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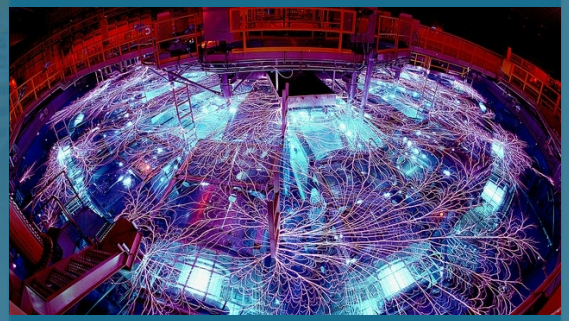
Sandia National Laboratories

Self-Breakdown Study of Spherical Electrodes in Air Spanning Pressures from Atmosphere to 2000 psia, and Stress Times from Multi-Second to Microsecond



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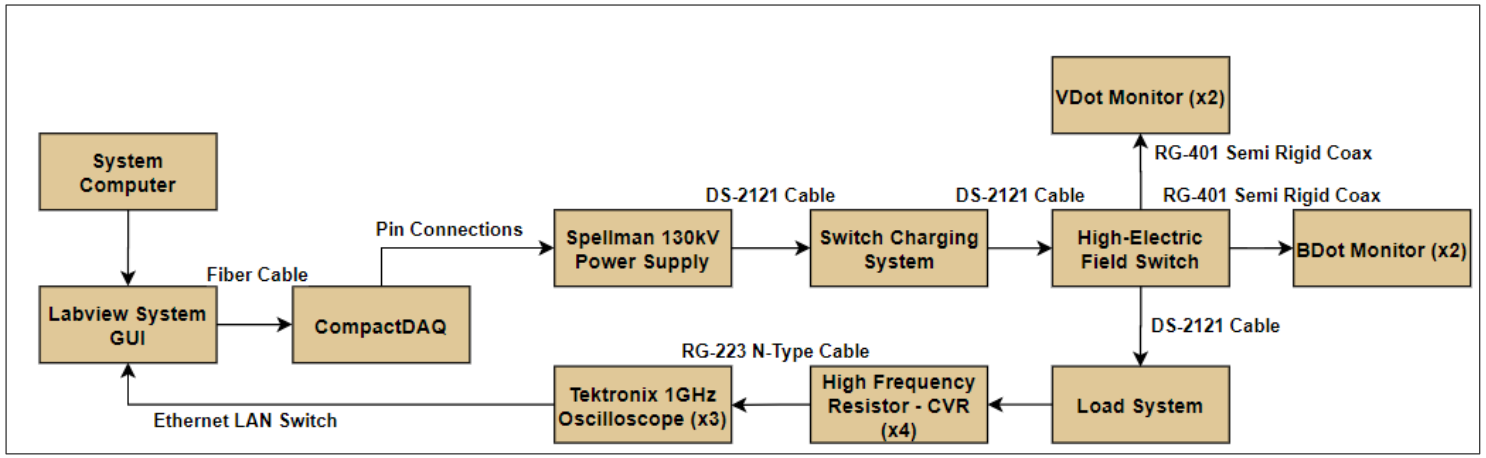
Outline

- Motivation
- Introduction
- Experimental System Setup
- Experimental Variables
- Experiment Results
- Future Work



Motivation

- Switches are among the most important components in pulsed power applications.

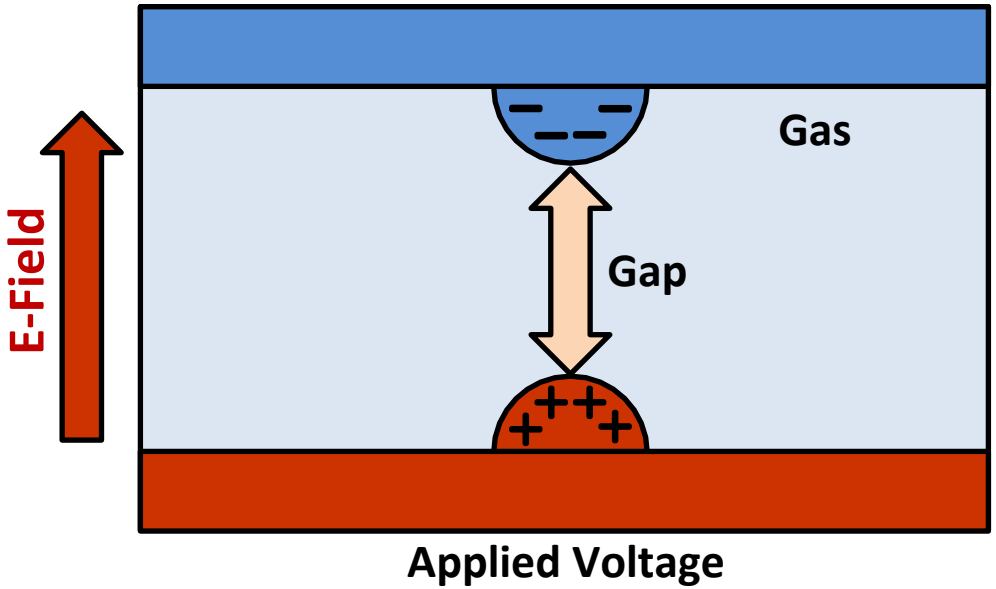
- Few studies have investigated equivalent ranges of pressure and stress time on breakdown voltage, standard deviations, and switch closure time.

