CIGRÉ (Council on Large Electric Systems) Technical Bulletin (TB) 549 (2013) Lightning Parameters for Engineering Applications

Created by Mick Maytum

Presented by Dr. Al Martin

TB 549 Project Details

- Objective was to produce an updated CIGRÉ document on cloud to ground lightning parameters that comprehended measurements taken since 1980.
- The work started in April 2008 and TB 549 was published in August 2013.
- The project team was headed by V. A. Rakov and had twenty international lightning experts.

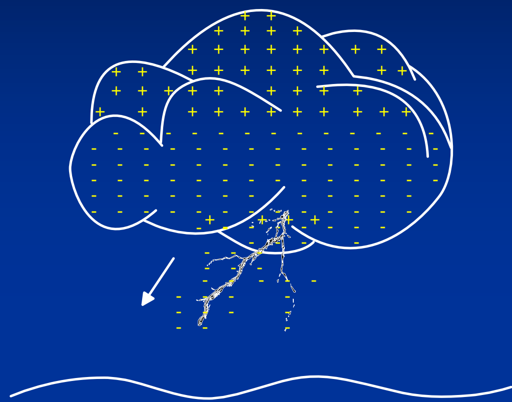
Previous CIGRÉ documents

- 1975: Berger, K., Anderson, R.B., and Kroninger, H.. Parameters of lightning flashes. Electra, No. 41, pp. 23-37.
- 1980: Anderson, R.B., and Eriksson, A.J.. Lightning parameters for engineering application. Electra, No. 69, pp. 65- 102.

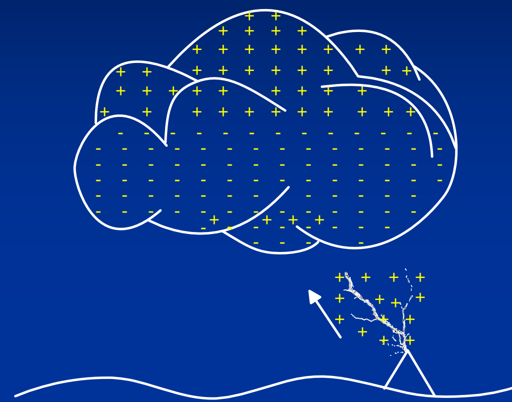
TB 549 Contents

Only the highlighted topics are covered here.

