



Active Arc Quenching Standards

Improving Critical Electrical System Reliability
and
Eliminating the requirement for arc-rated PPE

Tech4 LLC
Mike Bukovitz, P.E.

20 April 2020

Introduction

- My Background
- The Arc Terminator Project (1997-2000)
- August 2001 & The Funeral
- NFPA 70E in 2004 (2004 Edition)
- Arc flash mitigation between 2001-2010
- NEC beginning in 2014 Edition
- NFPA 70E beginning in 2018 Edition
- Arc Quenching Standards
- IEEE C37.20.7 Compliance
- Arc Quenching Application Examples

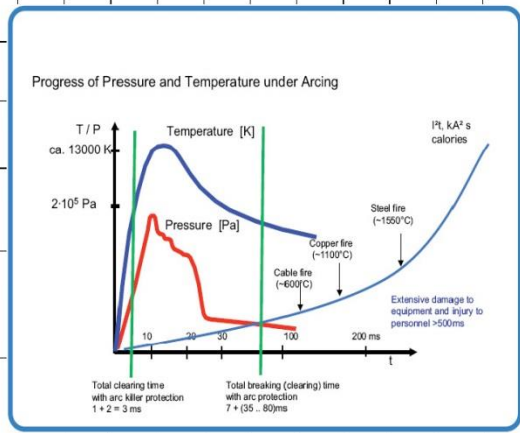
This is not a presentation on why arc flash events are catastrophic



Hotter than the sun! Vaporizing metal.
Deafening 160dB, and Blinding
Explosive pressure 1400kg/m²

The Arc Flash Mitigation Toolbox

Tech4 Engineering: Arc-Flash Detection, Reduction and Protection through Superior Design					
Equipment Type or Procedure	Arc-Flash Detection	Mechanism	Benefit	Approximate Clearing Time	Drawbacks
Forbid Energized Electrical Maintenance	None	De-energized equipment with lockout tagout (LOTO)	- Eliminates all arc-flash hazards with limited investment (education)	N/A	- Many electrical testing, troubleshooting and calibration tasks must be performed on energized assets.
Fuses as protective devices	Electrical current	Relies on current-limiting interruption	- Fastest interruption if $I_a >$ current-limiting threshold. Long history of reliable industry usage	Fast if $I_a >$ current limiting threshold. Slow if $I_a <$ current limiting threshold.	- Large fuses have high CL thresholds $>$ arcing current & may be slow to read. Concerns over fuse replacement & lack of other capabilities offered by circuit breakers
Current-limiting circuit breakers	Electrical current	Relies on current-limiting interruption	- Fast current interruption similar to fuses if $I_a >$ current-limiting threshold, expands standard AIC ratings of breakers to values as high as 200kAIC	Fast if $I_a >$ current limiting threshold. Slow if $I_a <$ current limiting threshold.	- Limited in availability relative to fuses and subject to similar limitations. May require replacement after limited number of operations. Not easily available in a broad range of sizes.
Circuit breaker with arc flash-inflated instantaneous trips	Electrical current which may be combined with light detection	Relies on fast fault interruption	- Provides moderately fast current interruption. Possibility for expanding selective coordination capabilities.	60ms - 70ms	- Not as fast as current-limiting fuses or circuit breakers. Use of the instantaneous arcing current levels may negatively affect selectivity. Requires adjustable-trip circuit breakers
Overcurrent protection relays (instantaneous overcurrent relays, ANSI-50)	Overcurrent 1-2 cycles	Relay based system	- Fast elimination of contributing fault sources. Basic overcurrent protection; instantaneous trip stage of a standard over-current relay cannot be set low enough.	32ms + circuit breaker mechanical latency time	- Slow MV breaker operation speed
Bus differential protection (ANSI-87B)	Current differential 1-2 cycles	Relay based system	- Fast elimination of all contributing fault sources. Very long history of reliable industry usage. Relied upon in many process industries.	32ms + circuit breaker mechanical latency time	- Breaker operation speed. 87B protection usually requires dedicated set of CT's for every breaker and dedicated Bus Diff Relays for each bus segment (including Tie CB if any). Expensive
Zone selective interlocking (ANSI-66)	Current with restraint signal 3-10 cycles	Trip unit or relay based	- Speeds up interruption of ST and/or OP and/or first protective functions. Maintains full-time selective coordination settings. Inexpensive.	166ms	- Breaker operation speed. Requires specific capable trip/relay system and wiring.
Instantaneous zone selective interlocking (i-ZSI) - ANSIS-68	Current restraint within the circuit breaker's instantaneous trip region	Trip unit based, currently only available on GE low-voltage circuit breakers	An improved implementation of ZSI, which frequently improves protective device coordination, useful in critical power applications.	Variable and dependent on the amount of available fault current	Only works with newer General Electric circuit breakers, has all the same implementation requirements as standard short-time ZSI.
Remote operation 1: Remote operating station 2: Remote Electrical (Automation), or Mechanical racking	None	Operator outside arc flash boundary	- No impact on system selectivity. Some remote racking devices can be used on existing equipment.	N/A	- Does not improve downstream or equipment protection. May be costly and difficult to retrofit into existing installations. Does not allow for energized testing, troubleshooting, or calibration at a safe incident energy level.
Traditional arc-resistant switchgear (NEMA 2, 2b, and 2bc switchgear) which meets IEEE C37.20.7. This traditional "venting" technology has been superseded by Arc Quenching solutions.	None	Enclose entire enclosure volume and "vent" (redirect) arc flash to the top of the equipment	- Protects ground-level of the switchgear from arc flash and blast energy. Mechanical/Structural solution.	High (same as standard switchgear). For MV breakers, 83ms plus protective relay response time.	- The most drawbacks of any solution. Enclosure integrity must be maintained (doors closed) for protection to work. Blast energy must be exhausted, resulting in a complex, expensive installation. Does not improve equipment protection nor can it be added to existing equipment. Does not allow for energized testing, troubleshooting, or calibration. Few benefits for an expensive solution.
Arc Flash Relays, used to shut-trip or open an LV or MV Circuit Breaker	Current & Light or Current & Light & Pressure	Protective Relay, used to assert (open) an upstream circuit breaker	Provides superior arc flash mitigation vs. relying solely on circuit breakers or fuses. Typical examples are Arctec AC-110P, SEL 751A, & ABB RB6, and Schneider Electric "VAMP" products.	Relay latency time (between 1ms and 7ms is typical) PLUS circuit breaker latency time, LV breakers are typically 60ms, while MV breakers are fixed at 83ms (5 cycles).	Frequently too slow to get the available arc flash incident energy below 4 calories per cm ² .
MV Arc Quencher System	Protective relay with light and current detection	Ultra-fast protection from arc blast and flash	- Eliminates arc flash and blast energy. Can also be configured to provide equal protection to downstream assets. Comprehensive real-time protection of people and assets.	Less than 7ms (less than 1/2 cycle)	None.
Temporarily reduced overcurrent protection settings ("maintenance switch")	Current measurement (O/C Protection Relay with more than one group) (Change group setting)	Reduces instantaneous trip setting by sacrificing the selective coordination which is mandated by the National Electric Code (NFPA 70)	- Temporarily reduces incident energy under specific conditions. Very inexpensive.	Varies - a power system study is always required.	- Requires specific capable trip systems and does not provide protection if the event does not occur during planned activity. Maintenance switch may accidentally be left in an "on" state.
Arc Quencher, either low-voltage or medium-voltage	Light detection with current; slower pressure detection is optional	Creates an upstream bolted short-circuit on all three phases.	- Provides lowest incident energy even with doors open - Protects personnel and reduces equipment damage - Applicable for both new and retrofit applications - Provides lowest incident energy in downstream assets with sensors and STARC protective relay system.	$>$ Clears MV arc flash events in 6.0ms $>$ Clears LV arc flash events in 5.0ms	- None. Provides the safest practical solution for mitigating arc flash risks in both low-voltage and medium-voltage assets. Assures safety of personnel and continuity of equipment assets.