- Understanding the impacts of these variables on switch behavior allows optimum designing of specific pulse generators.

Self-Breakdown Switch

➢Electrical Breakdown is the process of ionizing a gas gap. It changes the gas from an insulator to a highly conductive channel. The electric field across the gap accelerates electrons towards the anode electrode as shown below.

$$E\text{-}Field = \frac{Voltage}{Gap}$$

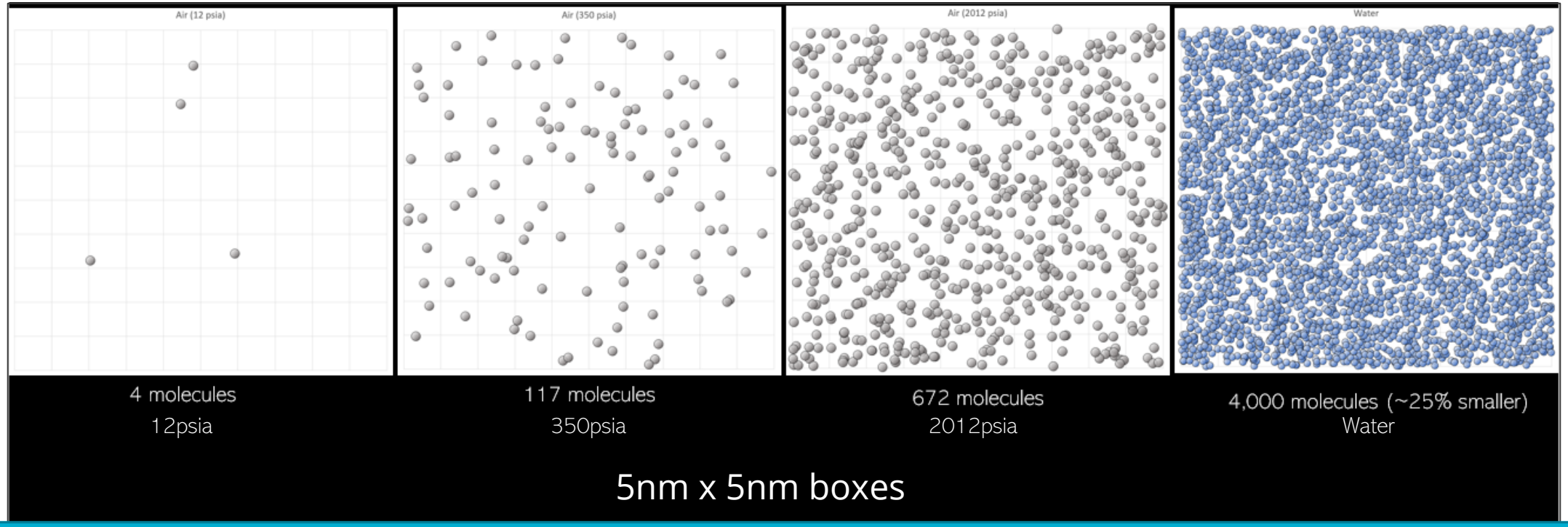


$$V_{max} = E_{max} * gap$$

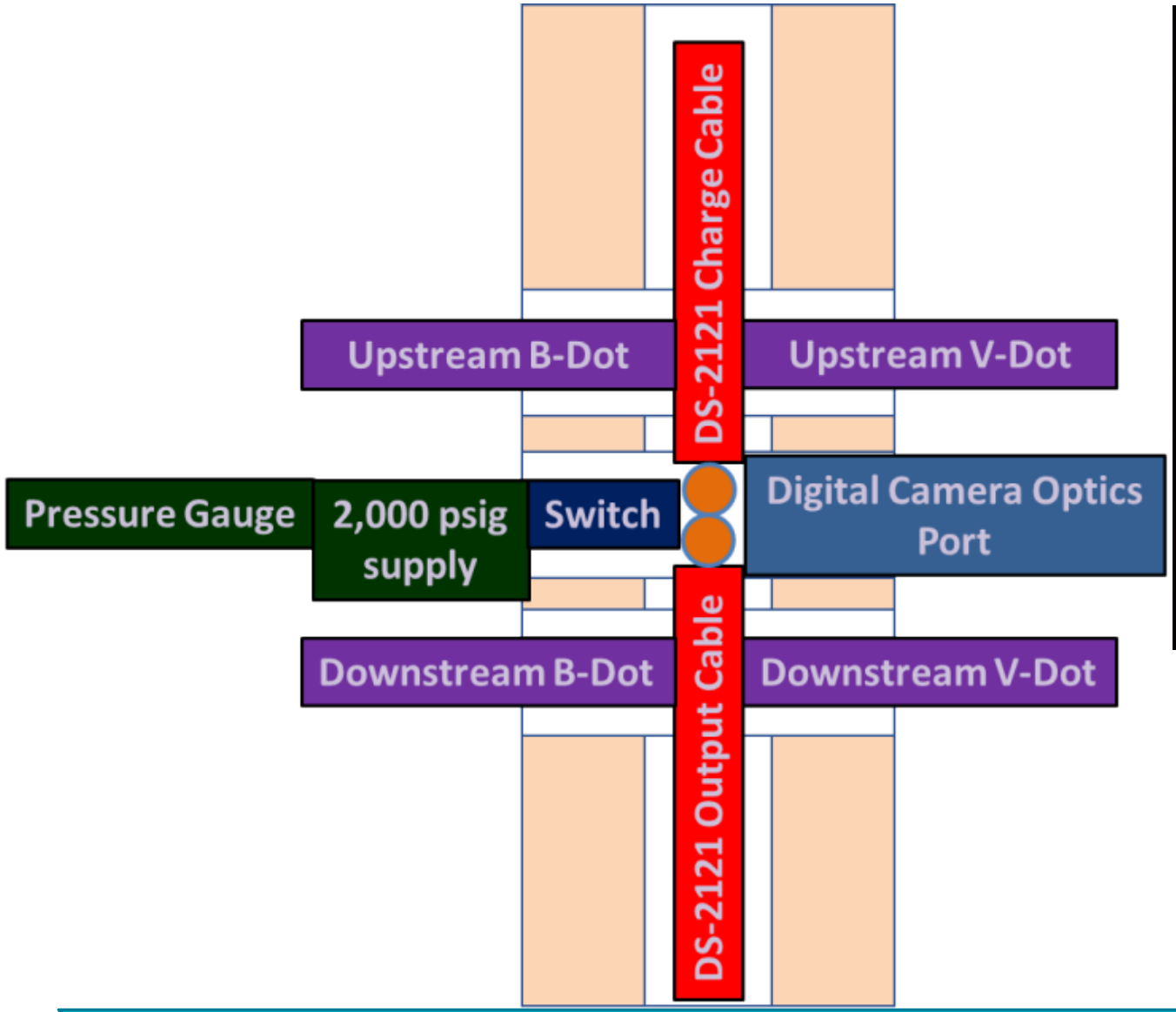
➢Gas type, gap distance, pressure, and voltage stress time affect switch performance.