Four Lightning Types



Negative Lightning — Downward - leader

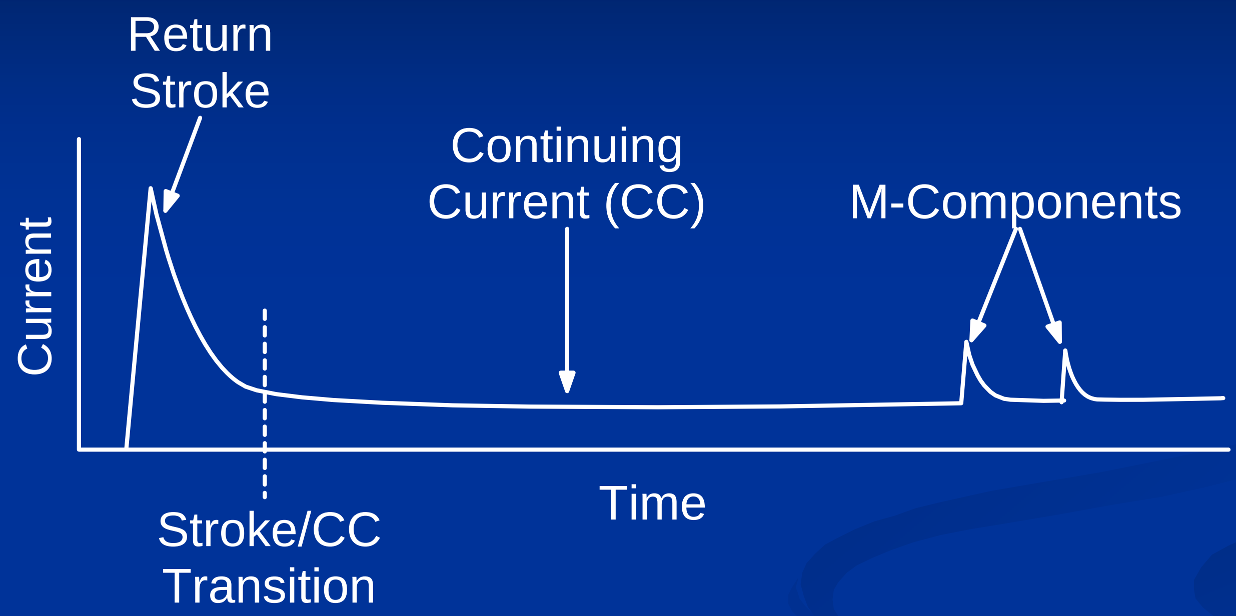


Negative Lightning — Upward + leader

Positive Lightning — Downward + leader

Positive Lightning — Upward - leader

Stroke Parameters

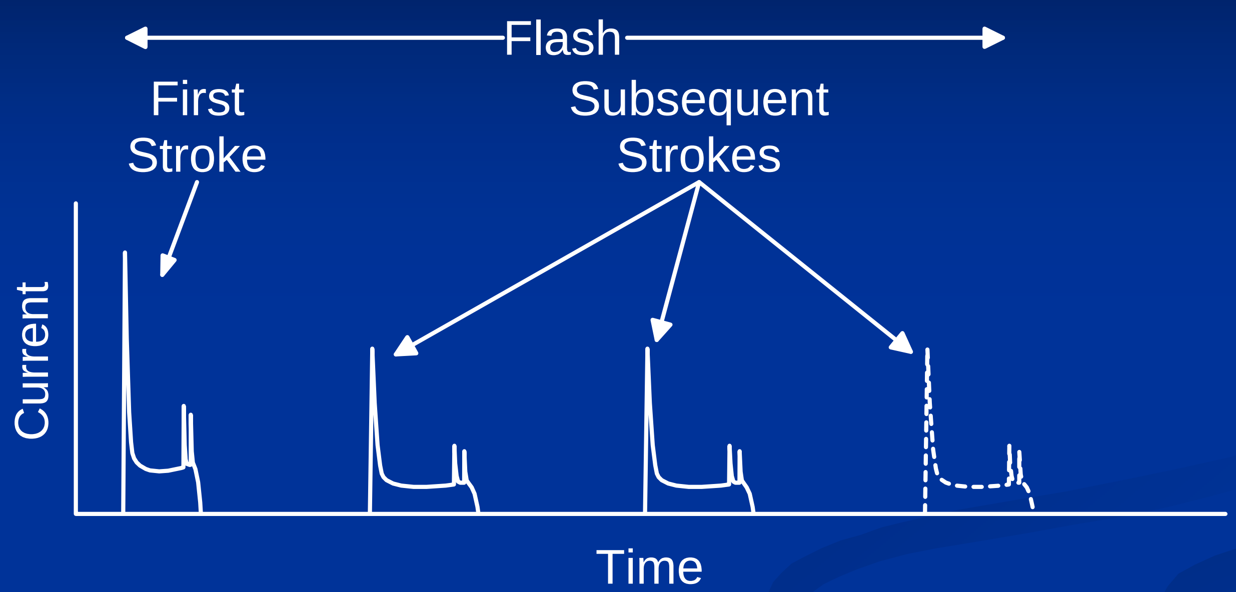


Stroke Parameters

Return Stroke (Impulse): Peak current, Charge (excluding CC), Front time to peak, Front maximum di/dt, Duration time to half peak value and i^2t (action integral)

CC: Peak current, Charge and Duration time

Flash Parameters



Flash Parameters

Number of strokes, Individual stroke parameters, Charge and Duration time

Lightning Data

- Measured current or luminosity values regarded as more credible than inferred values from lightning detection systems.
- This rational restricted the main data sources to instrumented towers and visual records.
  (Enhanced likelihood of upward initiated flashes — see slide 5)

Analysis

- Reviewed new measurements and compared them with previous measurements.
- If measurements confirmed old values, old values repeated.
- If measurements different to old values, new parameters established.

