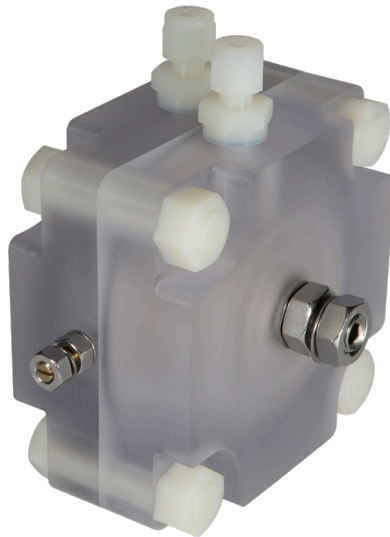


HIGH VOLTAGE TRIGGERED SPARK GAPS

Triggered Spark Gaps are used by pulsed power scientists who need to control gigawatts of electricity. Like a FET, the Triggered Spark Gap is voltage-controlled, and, like an SCR, it is a bistable device that can be turned on, but not off. Our Triggered Spark Gaps operate by using voltage to ignite a plasma between two terminals, which enables conduction. Once the current in the circuit drops, the plasma extinguishes, and the Triggered Spark Gap recovers to its original high-impedance state.



SPECIFICATIONS

	FLASH	FLARE
Max Operating Voltage	50 kV	150 kV
Min Operating Voltage	5 kV	10 kV
Inductance	18 nH	29 nH
On Resistance after 10 mC charge transfer	8 mΩ	19 mΩ
Max Current	100 kA	
Max Repetition Rate	10 Hz	
Max Recommended Charge Transfer per Shot	0.15 Coulomb	
Maintenance Interval	1,500 Coulombs	
Min Trigger Voltage	50% of operating voltage	
RMS Jitter	30 kV 40 ns rise time trigger: 24 ns at 40 kV 106% SBP 78 ns at 40 kV 125% SBP	
Trigger Electrode Capacitance	7 pF	
Interelectrode Capacitance	1 pF	
Max Pressure	50 psig or 3.4 bar	
Fill Gas	Compressed air	
Fill Gas Volume	9.5 in ³ or 155 cm ³	
Volume Displaced When Immersed in Oil	47 in ³ or 770 cm ³	
Recommended External Dielectrics	air, mineral oil, Shell Diala, Petro-Canada Luminol	

FEATURES

Wide voltage range

Operate at any voltage in the range without sacrificing jitter, prefire rate, or no-fire rate.

Choice of trigger

Use voltage- or pressure-triggering, whichever fits your experimental objectives better.

Low inductance

Take advantage of Hofstra Group Triggered Spark Gaps' fast, non-oscillating performance in your pulsed power circuits.

Ease of maintenance

Enjoy longevity and low cost of ownership made possible by rugged modular construction that facilitates cleaning.

Safety and durability

Ensure safety during experiments with our stronger, non-shattering polycarbonate housing.

Design support

Integrate our CAD and SPICE models into your precise designs and call our customer support at any stage in your process.

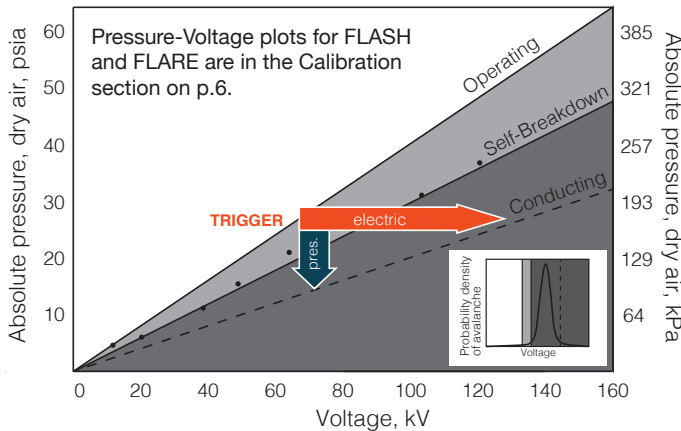
USING YOUR TRIGGERED SPARK GAP

Achieving reliable operation where your triggered spark gap always turns on when it's supposed to and never turns on spontaneously requires attention to trigger, jitter, prefire, no-fire, and rise time.