Arc Quenching is the appropriate arc flash mitigation solution for critical processes

- How would an arc flash effect the process?
- Impact on safety, profitability & corporate image?
- Manufacturing lead-time for replacement equipment?
- Is downtime an option, or is it unacceptable?
- Does ELIMINATION of the NFPA 70E requirement for arc-rated PPE improve safety and maintainability?

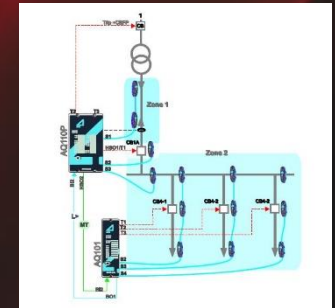
Note: A generator provides emergency power
but

What if downstream electrical assets are damaged?

Arc Quenching Definition

“A fast-acting low-impedance arc flash mitigation system which has a total clearing time from arc flash initiation to complete extinguishing of the arc flash event in less than .006 seconds (6ms).” - Draft Standard EN 50110.

Arc Quenching System



Arc Flash
Protective
Relay



Arc
Quenching
Device

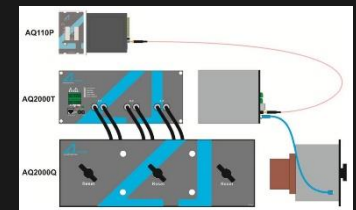


Annunciation
System

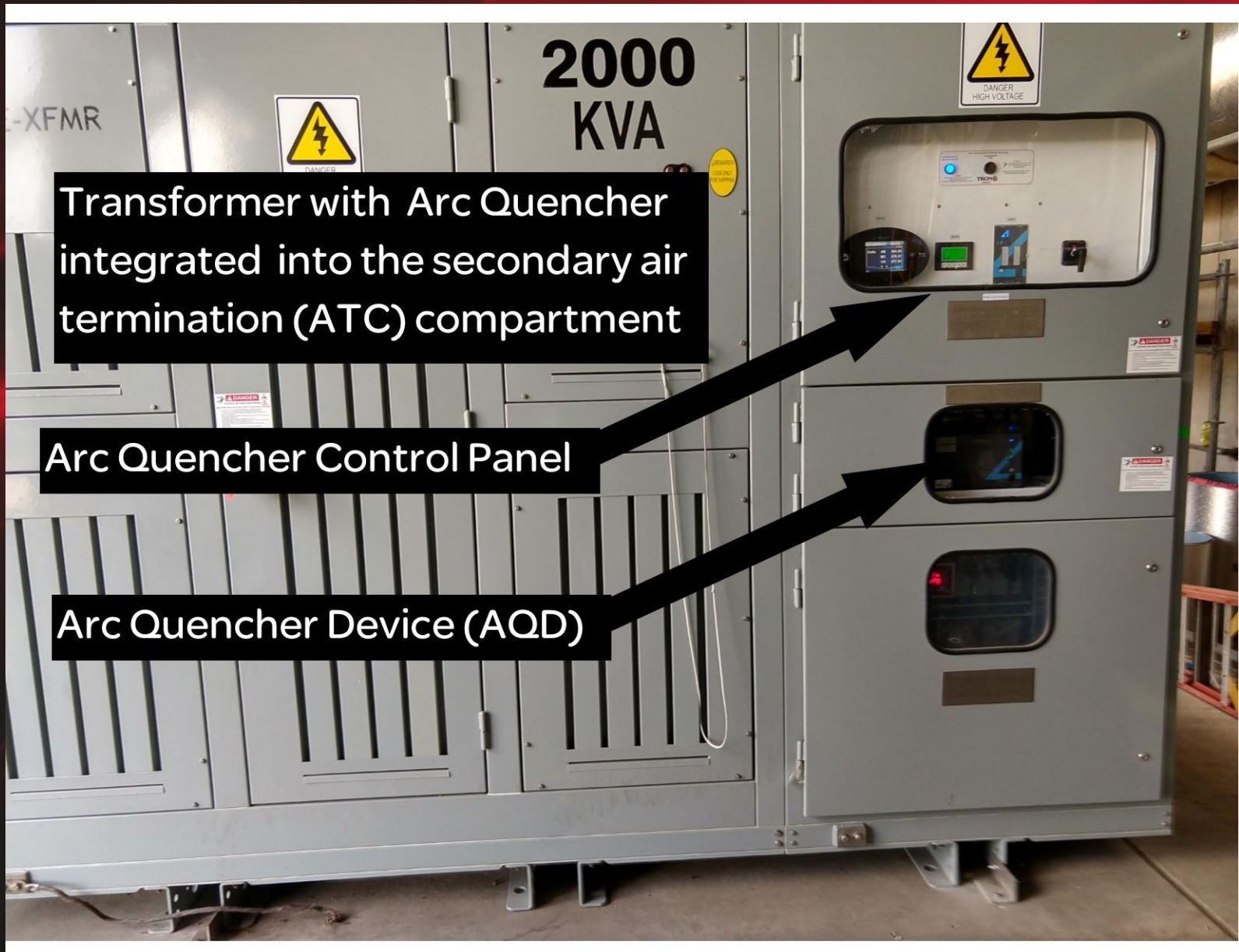


Arc
Quenching
System

Current
Transformers &
Light Sensors



Transformer-Integrated Arc Quencher Example



Arc Quenching Standards

- UL2748 Listed
 - The recognized North American Standard
 - Applicable to both resettable and one-time-use arc quenching devices
- IEC 60947-9-1
 - The global standard
- NFPA 70E Annex 0.2.3(4)
- NEC 240.87
- IEEE C37.20.7

Arc Quenching Standards

UL 2748 - Maximum (peak) fault current and short-time fault-current withstand. The Arcteq AQ-1000 has a peak current rating of 162.5kA and a short-time fault-current withstand of 100kA for 200ms.

IEC 60947-9-1 – The IEC standard defines the maximum voltage drop across the Arc Quenching Device (AQD) as 34 volts peak; this essentially precludes the addition of significant impedance between the AQD and ground.

Arc Quenching Definition – NFPA 70E

NFPA 70E – Annex O.2.3:

(4) Energy-reducing active arc flash mitigation system.

This system can reduce the arcing duration by creating a low impedance current path, located within a controlled compartment, to cause the arcing fault to transfer to the new current path, while the upstream breaker clears the circuit.

The system works without compromising existing selective coordination in the electrical distribution system.

Arc Quenching Suppliers Today