Downward Leader Negative Lightning — 1

General

- Now estimated that 80% of negative flashes have two or more strokes. Up from the previous 55 %.
- Some 30 % to 50 % of flashes have different stroke current paths to ground. Instrumented towers stroke counts need to be corrected by a factor of about 1.6. Up from the previous 1.1.
- Typically there are three to five strokes per flash separated by approximately 60 ms.
- Typically the first stroke current amplitude is two to three times larger than the subsequent strokes.
- Some 80 % of flashes have a CC and 30 % have a CC event of >40 ms

Downward Leader Negative Lightning — 2

Median stroke values given as:

- First: 30 kA, 5.5/75 and 5.2 C
- Subsequent: 12 kA, 1.1/32 and 1.4 C
- Inter-stroke interval: 60 ms
- Subsequent stroke number: 3 5

Downward Leader Positive Lightning — 1

General

- Little new data exists on positive lightning, leading to reliance on old data values. The old data comes from only 26 events of a questionable nature and so TB 549 advises caution is using the stroke waveshapes derived from this data[1].
- A small number of positive flashes have been observed as having more than one stroke.
- Something like 10 % of all lightning is positive.
- Has the highest measured peak currents (300 kA c.f. 200 kA negative) and charge values (hundreds of coulombs)
- Nearly 100 % of flashes have a CC and 70 % have a CC event of >40 ms

[1] The ten350.com website quotes 16 different TB 549 cautions on using the old positive lightning data at http://ten350.com/index-33-cigre-2.html

Downward Leader Positive Lightning — 2

The 50 % and 95 % (shown in parenthesis) values[1] are:

- Peak current 35 kA (250 kA)
- Impulse charge 16 C (150 C)
- Front time 22 µs (200 µs)
- Front maximum di/dt 2.4 kA/µs (32 kA/µs)
- Impulse duration 230 µs (2000 µs)
- i^2t 6.5×10^5 A^2s (1.5×10^7 A^2s)
- Flash charge 80 C (350 C)
- Flash duration 85 ms (500 ms)

[1] The ten350.com website quotes 16 different TB 549 cautions on using the old positive lightning data at http://ten350.com/index-33-cigre-2.html

Downward Leader Continuous Current (CC)

- Current flowing 3 ms after the start of a stroke are considered to be continuous currents.
- Long continuous currents have flow times of >40 ms
- There are many CC waveshapes and the quoted CC amplitude is calculated from the charge divided by the duration.
- Overall the CC duration of a positive flash is nearly ten times longer than a negative flash.
- Typically the negative flash CC amplitude is 200 A of a positive flash is nearly ten times larger than a negative flash.

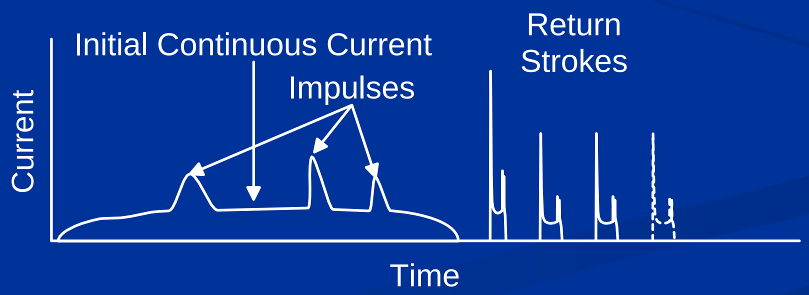
Downward leader Positive / Negative Lightning Comparison

- Positive lightning typically has higher stroke amplitude, charge, duration, i^2t and CC values.
- Negative lightning has faster front times, higher di/dt, more strokes and more discharge paths.

Upward Leader Negative Lightning

Lightning strikes to elevated structures, such as towers and wind turbines, can be the result of either upward leaders or nearby lightning activity.

- Negative upward lightning, caused by a positive leader, has an initial continuous current (ICC) period that *precedes* any return strokes.
- ICC parameters are typically 100 A, 200 ms – 300 ms, 30 C and 5×10^3 A^2s.
- In addition, M type impulses occur during the ICC period.
- Any return strokes that occur are similar to normal downward leader negative lightning leader negative lightning.