TRIGGER

The Triggered Spark Gap will start conducting whenever a plasma is ignited between its terminals. This transition between the high-impedance state and the conductive state occurs whenever the ratio of the voltage divided by the pressure inside the Triggered Spark Gap exceeds a critical value. That means that at low pressure or high voltage the Triggered Spark Gap will spontaneously start to conduct.

A trigger enables a controlled transition between the high-impedance and conducting states. Hofstra Group Triggered Spark Gaps can be triggered either electrically or by a drop in pressure. The diagram below represents how both an increase in voltage and a decrease in pressure achieve the same goal: crossing into the voltage-pressure space that allows for abundant ionization events and thus an avalanche that ignites conductive plasma between the terminals of the Triggered Spark Gap.



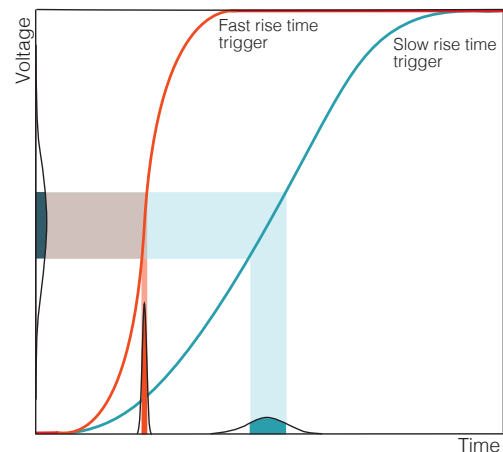
Electric trigger. Inject voltage into the Triggered Spark Gap via the Trigger Electrode Terminal using an external high voltage pulse generator. This rapid change in voltage inside the Triggered Spark Gap will ensure accurate timing for successful synchronization (such as in synchronized laser experiments or circuits involving many Spark Gap Switches like Marx generators and linear transformer drivers.)

Pressure trigger. Not concerned about synchronization? Simply lower the pressure inside the Triggered Spark Gap by using a valve. This works well for low repetition rate applications where timing doesn't matter, such as qualifying capacitors or surge testing.

JITTER, PREFIRE, AND NO-FIRE

The exact voltage at which plasma ignites inside the Triggered Spark Gap is difficult to predict in practice. This is because the plasma ignition voltage is a function of many parameters such as microscopic surface texture of the internal electrodes, atmospheric pressure, temperature, time since the switch was last fired, dust particles, humidity, and presence of cosmic rays. Due to this uncertainty, high performance applications demand that the operating point of the switch and the trigger characteristics be carefully selected to balance the following three interrelated performance metrics:

- Jitter** is the standard deviation of the time that the switch begins conducting referenced to the arrival of the trigger signal. As shown in the figure:



any statistical spread in the voltage at which breakdown occurs is mapped directly onto uncertainty about the time that the Triggered Spark Gap fires. A trigger signal that quickly passes through the range of voltages where the Triggered Spark Gap is likely to fire results in low jitter, but slowly rising trigger signals cause high jitter. Achieving low jitter requires operating the switch close to the transition between non-conducting and conducting unless a trigger generator is used that supplies a large voltage pulse to the Triggered Spark Gap, which is usually difficult.

2. Prefire is when the Triggered Spark Gap fires in the absence of a deliberate trigger signal. This is caused by operating the Triggered Spark Gap too close to the transition between high-impedance and conducting where uncontrolled events like cosmic rays can cause the switch to fire spontaneously. As the switch ages, dust

particles may accumulate inside the housing and lead to an increased rate of prefires.

Reactive gases and free ions form inside the Triggered Spark Gap during normal operation. These compounds destabilize triggering if they build up to high concentrations. We recommend injecting a continuous flow of fresh gas into one of the Gas Purge Ports while venting the same flow rate out the other Gas Purge Port to maintain constant pressure.