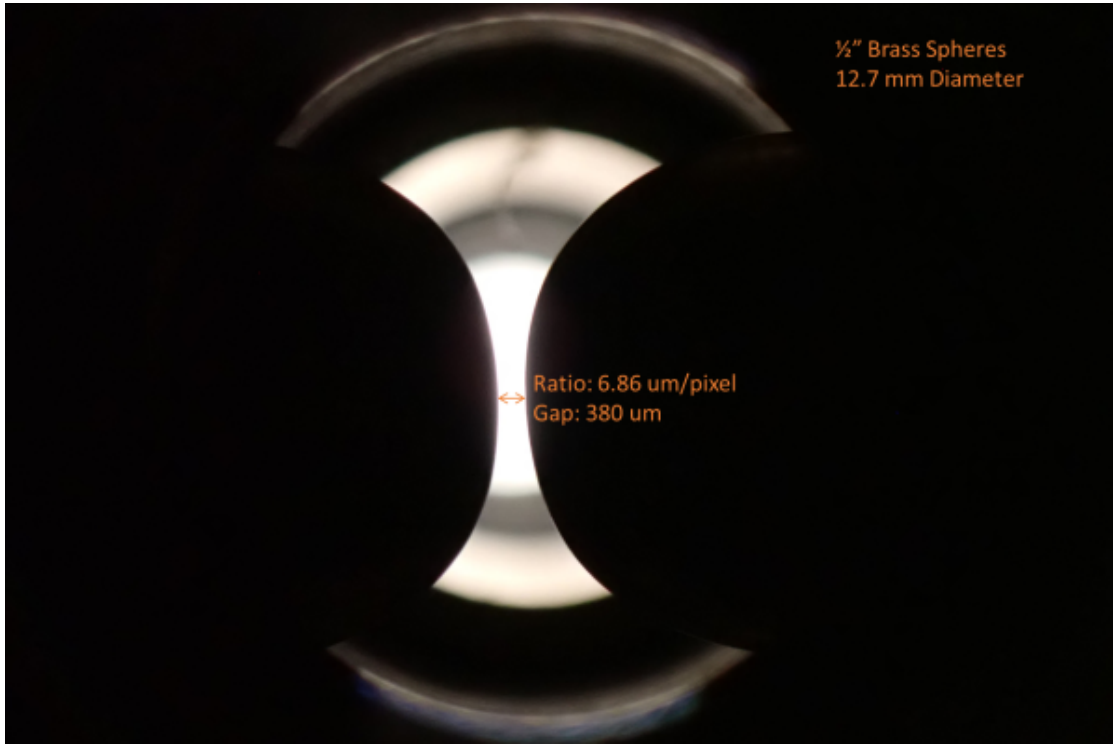
Gas Density & Mean Free Path

- As pressure increases, Gas Density increases and mean free path decreases.
- Strongly influences ionization processes, switch performance, & delay time.
- A greater number of gas molecules increases the number of interactions and collisions to cross the gap.