Upward Leader Positive Lightning

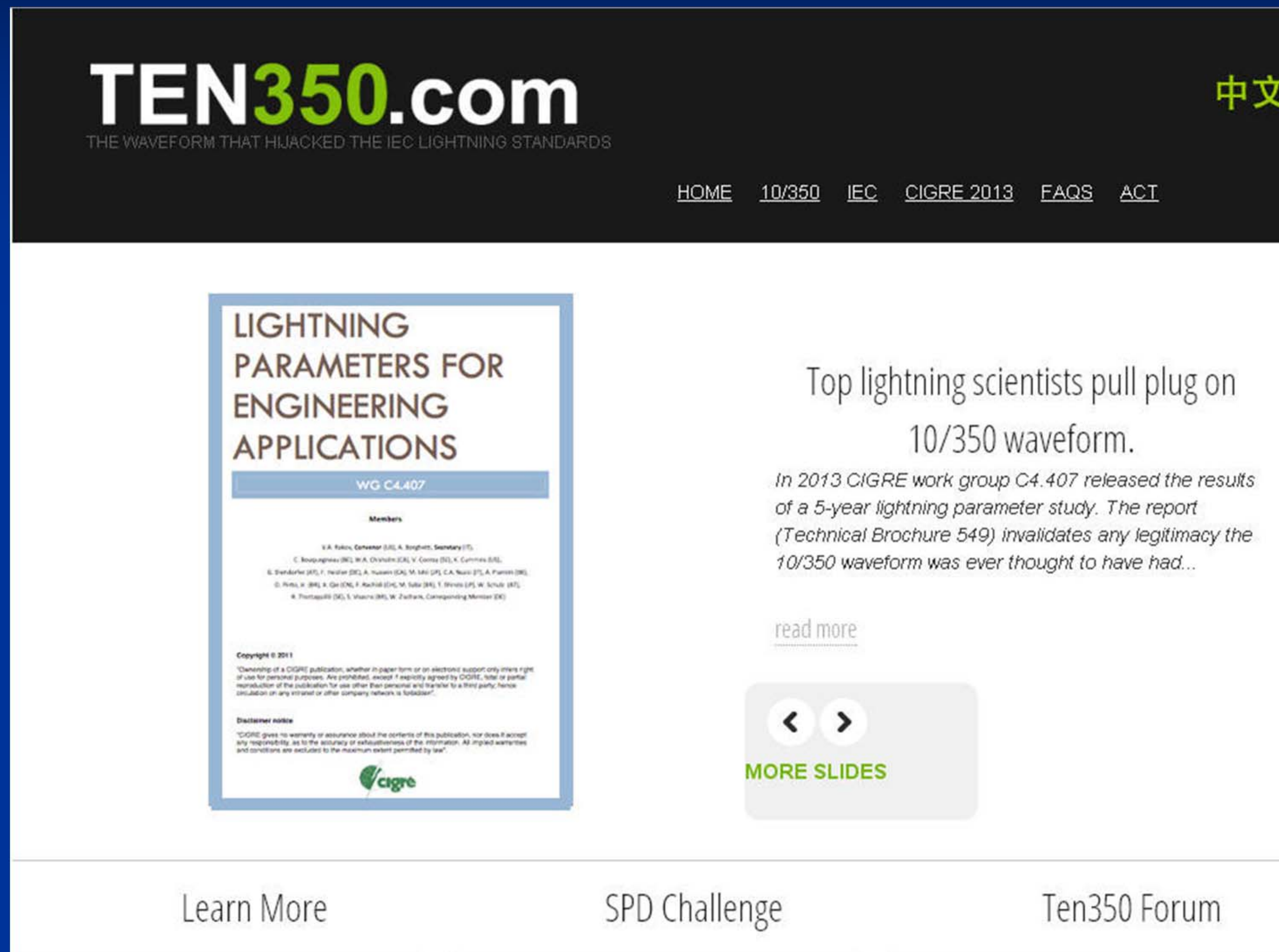
- Data on positive upward lightning is patchy. It is hoped that wind farm lightning data collection will provide better definition of the lightning parameters.
- Positive upward lightning, caused by an upward negative leader, amounts to about 10 % - 20 % of the lightning strikes to elevated structures.
- The positive lightning parameters from four structures where 1.5 kA to 11 kA peak current, 26 C – 169C charge, 40 ms – 80 ms flash duration and 160×10^3 A^2s - 390×10^3 A^2s i^2t.