- Arcteq AQ-1000 & AQ-2000 Arc Quenchers – Only UL-listed resettable arc quenchers.
- ABB UFES – Only arc quencher rated for 27kV & 34.5kV applications. Uses ABB REA protective relays.
- GE Arc Vault – One-time-use low-voltage Arc Quencher.
- Eaton Arc Quenching Magnum Switchgear – UL-listed low-voltage drawout switchgear, non-resettable. Uses Arcteq AQ-110P protective relays (EAFR).
- Schneider Electric Arc Terminator - The first arc quencher in the world, now obsolete; 5kV & 15kV Masterclad switchgear only.
- Siemens SIQuench – Resettable MV quencher; IEC-only, resettable five times at maximum fault current. Uses Arcteq AQ-110P protective relays.

Arc Resistant Switchgear

There are two choices for IEEE C37.20.7 compliance



Mechanical Venting
(Arc Redirection)



Arc Quenching
(Arc Elimination)



Typical mechanically-vented IEEE
C37.20.7-compliant switchgear



Typical mechanically-vented arc resistant switchgear exhaust plenums



Typical mechanically-vented arc resistant switchgear exhaust plenums



Typical mechanically-vented arc resistant switchgear exhaust plenum area



Traditional “Arc Resistant” Equipment

- **Popular because of the words “arc resistant”**
 - **Should more properly be called “arc venting” or “arc redirection” equipment**
- **Does not reduce arc flash incident energy vs. standard equipment; therefore, it delivers no additional “exposed energized” protection from arc flash hazards**
- **Traditional Arc Resistant switchgear does not protect downstream assets (such as MCCs, VFDs, and control cabinets) any more than standard equipment. It is old out of date technology!**
- **Expensive to purchase and expensive to install**

A popular *ad hominem* argument:

“I am concerned about Arc Quenching because it creates a high stress low-impedance current path.”



baloney

noun

1. Nonsense; pretentious talk; bold and deceitful absurdities; applesauce, bullshit, hooey: *No matter how you slice it, it's still baloney*
2. A stupid person : *You dumb baloney*

**CITE**

A→あ



verb

: *And don't try to baloney me, either*

[late 1920s+, perhaps fr Irish balonie, "nonsense"; about 1920 the word meant "an unskilled boxer; palooka"]

Why is system stress an ad hominen argument against arc quenching?

