GARD

Unparalleled Protection

Effective Workplace Electrical Safety

Arc Flash Hazard Control

www.i-gard.com

Hazard Control

Electrical injuries represent a serious workplace health and safety issue.

Regardless of the specifics of the Hazard there are always the same two concerns:

Concern #1 How likely is it to happen? → **RISK**

Concern #2 How bad will it be? → **IMPACT**

Hazard Control

Regardless of the specifics of the Hazard there are always the same two concerns:

Concern #1 How likely is it to happen? **What is the RISK?**

US Bureau of Labor Statistics indicate that there were nearly 6,000 fatal electrical injuries to workers in the US between 1992 and 2013.

BLS data also indicates there were 24,100 non-fatal electrical injuries from 2003 – 2012.

National Safety Council reported in its 2014 edition of Injury Facts that there were 961 fatal injuries from 2008 through 2010 due to exposure to electric current.

A study of electrical injuries over a 20 year period at a Texas burn center found that 40% of burns were electrical arc injuries.

Source : Occupational Injuries from Electric Shock and Arc Flash Events, The Fire Protection Research Foundation March 2015.

Hazard Control

Regardless of the specifics of the Hazard there are always the same two concerns:

Concern #2 How bad will it be? **What will be the IMPACT?**

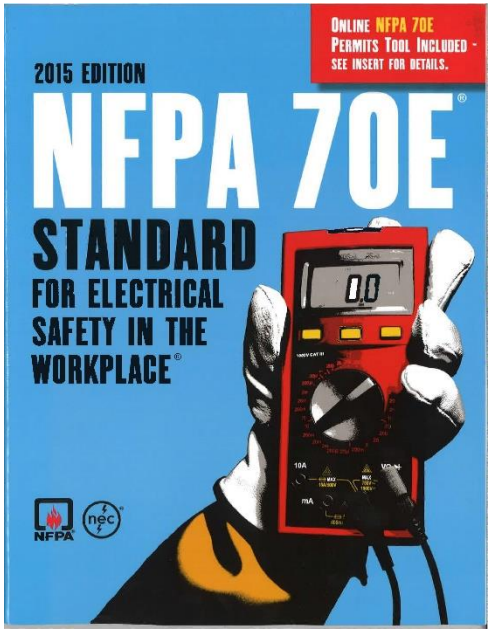
Washington State Department of Labor and Industries “Burn Injuries Facts” reported that worker’s compensation costs for 30 serious arc flash or blast burn injuries that took place between September 2000 and December 2005 were in excess of $1.3 million.

OSHA in 2014 estimates a value of $62,500 per non-fatal injury for workers performing electric distribution work (direct costs only).

American Society of Safety Engineers estimates that indirect costs may be as much as 20 times higher than direct costs.

Source : Occupational Injuries from Electric Shock and Arc Flash Events, The Fire Protection Research Foundation March 2015.

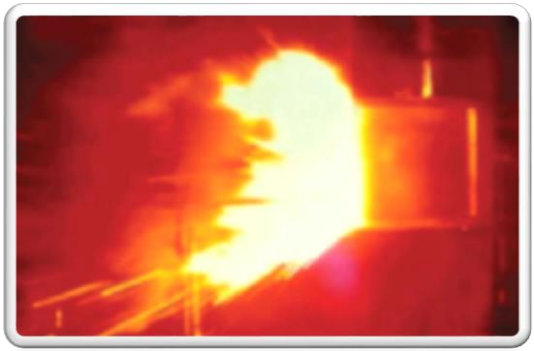
What is an Arc Flash?



According to NFPA 70E:

A dangerous condition associated with the release of energy caused by an electric arc.

A hazard beyond shock and electrocution.



What is an Arc Flash?

Electric arcing, commonly referred to as an arc flash, occurs when current passes through the air between two or more conducting surfaces or from conductors to ground.