Lightning Parameters Needed for Different Engineering Applications

Disappointingly, for the protection of ordinary structures this section of TB 549 reiterates the protection philosophy of IEC 62305, which has serious flaws in terminology and approach particularly for communications systems.

Ten350 Website - 1

The publication of TB 549 was the catalyst for the ten350 website.



Ten350.com Website - 2

The mission of the ten350.com website is to show that the 10/350 waveform used to represent positive lightning in power SPD IEC standards is invalid.

TEN350.com

THE WAVEFORM THAT HIJACKED THE IEC LIGHTNING STANDARDS

中文

HOME 10/350 IEC CIGRE 2013 FAQS ACT

Welcome to the TEN350.com website

The 10/350 Waveform

If you've been involved in lightning protection in 90% of the world's countries, it is almost a certainty that the concept of the 10/350 waveform has been foisted upon you without your consent. You may not know it, but its origins have been purposefully hidden, its true significance misrepresented, and its lack of workability casually ignored. This website fills in the missing pieces, sets the record straight on vital data, and lifts the veil on some rather uncomfortable issues.

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11 slides on the home page link to the main subject pages. Further links at the bottom of the home page, plus the navigation buttons at the top of every page, allow you to move around the site. Many references can be accessed by clicking on the underlined sections of the text.

WEBSITE MISSION: The goal of this website is to improve the quality of lightning surge protection by:

- Documenting how the 10/350 waveform and so-called "Class 1 Test" have severely damaged the workability of IEC lightning protection standards.
- Unveiling the true origin of the 10/350 waveform. (It's not what you have been told.)
- Annotating how CIGRE'S 2013 Technical Brochure 549 denies any possible basis for using a 10/350 waveform test.
- Documenting some of the earlier turmoil on this subject. Some of the original, hard to find, documents are made available for those who wish to go more deeply into the past record.
- Reminding one and all that surge protection can be workable and effective when not encumbered by a bad-hat monkey such as the 10/350 waveform.

Ten350.com Website - 3

The ten350.com website introduces the idea of 8/20 burst testing of SPDs instead of the 10/350

TEN350.com

THE WAVEFORM THAT HIJACKED THE IEC LIGHTNING STANDARDS

中文

HOME 10/350 IEC CIGRE 2013 FAQS ACT

SPD test for CIGRE-authenticated lightning parameters

A replacement for the Class 1 (10/350) SPD test

By the time you have reached this page, you will have figured out that the purpose of this website is to improve the workability of lightning protection by ridding international standards of the ill effects of the 10/350 waveform -- this includes mandatory 10/350 testing requirements for SPDs as well as the other practices infected by that waveform.

Achieving progress in an area may require one to stand up and vigorously denounce or eradicate destructive influences such as the 10/350 waveform. But as we all know, it can be all too easy to tear things down. At the same time one should be prepared to proffer an alternative that is at once more workable and can bring lightning protection a little closer to the ideal.

Our proposal is simple. Since the CIGRE 2013 Technical Report 549 has proven that the 10/350 waveform has nothing whatsoever to do with any significant percentage of any type of lightning, it must be eliminated as a mandatory test procedure. In its place, let's test the characteristics of real-world lightning that CIGRE's 2013 report has positively identified. Now that the key features of actual lightning have been documented, it behooves standards writers to use them in creating reality-driven test procedures for SPDs.

Ten350.com Website - 4

Burst 8/20 test plan. Eleven manufacturers SPDs were tested.

The following chart shows the sequence of 11 tests. The white checkmarks on the left indicate the test sequences passed only by the American SPD.