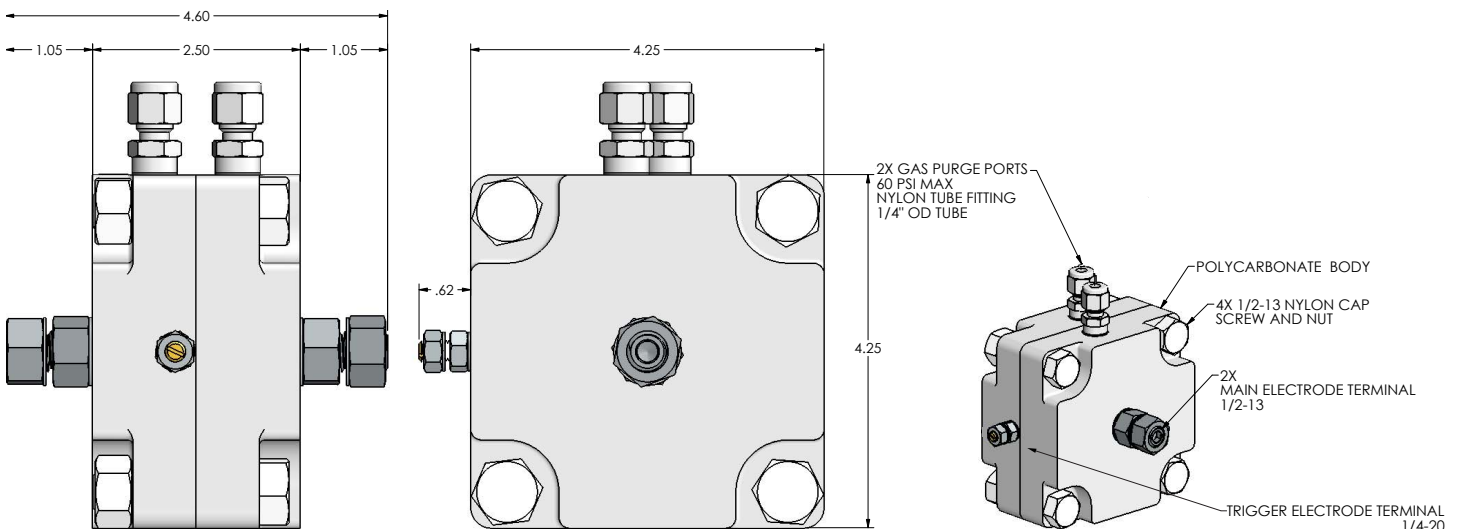
3. No-fire describes a Triggered Spark Gap not firing, or firing uncharacteristically late, when a deliberate trigger is present. No-fires are caused by operating too far from the transition between non-conducting and conducting. With age, no-fires may become more common as material is removed from the electrodes inside the Triggered Spark Gap.

RISE TIME

If rise time is a concern for your experimental outcome, keep in mind that at low impedances, even the slightest stray inductance will significantly degrade rise time. You will need to use wide, closely spaced conductors in a stripline configuration to keep the impedance throughout your circuit low.

Unless carefully designed and constructed, common components like resistors, capacitors, and transformers will present unacceptable inductance. Film resistors, wire-wound resistors, and connections made using wires are common causes of poor performance.

TRIGGERED SPARK GAP DESIGN

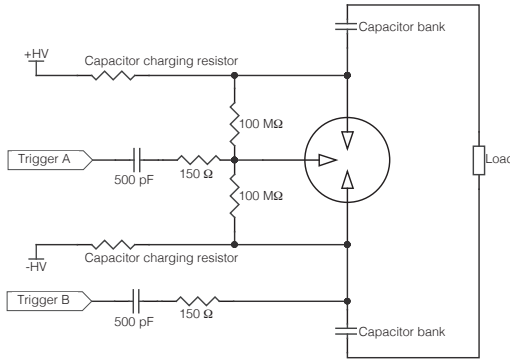


SAMPLE CIRCUITS

LINEAR TRANSFORMER DRIVER

This balanced circuit is great for achieving low output impedance at voltages up to twice the ratings of individual capacitors and power supplies.

Applications:
Z-pinch,
flash x-ray
sources,
inductive
voltage
adders (IVA)



Polarity of trigger may be either positive or negative.

