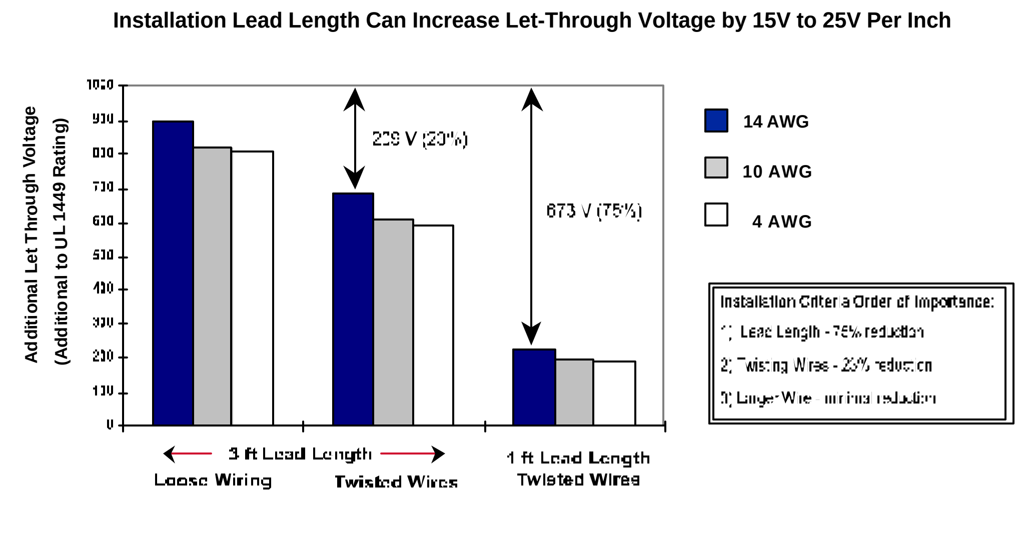


Figure 5. Additional Let-Through Voltage Using IEEE C1 (6000V, 3000A) Waveform (UL1449 Test Wave)

As one specifier said, "no matter which TVSS device you buy, it is the installation requirements/inspection that is the most important factor of the surge specification".

Published let through voltage ratings are for the device/module only. These ratings do not include installation lead length (which is dependent on the electrician installing the unit). The actual let through voltage for the system is measured at the bus bar and is based on two factors:

(1) the device rating (quality of the suppressor)
(2) the quality of the installation.

For example, our Clipper Power System has a 400 Volt rating (based on IEEE Cat C1 test waveform). Connected to a panelboard with just 14 inches of #14 wire, approximately 300 Volts are added to the let through voltage. The true let through at the bus bar is thus 700 V.

11. Why should suppressors be integrated into the electrical distribution equipment (panelboards, switchboards)?

Most consulting specifiers are now requiring the gear manufacturer integrate the suppressor inside the switchboard, panelboard or MCC. Integrated suppression offers a number of key benefits compared to externally mounted applications:

(1) Performance - Integrating the SPD into the electrical distribution equipment eliminates the installation lead length, ensuring significantly improved performance (much lower let through values).
(2) Control - There is no chance that field installation is done incorrectly. By having the suppressor factory installed and tested, the specifier does not have to check the installation and force the contractor to re-

install the device (a costly and time consuming process). This reduces future claims and problems for the engineer and end customer.