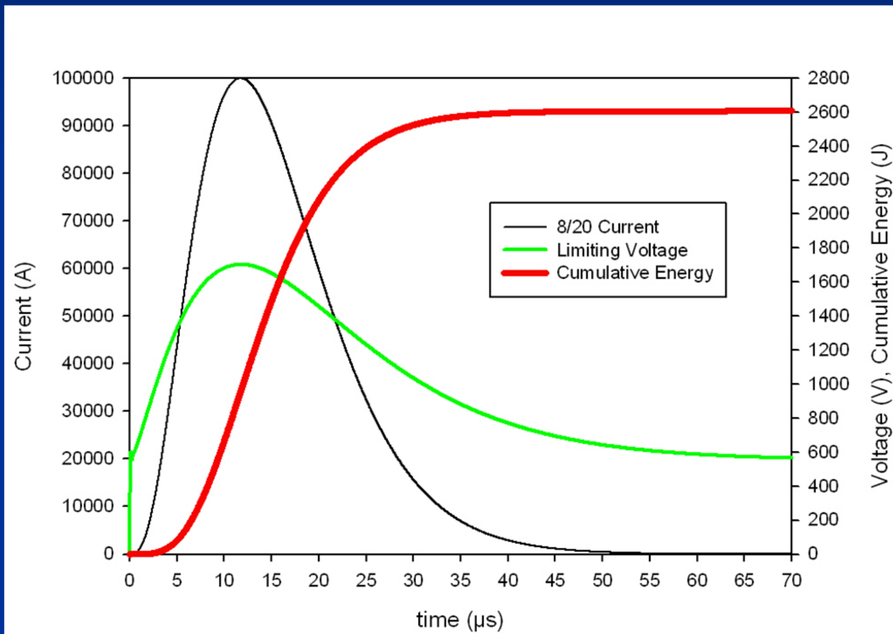
	Test number	# Impulses per test	Individual impulse current sizes (in kA) 8/20 µs										SPD failures
	1	3	30	15	30								
	2	5	30	15	15	15	30						
	3	7	30	15	15	15	15	15	30				1
	4	10	30	15	15	15	15	15	15	15	15	30	2
	5	3	60	30	60								1
	6	5	60	30	30	30	60						3
✓	7	7	60	30	30	30	30	30	60				3
✓	8	10	60	30	30	30	30	30	30	30	30	60	
✓	9	3	100	50	100								
✓	10	5	100	50	50	50	100						
✓	11	7	100	50	50	50	50	50	100				

KEY:

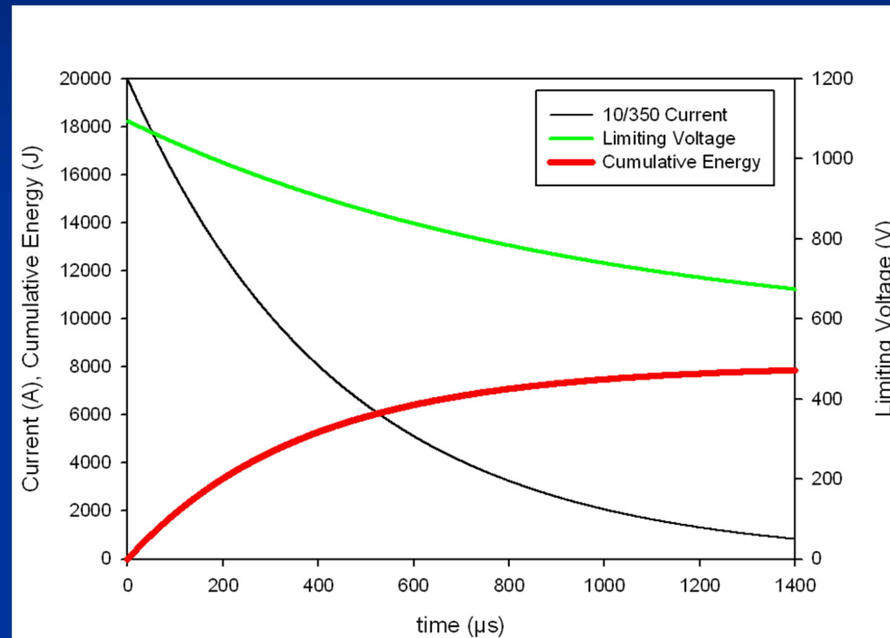
Blue numbers refer to the 11 parts of the test.
Green numbers show the number of impulses per test (either 3, 5, 7, or 10).
Black numbers show the Ipeak of the individual impulses in kA (8/20 µs).
Red numbers show the number of manufacturers whose entry was destroyed at that level of test.
White check marks (and yellow boxes) show the parts of the test passed only by the winning SPD.