High-Field Switch – Self-Break

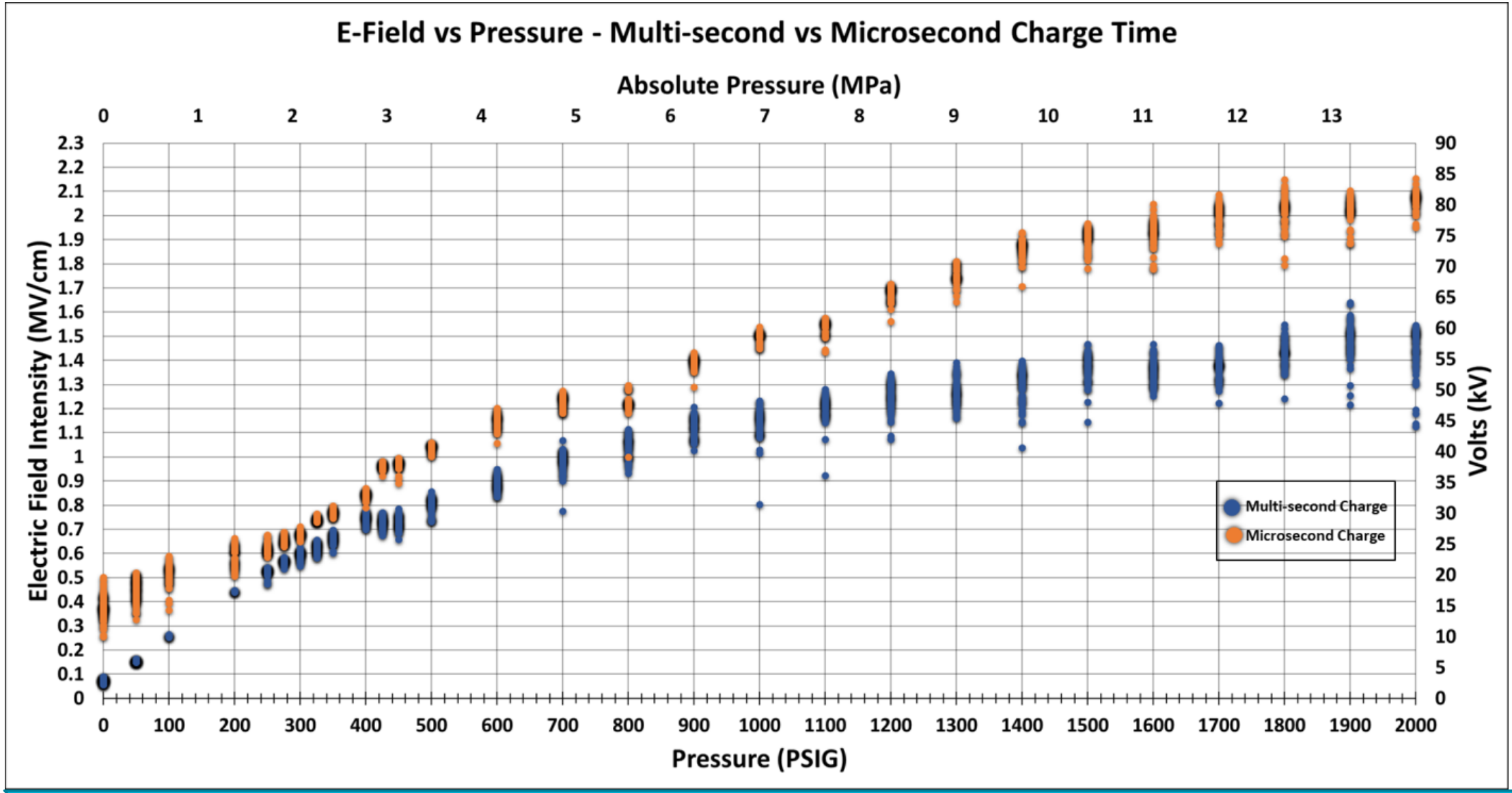




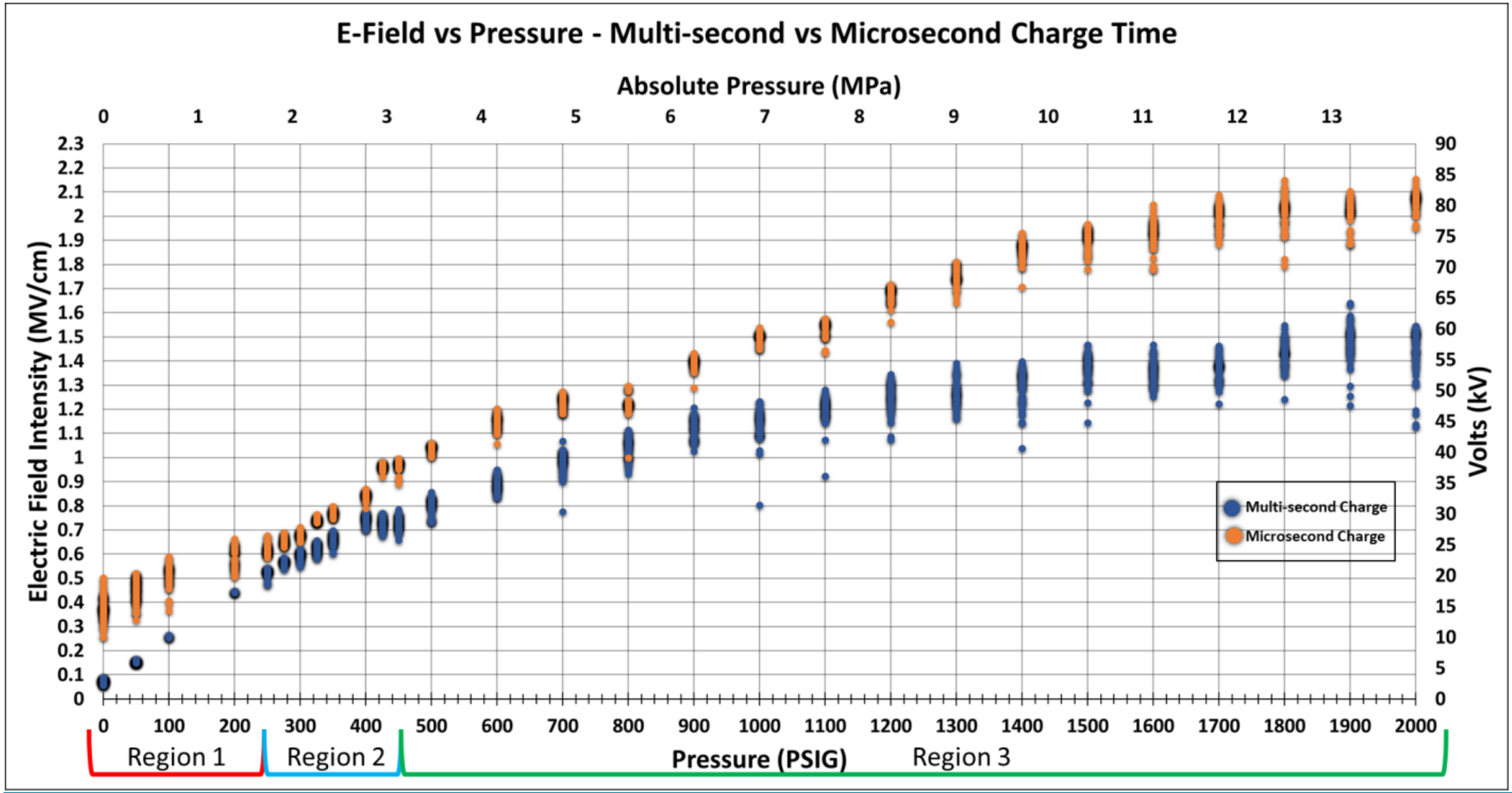
Experimental Variables

- Pressure: full scan of pressure (from atmosphere to 2000 psia)
  - Ultra-Zero Pure Air
  - Gas density, number of gas molecules, formative time effect, delay time effect, and ionization
- Stress Time: range of charge times (multi-seconds to nanoseconds)
  - Effects on switch behavior, E-Field stress, self-break threshold, and delay times
  - Switch closure within 90%-100% of peak pulse charge voltage
- Switch Gap Spacing (monitored)
  - Average 380-micron switch gap
  - Digital camera with μm/pixel precision