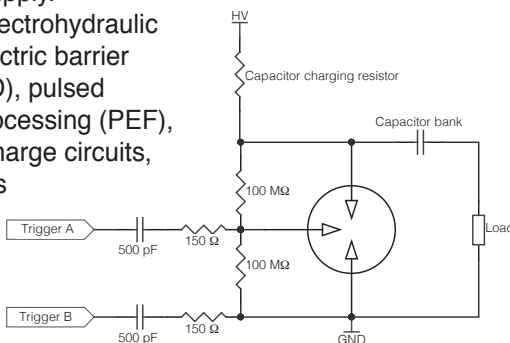
Magnitude of trigger pulse must be greater than HV.

Capacitor bank charging currents return to ground via load, so a load that is a diode or a small capacitance may prevent capacitor banks from charging and load may float to high voltage during charging.

CAPACITOR DISCHARGE, LOW-SIDE

This circuit is great for medium-voltage applications with a single power supply.

Applications: electrohydraulic
fracturing, dielectric barrier
discharge (DBD), pulsed
electric field processing (PEF),
capacitive discharge circuits,
current injectors



Polarity of Trigger A must be opposite that of HV.

Magnitude of trigger pulse must be greater than 50% of HV.

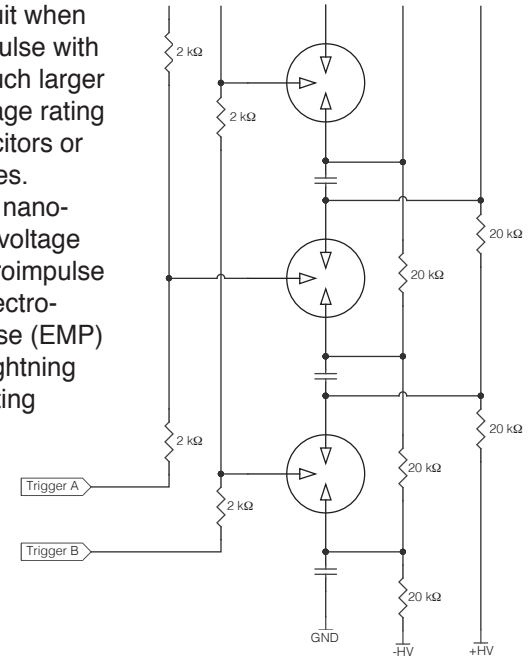
Capacitor bank charging current returns to ground via load, so a load that is a diode or a small capacitance may prevent capacitor bank from charging and load may float to high voltage during charging.

Voltage across load when triggered Spark Gap Switch fires is of opposite polarity to HV.

MARX GENERATOR

Use this circuit when you need a pulse with amplitude much larger than the voltage rating of your capacitors or power supplies.

Applications: nano-second high-voltage pulses, electroimpulse fracturing, electro-magnetic pulse (EMP) simulation, lightning immunity testing



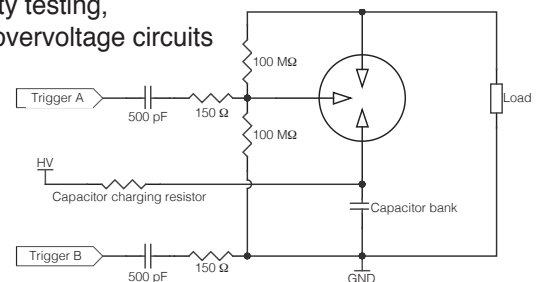
Polarity of trigger may be either positive or negative.

Magnitude of trigger pulse must be greater than 2x HV.