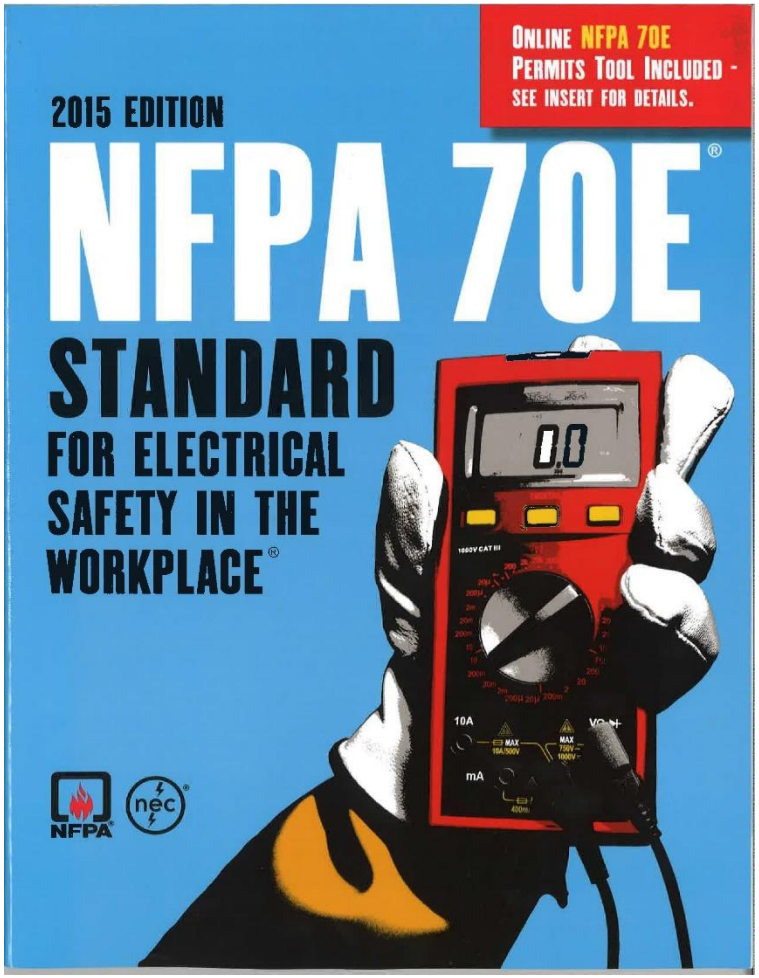
(Workplace Safety Awareness Council) Electric arcing may produce temperatures as high as 35,000 degrees and may cause severe burns, hearing loss, eye injuries, skin damage from molten metal, lung damage and blast injuries.

Source : Occupational Injuries from Electric Shock and Arc Flash Events, The Fire Protection Research Foundation March 2015

Arc Flash

What does it do?

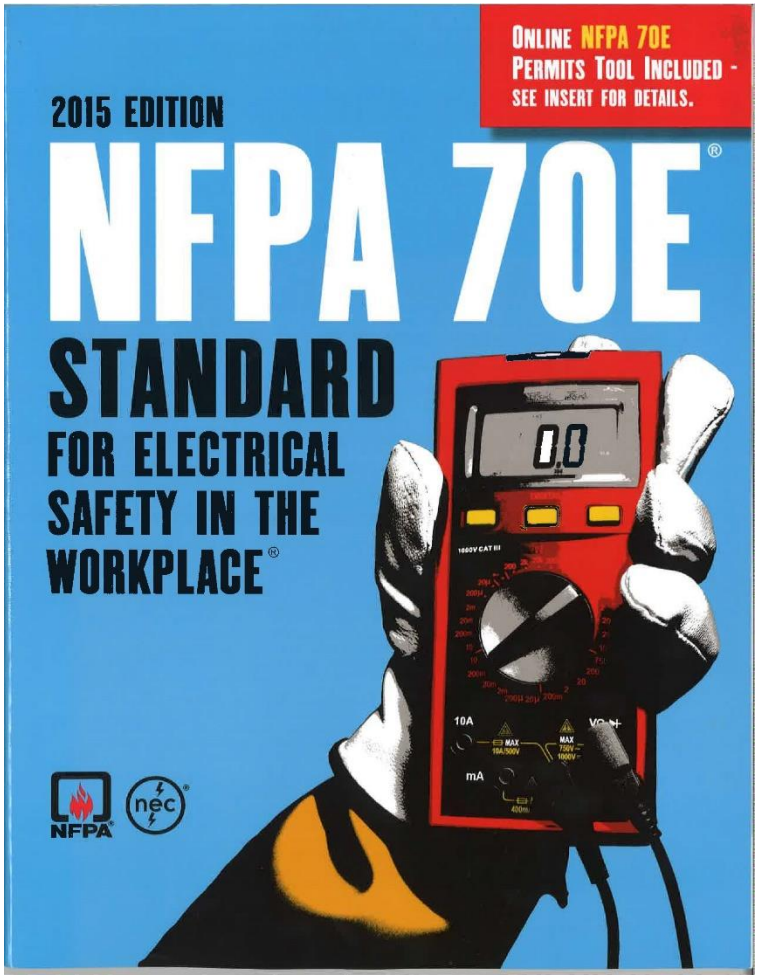
- It hurts people !
- It destroys equipment !
- It Results in Penalties from OSHA
- It Causes outages !
- It Affects morale !



