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ARCS vs. SPARKS

What's The Deal?

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"Arcs" and "Sparks" Are ***NOT*** the Same

Arcs and Sparks share similarities in that both are embodiments of an "arc-discharge" phenomena. This is one reason why so many people use the terms interchangeably. For example, Thomas Edison's patents refer to arc discharges as "sparks," while Nikola Tesla's patents refer to the same phenomena as "arcs." Today's engineers, however, must differentiate between arcs and sparks if they are to properly and effectively mitigate the damage caused by contact current arcing. Fortunately, arcs and sparks may be easily differentiated by a combination of their initiation and power source.

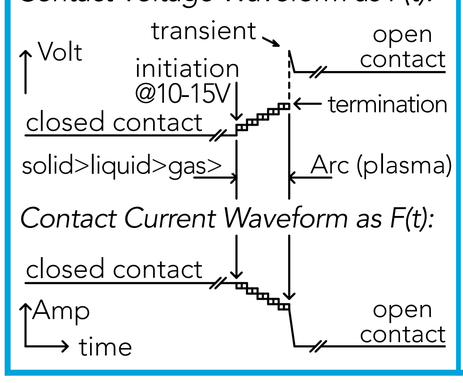
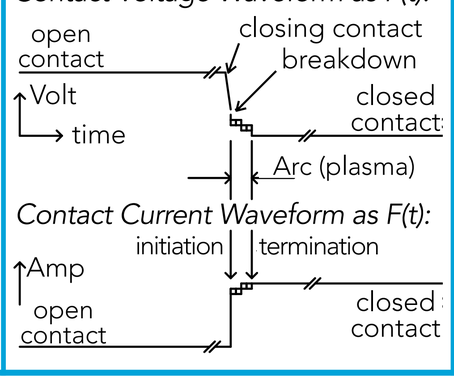
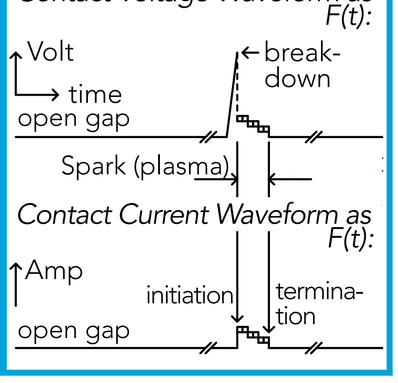
Arcs (Permanent AC or DC Power Source)		**Sparks** (Temporary Power Source)
Thermionic Emission — "T-Arc"	**Field Emission — "F-Arc"**	**Field Emission — Spark**
"Heat Driven" **P = I²R**	**"Field Driven"** **E = V / d**	**"Field Driven"** **E = V / d** *(see Table III)*
Contact Voltage Waveform as F(t): 	*Contact Voltage Waveform as F(t):* 	*Contact Voltage Waveform as F(t):* 

Table I: *Two initiation mechanisms for Arcs; and one initiation mechanism for Sparks.*