Note: The starting and ending impulses of each test sequence have the same current amplitude. Intermediate impulses, which may be 1, 3, 5 or 8 in number, have half the amplitude of the starting and ending impulses.

MOV Energy developed for 8/20 and 10/350 surges



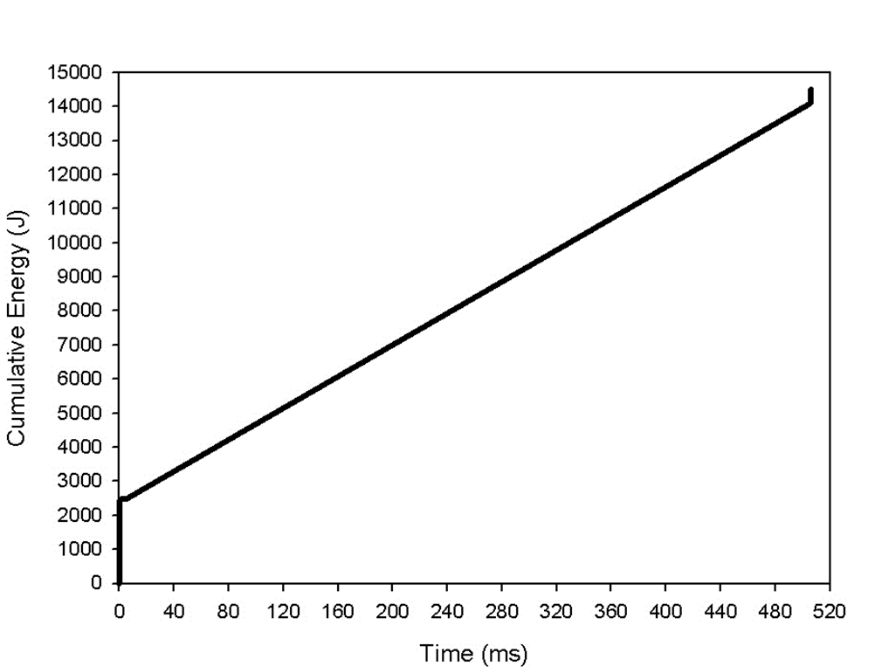
100 kA 8/20 2.6 kJ



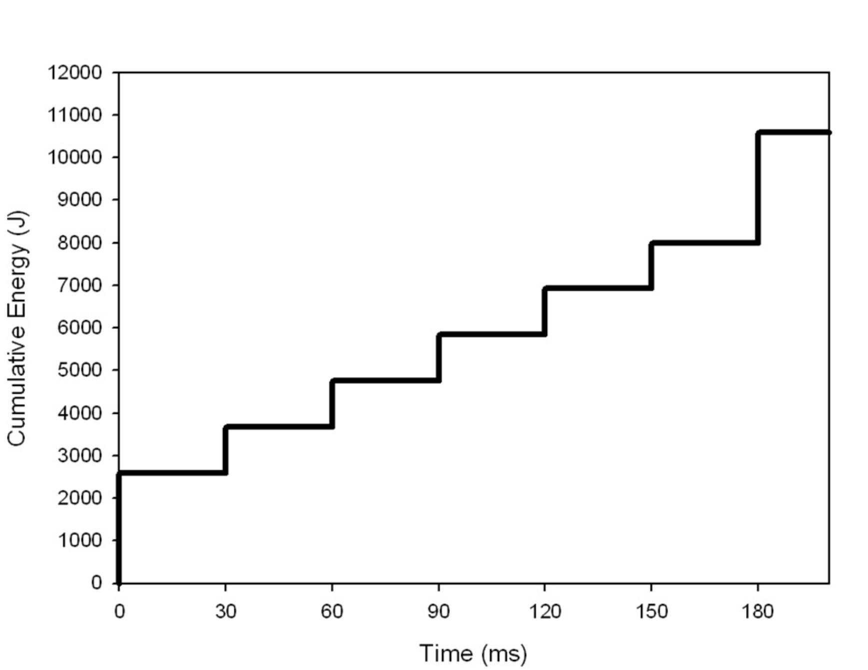
20 kA 10/350 8.1 kJ

More test details at
http://pes-spdc.org/content/ten350-web-site?page=1#comment-102