NFPA 70E Annex 0

General Design Requirements 0.2.1

Employers, facility owners, and managers who have responsibility for facilities and installations having electrical energy as a potential hazard to employees and other personnel should ensure that electrical hazards risk assessments are performed during the design of electrical systems and installations”



NFPA 70E Annex 0

General Design Requirements 0.2.2

Design option decision should facilitate the ability to eliminate hazards or reduce risk by doing the following:

1. Reducing the likelihood of exposure

2. Reducing the magnitude or severity of exposure

Informative Annex O Safety-Related Design Requirements

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O.1 Introduction. This informative annex addresses the responsibilities of the facility owner or manager or the employer having responsibility for facility ownership or operations management to perform a risk assessment during the design of electrical systems and installations.

O.1.1 This informative annex covers employee safety-related design concepts for electrical equipment and installations in workplaces covered by the scope of this standard. This informative annex discusses design considerations that have impact on the application of the safety-related work practices only.

O.1.2 This informative annex does not discuss specific design requirements. The facility owner or manager or the employer should choose design options that eliminate hazards or reduce risk and enhance the effectiveness of safety-related work practices.

O.2 General Design Considerations.

O.2.1 Employers, facility owners, and managers who have responsibility for facilities and installations having electrical energy as a potential hazard to employees and other personnel should ensure that electrical hazards risk assessments are performed during the design of electrical systems and installations.

O.2.2 Design option decisions should facilitate the ability to eliminate hazards or reduce risk by doing the following:

(1) Reducing the likelihood of exposure

(2) Reducing the magnitude or severity of exposure

(3) Enabling achievement of an electrically safe work condition

O.2.3 Incident Energy Reduction Methods. The following methods have proved to be effective in reducing incident energy:

(1) Zone-selective interlocking. A method that allows two or more circuit breakers to communicate with each other so that a short circuit or ground fault will be cleared by the breaker closest to the fault with no intentional delay. Clearing the fault in the shortest time aids in reducing the incident energy.

(2) Differential relaying. The concept of this protection method is that current flowing into protected equipment must equal the current out of the equipment. If these two currents are not equal, a fault must exist within the equipment, and the relaying can be set to operate for a fast interruption. Differential relaying uses current transformers located on the line and load sides of the protected equipment and fast acting relay.

(3) Energy-reducing maintenance switching with a local status indicator. An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to operate faster while the worker is working within an arc flash boundary, as defined in NFPA 70E, and then to set the circuit breaker back to a normal setting after the work is complete.