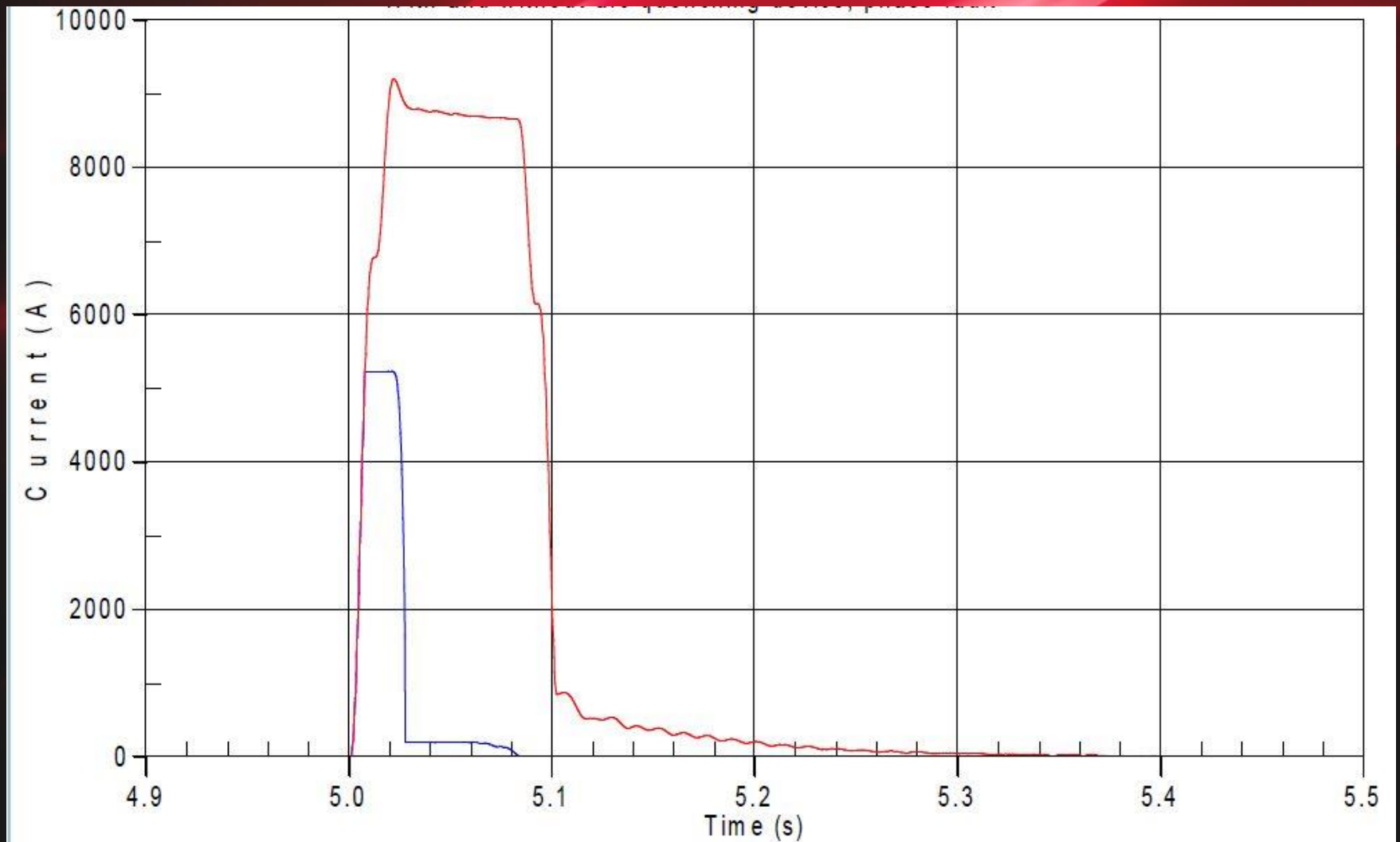
1. Must be “Properly applied and installed” for the maximum available fault current.
2. All upstream and downstream transformers must be protected within their damage curves.

“Trust is good, but verification is better”