CAPACITOR DISCHARGE, HIGH-SIDE

Use in medium-voltage applications with a single power supply

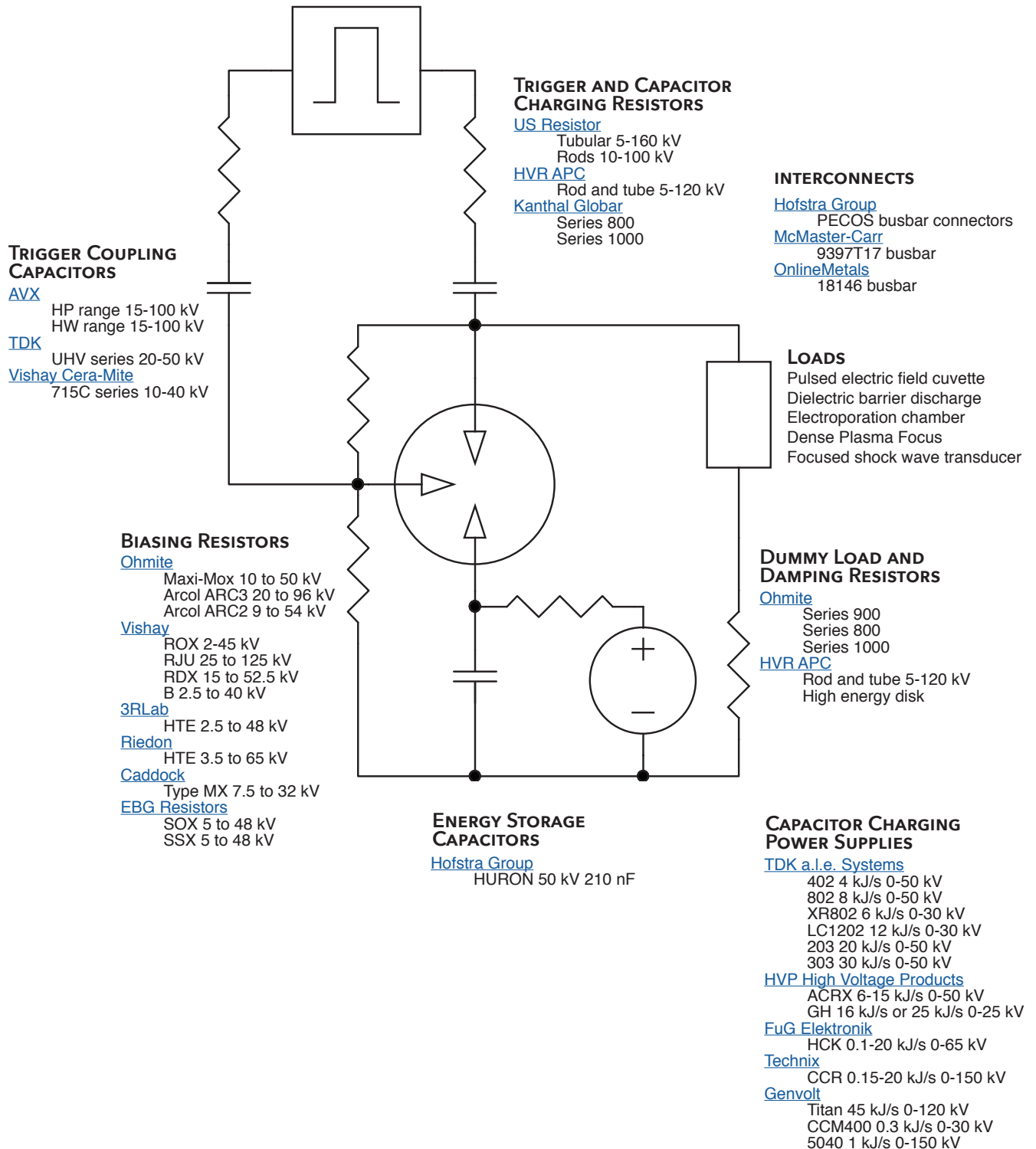
Applications: extracorporeal shock wave lithotripsy (ESWL), electrohydraulic forming, laser drivers, surge immunity testing, crowbar and overvoltage circuits



Polarity of Trigger A must be opposite that of HV.

Magnitude of trigger pulse must be greater than 50% of HV.

