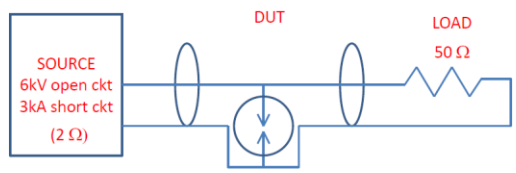
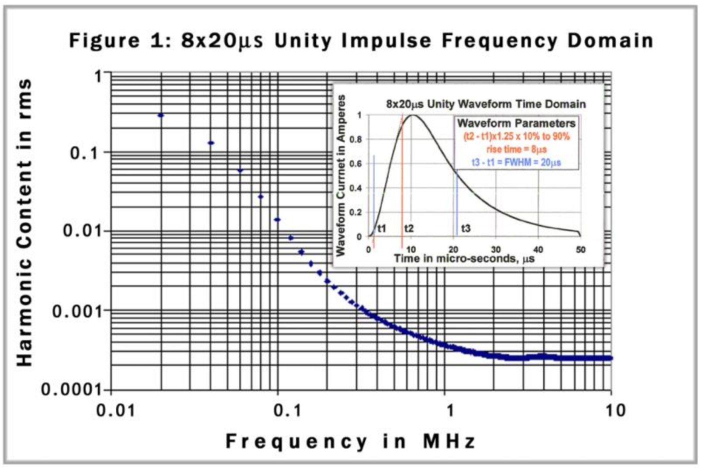
The circuit for lightning transient testing a GDT based coaxial protector is shown to the right.



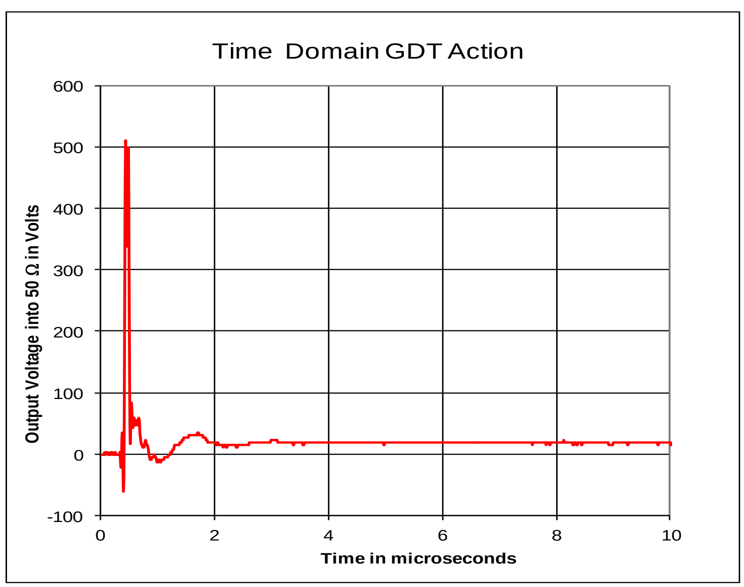

The most common high voltage pulse source used in the industry has an 8x20µs waveform into a shunting type protector, with a source impedance of about 2 Ohms. The DUT is connected to the pulse source, then to a back load. For coaxial applications the default backload would be the nominal impedance of the system, our usually 50 Ohms. This nominal impedance would be normally used to characterize energy into a typical load. However, specific applications usually have impedances close to nominal with an operating band. In some cases, testing with the actual load is important.




The current source is typically an 8x20us pulse, as shown on the left.

The voltage produced by a GDT based suppressor usually has an initial spike and then a following "dc" voltage until flow current stops. If the common 6kV/3kA transient is applied, the pulse shown below is a typical output.

There is practically no transient current flowing during the spike duration. The leading edge of the waveform is usually exactly the input Voc waveform of the pulse generator. The GDT turns on during the voltage abrupt fall (negative slope), then after some settling out, a nearly constant voltage appears across the GDT and the load. In this case the ramp up to a little over 500 volts occurs, followed by a GDT crowbar or shunting action at about 100ns, then settling to about 18 volts. This 18 volts extends until about 60µs, far to the right of the maximum time shown on this curve.




While the above is shown at 6kV and 3kA, the same principles apply at full rated currents of 20kA. Although more routine product testing for energy is done at much less than full magnitude testing. However, since these are suppressors that limit voltage, and are VERY nonlinear, results may not be much different at 3kA versus 20kA.

With all of these effects, there are three energies to be concerned with:

1. The source or generator.
2. the arrestor
3. The load

1. Generator - The generator is the easiest one to estimate. There is a charging capacitance that contains the energy *1/2CV²*. Typical values for this require a charging energy of 2J when charged to 6kV. This energy is dissipated by the wave forming circuit, especially including the series 2 Ohm resistance. In a Thevenin world with a 2 Ohm load, 50% of this stored energy could be deposited into the load. However, loads are usually 50 Ohms, and the suppressor switches from nearly infinite to a very low impedance shunt.

2. Arrestor - The arrestor starts off essentially non-conductive, then transitions into a ~15 volt zener type clamp. The absorbed energy is associated with GDT switching and current flow in the GDT on state. The current flow energy is related to the flow current into a 15 volts produces an energy of x i(t)*15Vdt, evaluated during the entire current flow time of about 50µs. This equated to about 0.5J. The switching energy of x i(t)*V(t)dt, evaluated only for about 1 to 2 ns (during the fall time where current and voltage might be high). This switching energy is usually less than 1mJ, and is frequency neglected in energy calculations, unless rapid and sustained switching is performed, with little flow current. Note that the effective shunt impedance of a 3kA impulse is about 20V/2kA or .01 Ohm. Higher current impulses have correspondingly lower impedances.

   *Note that protectors that do not shunt to very low voltages like a GDT does, such as MOVs or Zeners, have very significant current flow energy, since the voltage can increase from 15 volts to hundreds of volts.*

3. Load - The energy absorbed by the load is x V(t)2/50Ωdt. This energy is evaluated numerically, and results in about 200µJ to 400µJ for a typical low voltage protector into a 50 ohm load.

**SUMMARY**

Where does the energy go? According to the calculations above, the energies for each circuit element are as follows: 2J source, .5J dissipated in the arrestor, and .0003J into the load.

- From a time domain or circuit analysis perspective, the source impedance absorbs the vast majority of the energy. From a frequency domain perspective, the energy is reflected by impedance mismatch back to the source. Both effects are happening during this testing.
- If higher energy sources are used, such as a 200 Joule example which could produce 20kA of current, the energy of a GDT arrestor will tend to increase in proportion to the increase in current for the same waveform. [GDTs can be evaluated for current handling outside of a coaxial system.]
- The load energy figure will also increase as higher source energies are used, but the load's share of total energy diminishes.