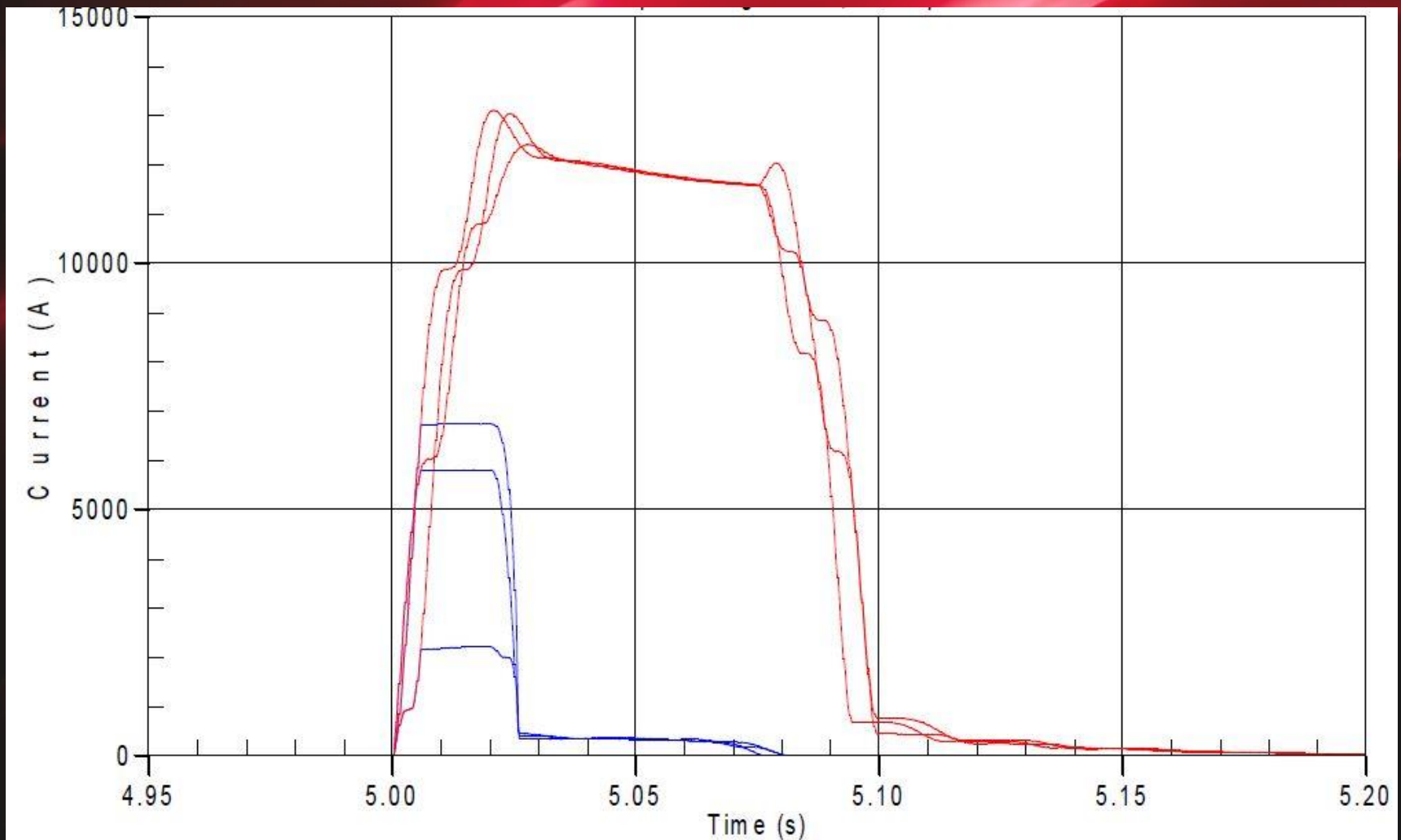
Independent tests run at various LV and MV voltages, comparing arcing faults using both arc quenchers and circuit breakers under identical fault conditions.

In both case studies, there was less stress with the **Arc Quencher™** than with a circuit breaker by itself.

15kV Arc Fault Currents At The Fault Location With & Without an Arc Quenching Device Ground Fault. Single Phase



15kV Arc Fault Currents At The Fault Location With & Without an Arc Quenching Device Three-Phase Fault



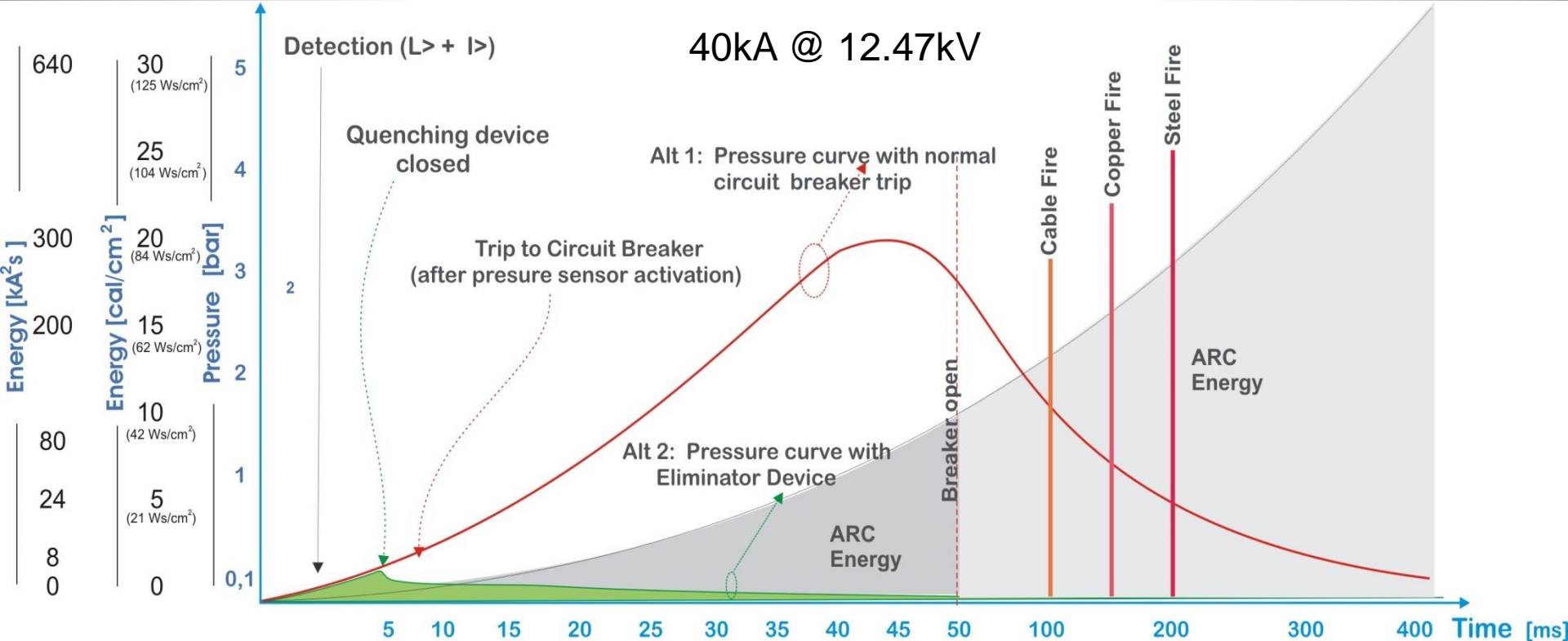
Arc Quenching Decision

Three Practical Application Questions:

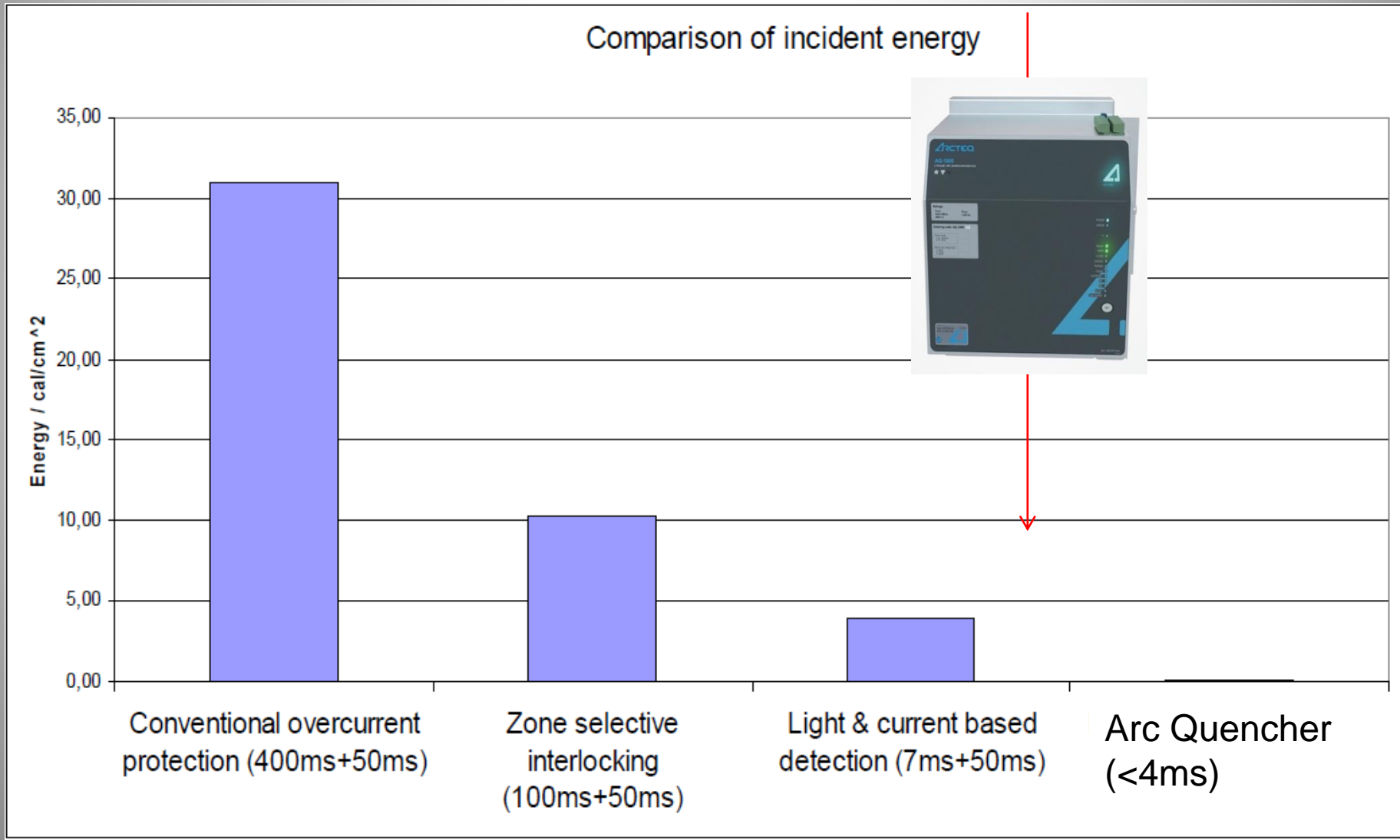
1. How important is uptime and power system continuity?
2. How important is reducing arc flash hazards?
(Lowering the arc flash thermal incident energy to < 1.2 calories per cm² at the Working Distance)
3. Are there benefits associated with eliminating the NFPA 70E requirement for arc-rated PPE clothing?

The Four Primary Arc Quenching Benefits

- Minimize arc flash incident energy
- Maximize personnel / Qualified Person safety
- Minimize downtime and equipment damage
- Eliminate the requirement for arc-rated PPE clothing