COMPONENTS THAT WILL DELIVER BEST CIRCUIT PERFORMANCE

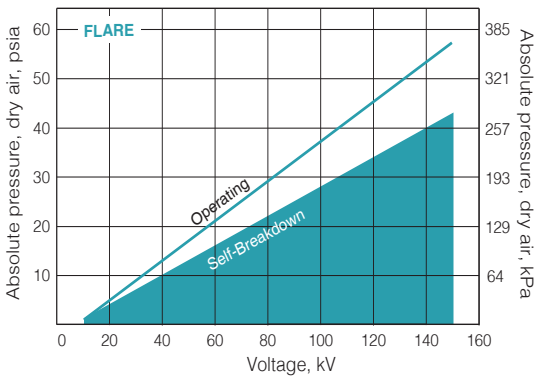
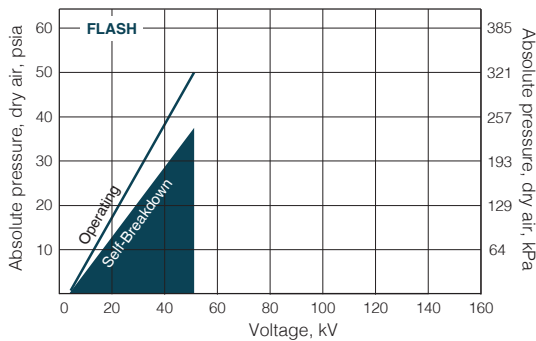


GETTING THE MOST OUT OF YOUR TRIGGERED SPARK GAP

We know you want to make the most out of each day in the lab and that maintenance and calibration are unlikely to be your favorite things to do. But they are critical to the success and reproducibility of your experiment. It may be impractical for you to go through all of these procedures every day, but we hope to help you understand outcomes of cutting corners.

CALIBRATION

The plot below is a good starting point for selecting the best pressure to use for your operating voltage. However, numerous environmental factors that change every day influence this range. We have done our best to ensure the inside of the Triggered Spark Gap is stable, but, unfortunately, environmental factors are out of our control.



MAINTENANCE

When your Triggered Spark Gap looks dirty inside or misfires or prefires even after calibration, it is time for maintenance. Contact us for spare parts, drawings, maintenance instructions, and torque values.

Thus, every day you set out to use the Triggered Spark Gap:

1. Identify whether you are using the 5-50 kV (FLASH) or the 10-150 kV (FLARE) Triggered Spark Gap.
2. Locate the appropriate line on the plot to the left.
3. Find the voltage you want to operate at on the x-axis.
4. Find the corresponding operating pressure on the y-axis at the intersection with the appropriate line.
5. Pressurize the Triggered Spark Gap to the pressure you identified in 4.
6. Turn on the high voltage.
7. Slowly lower the pressure until the Triggered Spark Gap fires spontaneously. This is the self-breakdown pressure.
8. Increase the pressure to 1.25 times the pressure at which self-breakdown occurred. This is the operating pressure for the day.
9. If operating pressure for the day is more than double that in the plot, it may be time for maintenance, and you are likely to observe no-fires or prefires.

If you skip this calibration step: You will observe significant jitter or unreliable or unexpected triggering. We have found that operating the Triggered Spark Gap at 125% of the pressure at which self-breakdown occurs results in the best balance between jitter, prefire, and no-fire.

If you skip this maintenance step: Your Triggered Spark Gap will eventually be destroyed by surface tracking across the inside of the housing. Once the housing is destroyed, the Triggered Spark Gap will spontaneously trigger even at low voltages.

Q&A

Q: How do I adjust the operating voltage?

A: By changing the pressure inside the Triggered Spark Gap. Because voltage and pressure have opposing effects on the system, if you want to raise your operating voltage, you have to raise the pressure as well.

Q: I want to operate at voltage X kV. Will your Triggered Spark Gap do that?

A: If your desired voltage falls between 5 and 150 kV, we've got a Triggered Spark Gap for you. You'll pressurize the Triggered Spark Gap to support your operating voltage.

Q: How much charge can this Triggered Spark Gap transfer?

A: Depends on the individual transfers. In general, the Triggered Spark Gap can take about 1,500 Coulombs of cumulative transfer between maintenance, but it can be less if your individual charge transfers are very large.

Q: Can I get a custom Triggered Spark Gap?

A: Absolutely! We can design a Triggered Spark Gap that fits your specialized setup.