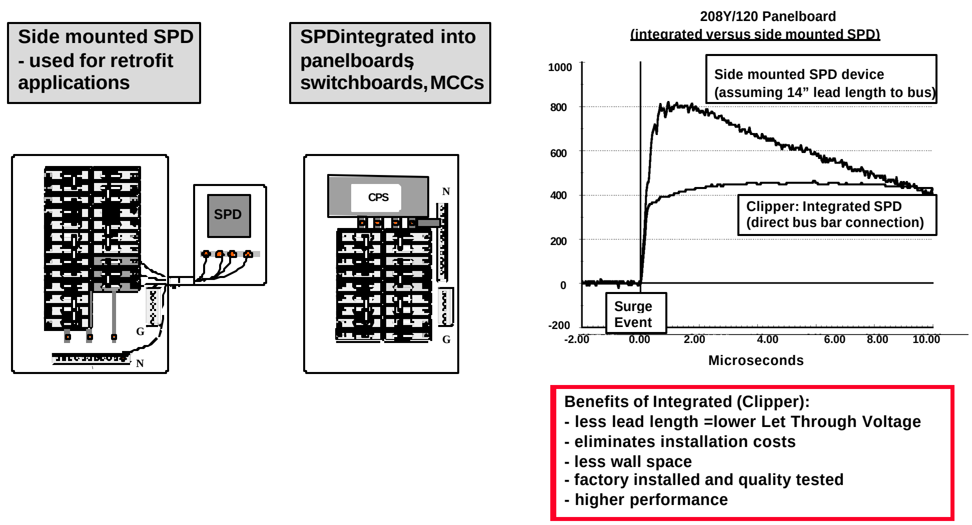
(3) Reduce wall space. Integrating the suppressor eliminates the wall space taken up by the externally mounted suppressor (between 2 and 3 feet!).

(4) One source for warranty claims. Should a problem occur, the customer eliminates potential warranty conflicts between manufacturers.

(5) Reduced installation costs. There is no contractor fees for mounting SPDs.

Cutler-Hammer's Clipper Power System is integrated into all of our low voltage distribution equipment. Through our innovative direct bus bar connection, we limit the lead length between the SPD and electrical equipment. For example, the Clipper Power System carries a UL 1449 let through voltage rating of 400V. Through our "zero lead length" direct bus bar connection, we obtain a let through voltage of **420 V** at the panelboard bus bar. A significant performance advantage over traditional cable connected designs.

Figure 6: Integrated SPD Performance



Some SPD manufacturers have obtained a UL procedure for installing their SPD into another manufacturer's panelboard. When this occurs, the original panelboard manufacturer's UL label (UL67) is void, as is the warranty provided by that manufacturer. The SPD manufacturer then modifies and integrates the SPD into its panelboard, and must assume all warranty and liability issues regarding the panelboard and SPD. In most cases, the original panelboard manufacturer's nameplate data is not removed and replaced by that of the SPD manufacturer. This can cause problems for the end customer as different panelboards within this facility carry the nameplates from the original panelboard manufacturer, but two separate companies cover the warranty.

12. What is the benefit of Filtering (Sine Wave Tracking)? - Filtering eliminates electrical line noise and ringing transients by adding capacitors to the suppression device. (See Figures 7 and 8).

Figure 7: Internally generated Ringwave Transient. Ringwaves typically resonate within a facility at frequencies between 50 kHz and 250 kHz.

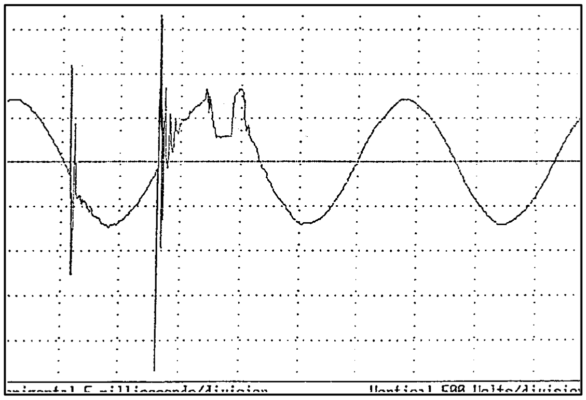
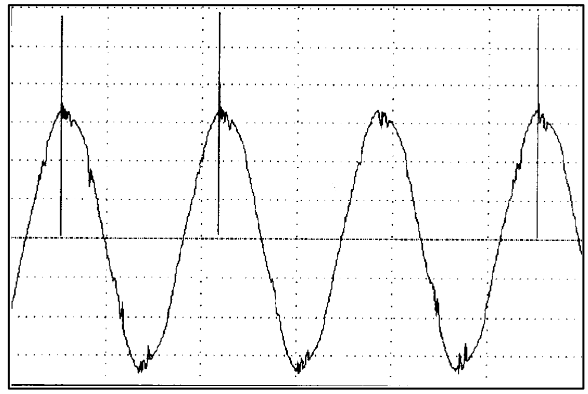


Figure 8: Noise (EMI/RFI, Electrical line noise) is any unwanted electrical signal that produces undesirable effects. Noise is typically less than 2 times peak voltage.