MOV Energy developed for aircraft ABCD test and 8/20 burst



Aircraft ABCD test 14.5 kJ
Most energy from 200 A 500 ms CC



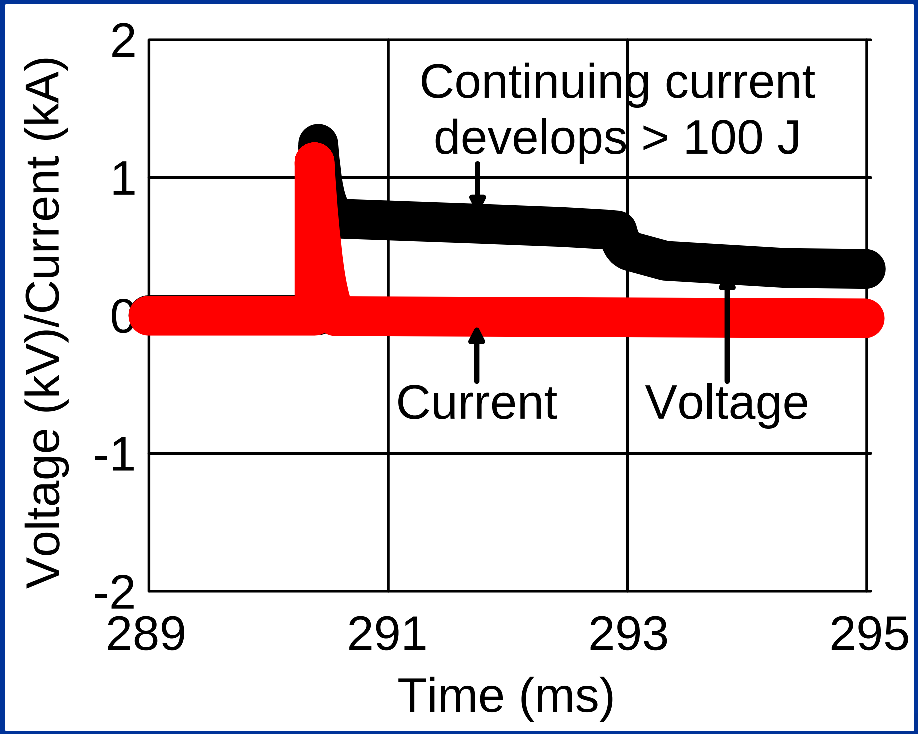
Proposed 8/20 burst test #11 10.6 kJ
Energy steps: 2x100 kA 8/20 & 5x50 kA 8/20
More Energy than 20 kA 10/350

More test details at
http://pes-spdc.org/content/ten350-web-site?page=1#comment-102

Ten350.com Website - 5

Q: Why did a 40 kA SPD fail at lightning currents no greater than 1.6 kA?

From Triggered Lightning Analysis Gives New Insight into Over Current Effects on Surge Protective Devices, for paper see www.ten350.com/papers/icae-conghua.pdf



A: Appears to be the cumulative energy delivered by the 350 A, 0.5/29.5 first stroke followed by eight return strokes ranging from 0.22 kA to 1.64 kA with a geometric mean waveshape of 15.6/63.3 plus several impulses show a continuing current content lasting some 3 ms and delivering 100 J.

TB 549

What does Technical Brochure (TB 549) tell us?

- Downward Leader Negative Lightning: Revised percentage of multi-stroke flashes and the number of stroke paths during a flash.

- Downward Leader Positive Lightning: Lack of new data, means old values must be used with caution. More Data needed.

- Upward Leader Negative Lightning: Apart from the initial relatively mild ICC period any return strokes are similar to downward leader negative lightning

- Upward Leader Positive Lightning: Flash conditions appear to be relatively mild except one location reported a charge value of nearly 200 C. More data needed.

- Continuing Current: Basic parameters established, could do with more waveshape clarification.