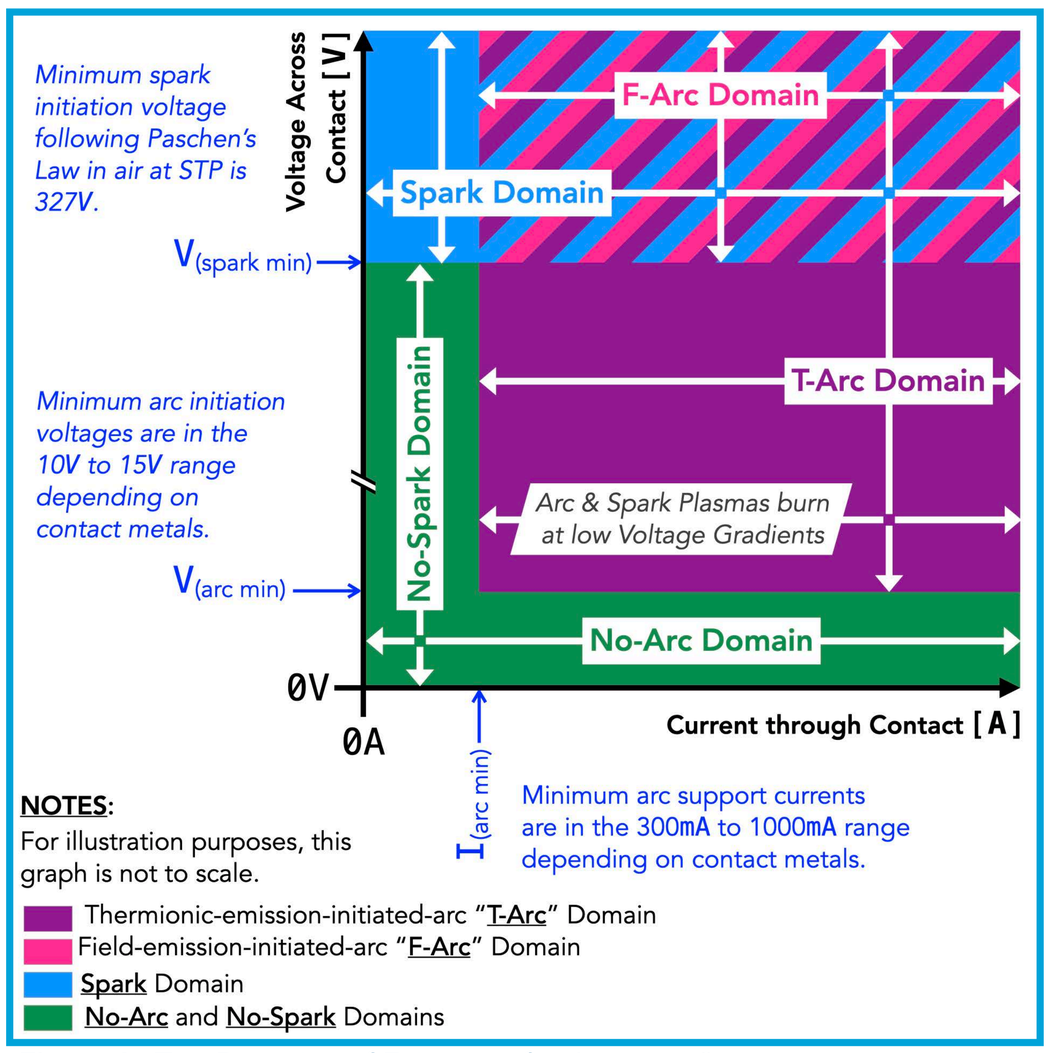


Figure I: *The Domains of Existence for Arcs and Sparks.*

Arc and Spark Initiation and Power Sources

Arcs are either a thermionic-emission-initiated-arc (**T-Arc**) or a field-emissions-initiated-arc (**F-Arc**), and are maintained by a continuous supply of power (think of an arc welder or a Xenon arc lamp). **Sparks**, in contrast, are only initiated by field emissions, and briefly supported by a quickly-depleted power source such as a capacitor, an inductor, or a piezoelectric ignitor (think of lightning, an electrostatic shock "zapping" your finger, or igniting a gas grill).

When initial conditions are favorable, both Arcs and Sparks are initiated before their plasmas ignite. There is a more than 300V difference between the minimum arc initiation voltage, $V_{(arc\ min)}$, and the minimum spark initiation volt-age, $V_{(spark\ min)}$, meaning that arcs and sparks occupy completely different "domains of existence" (fig. I).

An arc's existence consists of the following consecutive elements:

1. **Initiation** — ("birth") either T-Arc or F-Arc
2. **Plasma** — ("life") consisting of the consecutive elements:
   2a. Ignition, 2b. Burn, and 2c. Extinction (starved of current or cooled to extinction)
3. **Dissipation** — ("death") dispersion of ionization, heat, and debris
4. **Possible Re-Initiation** — ("afterlife") either re-initiated arc or re-ignited plasma

Contact Cycle State	Notes	Arc-Discharge Initiation Mechanism
I. OPEN	A fault can occur if the voltage across the opened contact exceeds the contact's dielectric isolation voltage rating.	Breakdown
II. MAKE	The closing contact will experience a normal dielectric breakdown before making contact.	Breakdown Thermionic
III. CLOSED	A fault can occur if the current through the closed contact exceeds the contact's short circuit current rating.	Thermionic
IV. BREAK	The opening contact will experience a normal Joule heating ($I^2 R$ effect) before breaking contact.	Thermionic Breakdown

Table II *(above): List of arcs that may occur in each stage of the contact cycle.*

Here's the Deal … It Matters!

In spite of some similarities, **Arcs and Sparks are quite different** … and it matters because **this is not "common knowledge."** There are **NO SPARKS** in the powered contact cycle of relays and contactors … **ONLY ARCS!** (Table II, Ref. 2). In contrast, sparks are **ONLY initiated by field emissions** (Table III). In other words, because arcs and sparks occupy significantly different domains, they must be mitigated in different ways.

Our insights are derived from more than 10 years of industrial research on contact arcing. Knowing that sparks and arcs are not the same can ultimately help engineers, designers, and technicians **protect contacts** which will **save money** and even **save lives**!

Spark (In a Gap) Powered by	Status of Electric Field in C or Magnetic Field in L	Spark-Discharge Initiation Mechanism
Capacitance	Increasing E-Field in capacitor produces: $V_c = Q / C$	Breakdown occurs if V_c is sufficiently high
Inductance	Collapsing M-Field in inductor produces: $V_i = -L\ di / dt$	Breakdown occurs if V_i is sufficiently high

Table III: *Two examples of spark initiation mechanisms and types.*

References:
1. M. Atalla, Mechanisms of the initiation of the short Arc, 1954
2. R. Holm, Electric Contacts Handbook, Springer Verlag, 1958