Hybrid SPD - A device that combines the benefits of both MOVs and filtering. A properly designed hybrid SPD will vastly outperform any SPD using only MOVs.

Beware: Filtering is often referred to as “sine wave tracking or active tracking”. These are marketing terms and have no relevance to filter performance. Not all SPDs provide filtering, and many SPDs claim to posses “sine wave tracking”, “sine wave contour”, or EMI/RFI noise attenuation, but may not employ a quality filter. (See Tech Note CPS-9 or more on filtering).

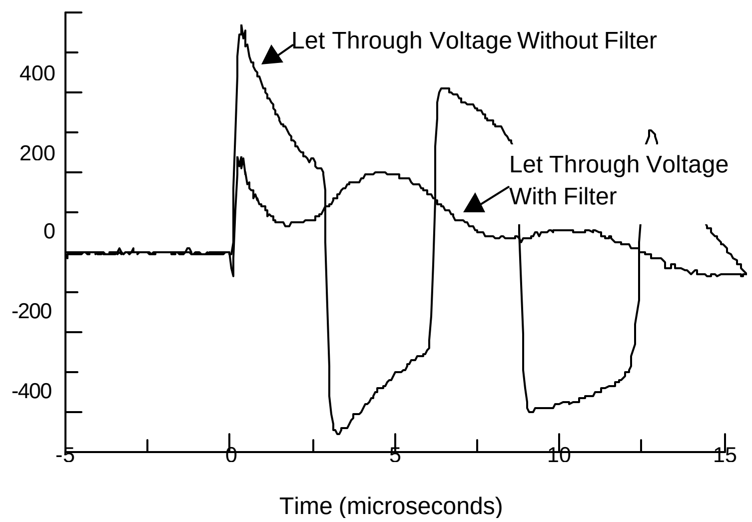
Key filtering specifications:

- MIL-STD-220A attenuation @ 100 kHz measured in dB. A higher dB rating (i.e. >40 dB) reflects better performance.
- Let Through Voltage: IEEE C62.41 Category B3 Ringwave. On a 120V system L-N should be <200V.
- UL 1283 listing for noise filtration.

13. Why Joules and Response Time Are Irrelevant Specifications?

Joule ratings are not an approved specification for surge protection devices. IEEE, IEC, and NEMA do not recommend using Joule ratings when specifying or comparing surge suppressors because they can provide misleading and conflicting information. For example, on a 120 Volt system, a 150 Volt or 175 Volt MOV could be used. Even though the 175 Volt MOV has a higher Joule rating, the 150 Volt has a much lower let through voltage and offers better surge protection.

Figure 8: Filter performance based on Cat B3, 100 kHz, 6000V



Joule ratings are a function of let through voltage, surge current and surge duration (time). Each manufacturer may use a different standard surge wave when publishing Joules. Given the confusion regarding Joule ratings, the power quality industry does not recommend the use of Joule ratings in performance specifications.

Response Time - All suppressors have sufficient **response time** to react to surges. In fact, the MOV will react 1000 times faster than the surge. NEMA and IEEE do not recommend using "response time" as a performance criteria when comparing SPDs.

14. Is a SPD with replaceable "modules" superior to non-replaceable designs?

No. Some manufacturers promote a modular design to minimize production costs, and create an "after market business" in modules. There are a number of technical flaws with many modular designs.

(1) If one module is damaged, all modules should be replaced (undamaged modules are stressed and provide unbalanced protection). Cutler-Hammer, as well as several other manufacturers, recommend a complete replacement, or replacement of all modules to ensure safety and reliability.

(2) Easy to cheat on performance specifications (often suppression ratings are for an individual module; unit ratings are not published).

(3) Modular designs utilize "Banana" pin connectors to connect modules rather than a low impedance bolt-on connection.

15. Is Maintenance Required for an SPD?

Maintenance is not a requirement for a quality SPD. A quality SPD should last over 25 years without any preventive maintenance program. Note the recommendations by Dr. Ronald B. Standler (a leading authority on SPDs) in his book "Protection of Electronic Circuits from Overvoltages" page 229:

> "The protection circuit should require minimal or no routine maintenance. Consumable components, such as fuses, should have an indicator lamp to signal the need for replacement. Requiring routine maintenance increases the cost of the protection circuits, although the money comes from a different budget."