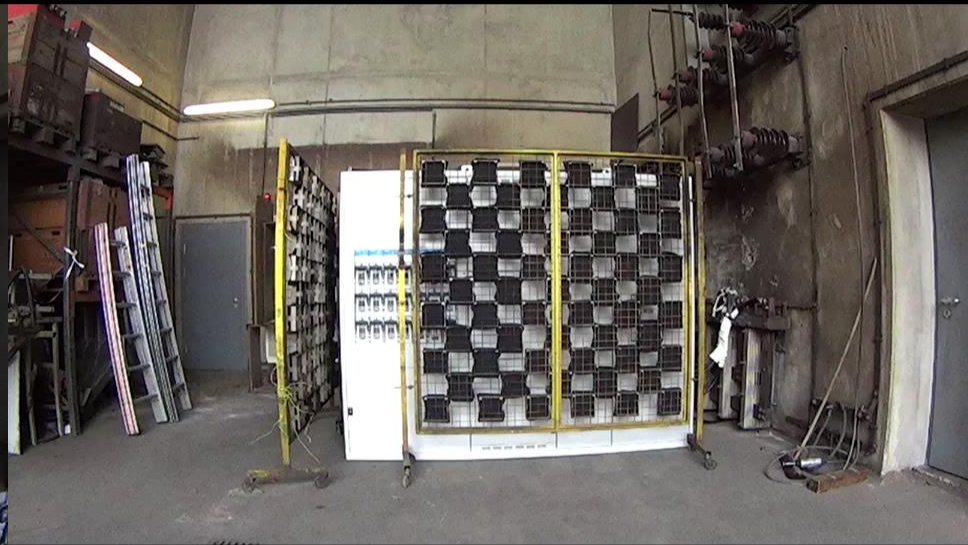
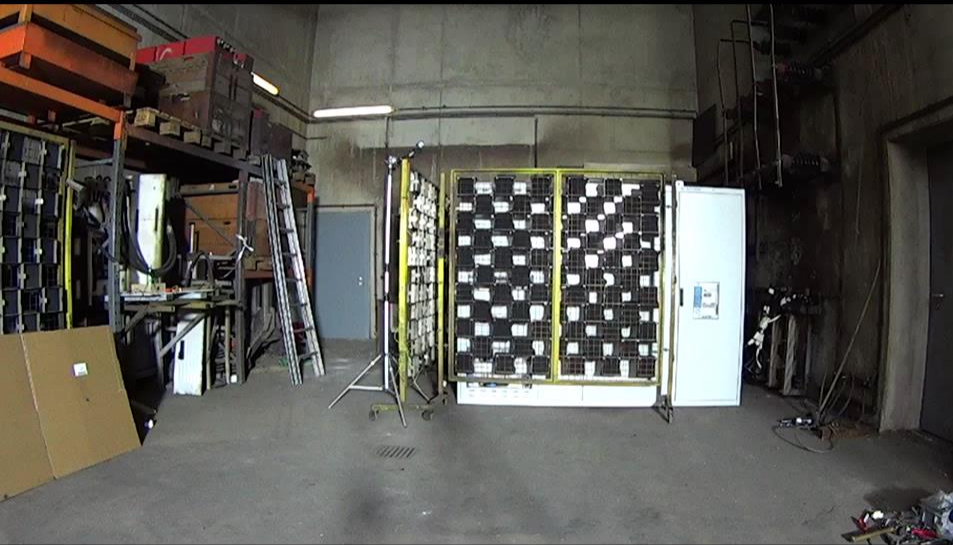
480V Arc Flash Energy Comparison



65 kA / 480V arc test, peak transient 163kA

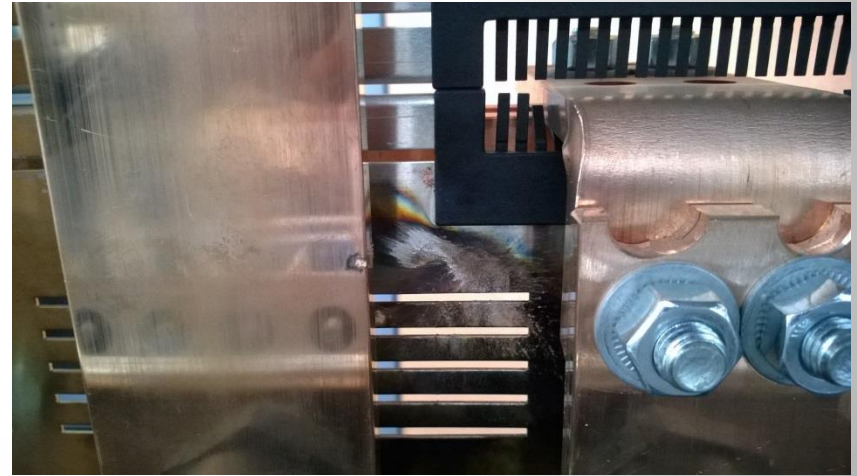
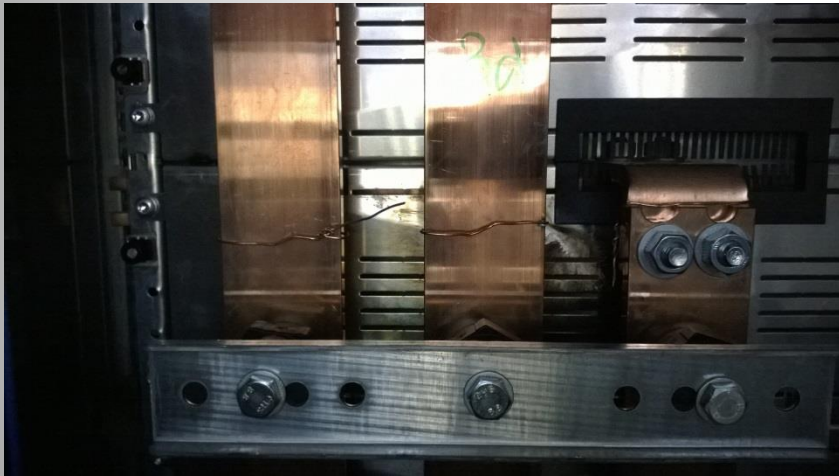
Quenching time 4ms