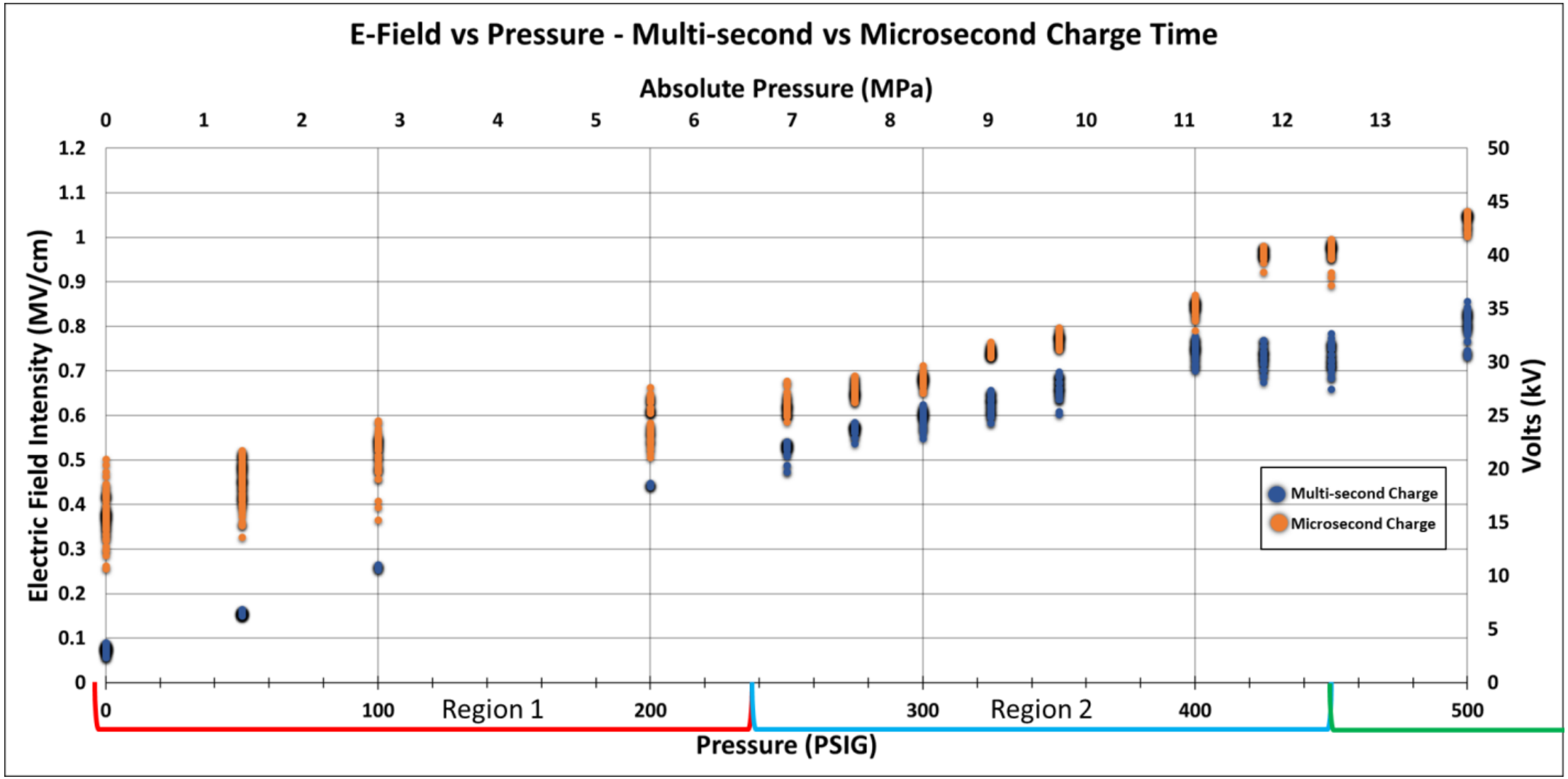
Multi-Second vs Microsecond Charge Time



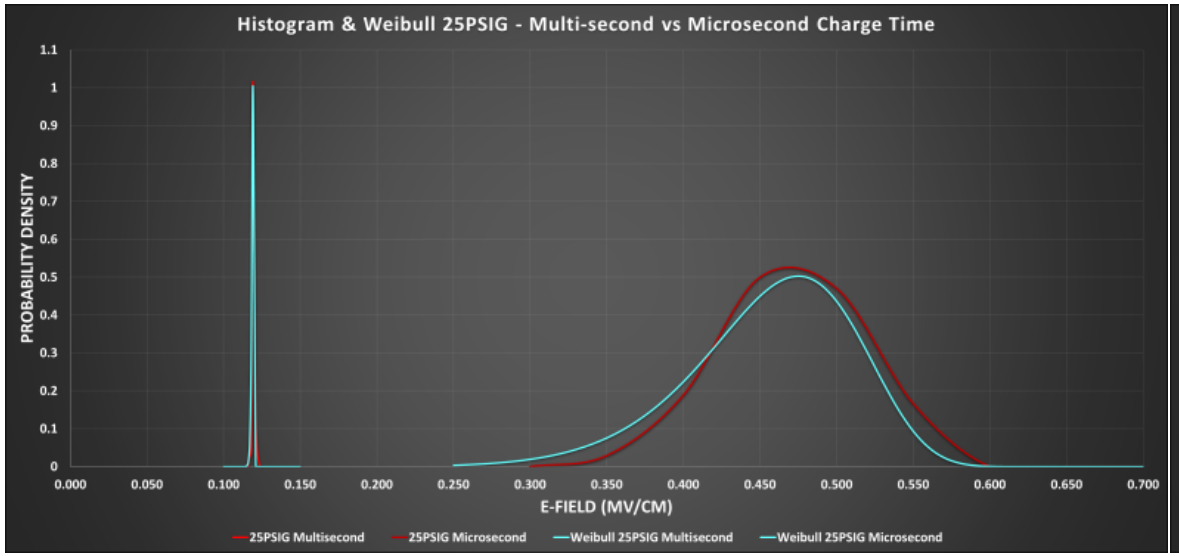
Multi-Second vs Microsecond Charge Time - Region Classification