The SPD should come with a diagnostic system that will provide continuous monitoring of the fusing system and protection circuits (including neutral to ground) and be capable of identifying any open circuit failures. The monitoring system should also include a detection circuit to monitor for overheating (in all modes) due to thermal runaway. (See Tech Note CPS-11 for more information).

16. What is the difference between a Surge Protector and an Arrestor?

Prior to the microprocessor revolution, most electrical devices were linear loads, relays, coils, step switches, motors, resistors, etc. Utility companies and end users were primarily concerned with preventing voltage surges from exceeding the Basic Insulation Level (BIL) of the conductor wires, transformer windings, and other equipment. Consequently, lightning arrestors were developed for use in low, medium, and high voltage applications. The fact that these devices create a "crowbar" between the phase conductor and ground does not matter to linear loads, as this is cleared within a few cycles.

Lightning arrestors are still used in the electrical industry primarily along the transmission lines and upstream of a facility's service entrance. Low voltage systems (600 Volts and below), now have surge protectors at the service entrance and branch panels in place of lightning arrestors. Surge protectors offer the following advantages over arrestors:

- Low let through voltage (better performance)
- Longer life expectancy
- Improved safety (less destructive debris if damaged)
- Full monitoring capability
- Internal fusing
- Filtering capabilities to remove low level surge/noise

(See Tech Note CPS-5 for more information).

17. Does A SPD Give Me 100% Coverage for Electrical Loads?

No! A SPD protects against surges – one of the most common types of electrical disturbances. Some SPDs also contain filtering to remove high frequency noise (50 kHz to 250 kHz)*. They do not provide filtering against harmonic loads (3rd through 50th harmonic equals 180 to 3000 Hz).*

A SPD can not prevent damage caused by a direct lightning strike. A direct lightning strike is a very rare occurrence; in most cases lightning causes induced surges on the power line which are reduced by the SPD. There is no device that can prevent damage from direct lightning strikes.

A SPD can not stop or limit problems due to temporary overvoltage. Temporary overvoltage is a rare disturbance caused by a severe fault in the utility power or due to problems with the ground (poor or non-existent N-G bond). Temporary overvoltage occurs when the AC voltage exceeds the nominal voltage (120 volts) for a short duration (millisecond to a few minutes). If the voltage exceeds 25% of the nominal system voltage, the SPD and other loads may become damaged.

A SPD device does not provide back-up power during a power outage. An uninterruptible power system (UPS) is required to provide battery back-up power. (See Tech Note CPS-6 for more information).

ABBREVIATIONS, REFERENCES AND DEFINITIONS

Abbreviations

ANSI:	American National Standards Institute
CSA	Canadian Standards Association
EMP	Electromagnetic Pulse
EMI	Electromagnetic Interference
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
NEMA	National Electrical Manufacturers Association
RFI	Radio Frequency Interference
UL	Underwriter Laboratories
LEMP	Lightning EMP
NEMP	Nuclear EMP

References

Institute of Electrical and Electronics Engineers (IEEE) Standard 100-1988
Standard Dictionary of Electrical and Electronic Terms

IEEE - C62	Collection of Guides and Standards for Surge Protection
IEEE - C62.41	Guide for Surge Voltages in Low Voltage AC Power Circuits
IEEE - C62.45	Guide on Surge Testing for Equipment Connected To Low Voltage AC Power Circuits
IEEE (std 1100)	Emerald Book
UL 96	Standard For Safety-Installation Requirements for Lightning Protection Systems
UL 452	Standard for Safety- Antenna Discharge Units
UL 497A	Standard for Safety-Secondary Protectors for Communication Circuits
UL 498	Standard for Safety-Receptacle and Receptacle Plugs (Including Direct Plug-In Devices)
UL 544	Standard for Safety-Medical and Dental Equipment
UL 1283	Standard for Safety-Electromagnetic Interference Filters
UL 1363	Standard for Safety-Temporary Power Taps (Power Strips)
UL 1449	Standard for Safety-Transient Voltage Surge Suppressors
NEMA LS-1	Low Voltage Surge Protective Devices