Tripping time 50ms



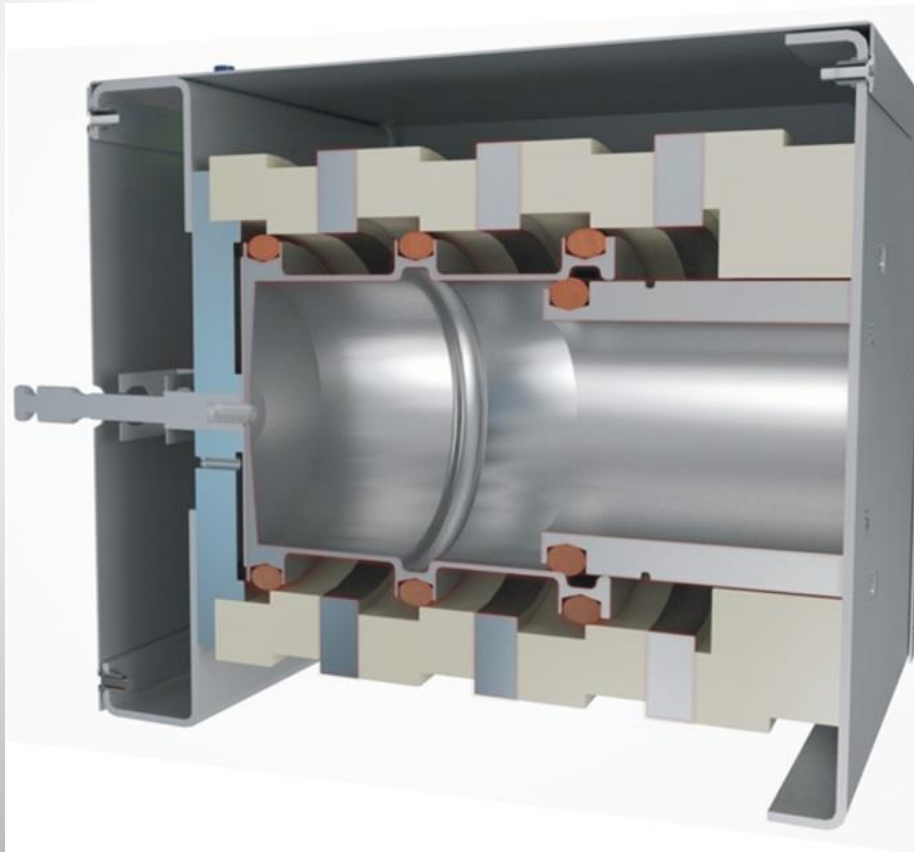
65 kA / 480V arc flash test Low Voltage Square D QED-2 Switchboard (peak transient current 163kA)

Quenching time 4ms



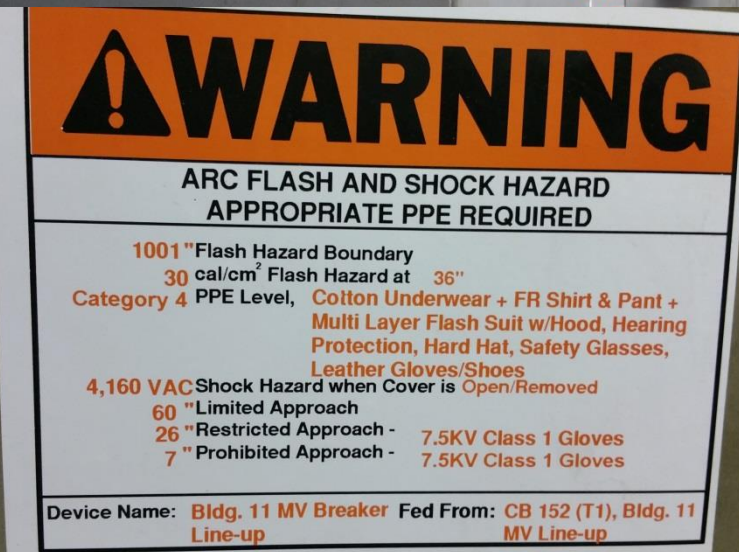
Arc Quencher Device Example

- Thompson coil-based system (a resettable electromagnet)
- Must include full diagnostics and intelligent controls
- UL 2748-listed to withstand 100kA for 500ms



Installation / Application Examples

“Before” @ Kimberly-Clark



! WARNING

**ARC FLASH AND SHOCK HAZARD
APPROPRIATE PPE REQUIRED**

1001" Flash Hazard Boundary
30 cal/cm² Flash Hazard at 36"
Category 4 PPE Level, Cotton Underwear + FR Shirt & Pant +
Multi Layer Flash Suit w/Hood, Hearing
Protection, Hard Hat, Safety Glasses,
Leather Gloves/Shoes

4,160 VAC Shock Hazard when Cover is Open/Removed
60" Limited Approach
26" Restricted Approach - 7.5KV Class 1 Gloves
7" Prohibited Approach - 7.5KV Class 1 Gloves

Device Name: **Bldg. 11 MV Breaker** Fed From: **CB 152 (T1), Bldg. 11
Line-up MV Line-up**



“After” @ Kimberly-Clark: 0.4 Calories per cm²



Green Bay Waste Water Treatment Plant (NEW Water) – Arc Quencher™ Front Panel



Land O'Lakes Fertilizer Plant Caledonia, New York



Arc Quencher™ System Testing & Validation



- Just like a circuit breaker, the Arc Quencher™ system is an electromechanical life-safety device. As such, it must be periodically tested to assure a compliant clearing-time.
- Factory testing
- Jobsite testing
- Recommended testing frequency





- With “representative testing”, complies with all ANSI/IEEE C37.20.7-2007 arc resistant equipment requirements
- An Arc Quencher solution does not “redirect” or “vent” the electrical arc: it *eliminates* the arc.
- The Arc Quencher solution is superior to traditional “arc resistant” switchgear in all respects:
 - Only Arc Quenchers protects both people *and* the physical equipment assets from the damaging effects of arc flash events, *even when exposed-energized*
 - Only Arc Quencher systems may be configured and expanded to protect downstream assets
 - Only the Arc Quencher eliminates the NFPA 70E requirement for AR-rated PPE

Arc Quenching System Design Considerations

1. Does it need to be resettable?
2. Does it need to protect the primary switchgear equipment?
3. Does it need to protect downstream assets?
4. Are there safety and maintainability benefits associated with eliminating the NFPA 70E requirement for arc-rated PPE?
5. New application or retrofit application?



Mike Bukovitz

Tech4 LLC

3547 French Road

De Pere, WI 54115

Office Phone: 920-532-0480

Mobile Phone: 920-540-2274

Email: mikeb@tech4.com

www.tech4.com

➤ Thank you for your time!