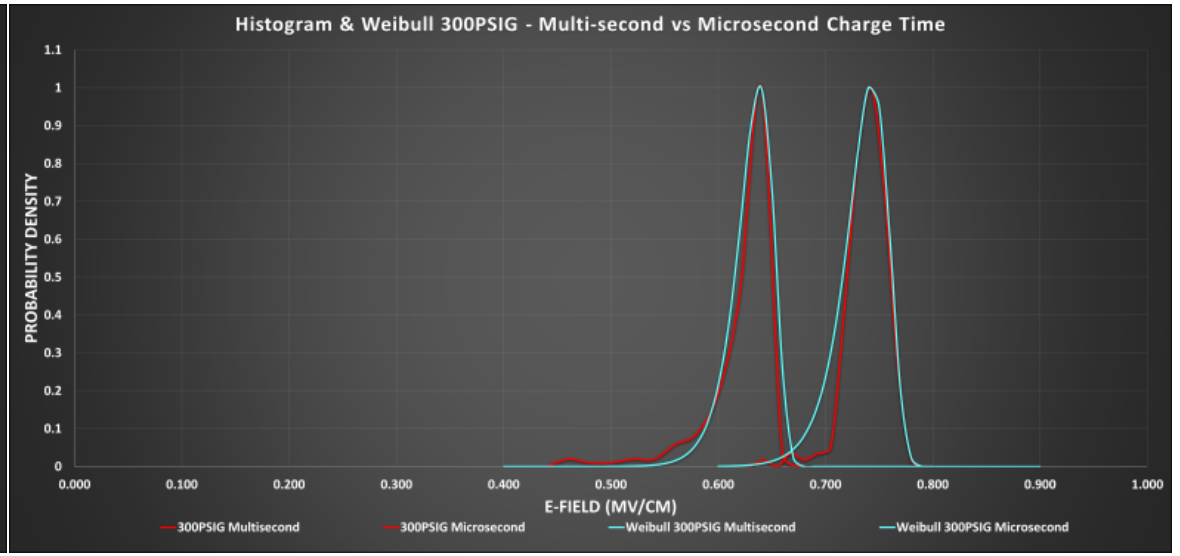


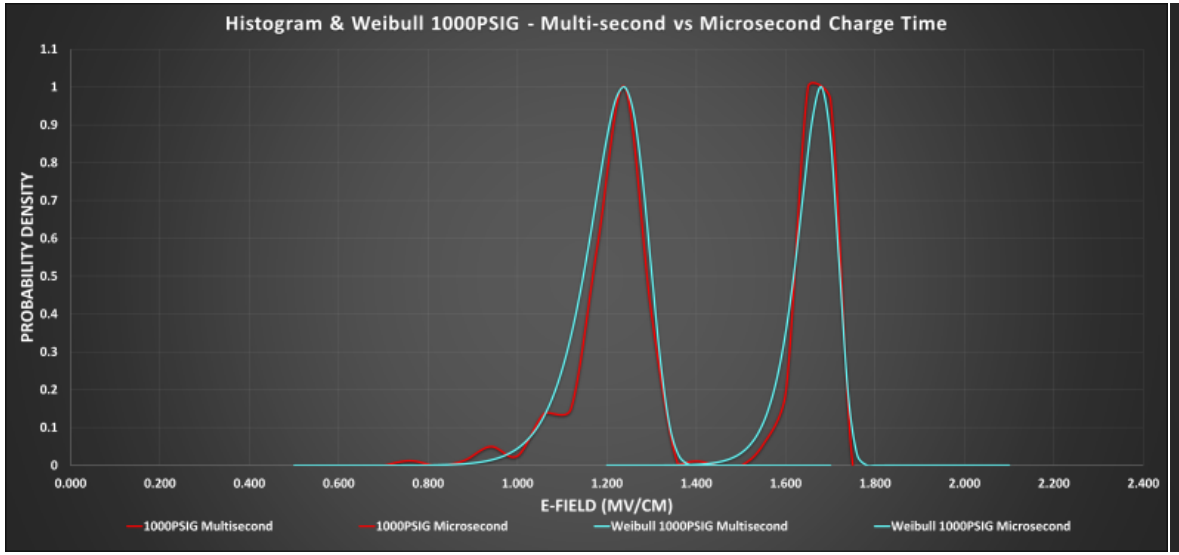
Concentrated in Region I and Region II

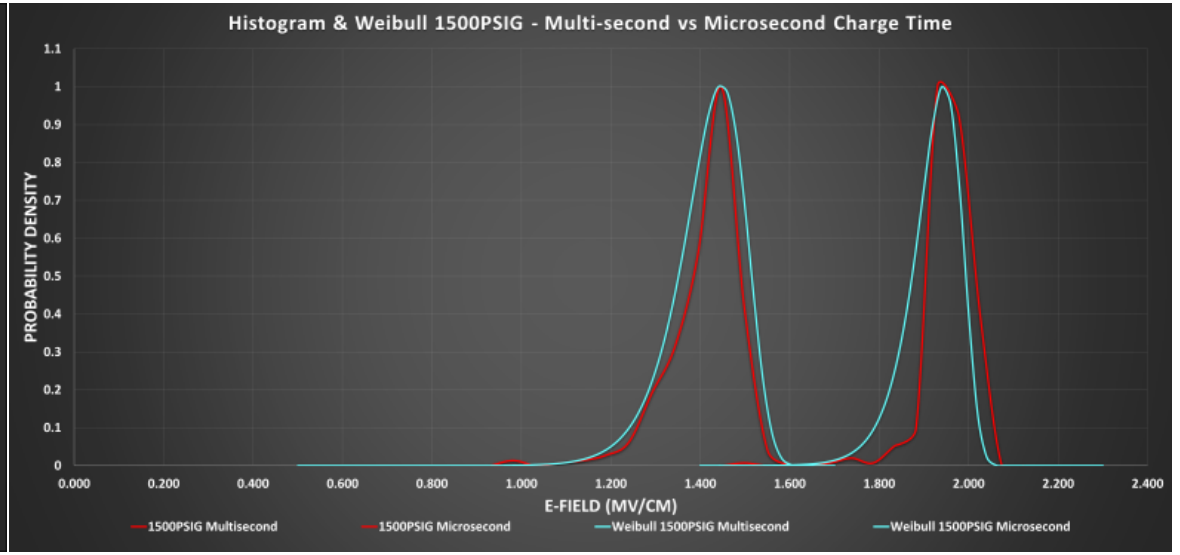


Probability Distribution









Summary

- The average breakdown E-Field increases with increasing gas density (or pressure at a fixed temperature) and reduced stress duration
- % of increase is dependent on the pressure level, voltage stress, and region or operation
- Rate of breakdown E-Field increase mostly linearly with pressure, but significantly diminishes after 1500 psia
- Experiments with a 380-micron gap pressurized at 300 psia provide the optimum operation point
- The proposed method of measuring the breakdown E-Field and probability distribution allows optimal operating switch pressure and applied voltage for any given trigger gap