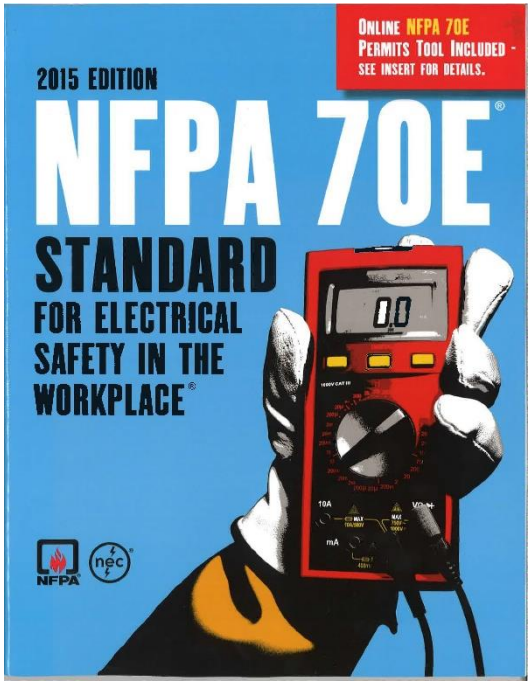
O.2.4 Other Methods.

(1) 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.

(2) Arc flash relay. An arc flash relay typically uses light sensors to detect the light produced by an arc flash event. Once a certain level of light is detected the relay will issue a trip signal to an upstream overcurrent device.

(3) High-resistance grounding. A great majority of electrical faults are of the phase-to-ground type. High-resistance grounding will insert an impedance in the ground return path and will typically limit the fault current to 10 amperes and below (at 5 kV nominal or below), leaving insufficient fault energy and thereby helping reduce the arc flash hazard level. High-resistance grounding will not affect arc flash energy for line-to-line or line-to-line-to-line arcs.

(4) Current-limiting devices. Current-limiting protective devices reduce incident energy by clearing the fault faster and by reducing the current seen at the arc source. The energy reduction becomes effective for current above the current-limiting threshold of the current-limiting fuse or current limiting circuit breaker.



ANSI Z10 Hierarchy

Hierarchy of Hazard Control Measures
From ANSI Z10

Control Effectiveness

Elimination
Eliminate the hazard during design

Substitution
Substitution of less hazardous equipment, system or energy

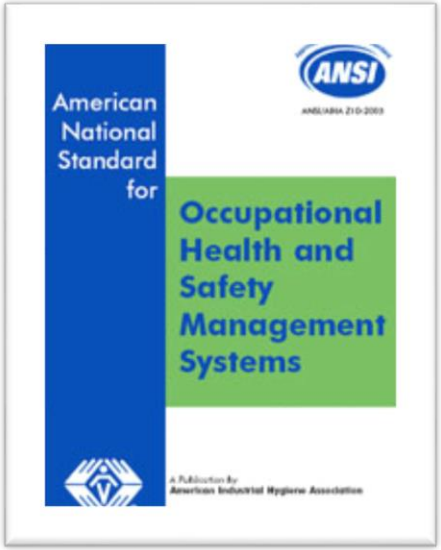
Engineering Controls
Design options that automatically reduces risk

Warnings
Automatic or manual, permanent or temporary, visible or audible warning systems, signs, barriers and labels

Administrative Controls
Planning processes, training, permits, safe work practices, maintenance systems, communications, and work management

Personal Protective Equipment
Available, effective, easy to use

Life Cycle Value



Hierarchy of Hazard Control Measures from ANSI Z10

Control effectiveness

ELIMINATION	SUBSTITUTION	ENGINEERING CONTROLS	WARNINGS	ADMINISTRATIVE CONTROLS	PERSONAL PROTECTIVE EQUIPMENT
Eliminate the hazard during the design phase	Substitute for a lower energy level. Reduce the magnitude of the hazard.	Design options that automatically reduce risk. Increase distance away from hazard.	Automatic or manual, permanent or temporary, visible or audible warning systems, signs, barriers and labels.	Planning processes, training permits, safe work practices, maintenance systems, communications and work management	Available, effective, easy to use.

Life Cycle Value

Conventional Approach

Hierarchy of Hazard Control Measures from ANSI Z10

Control effectiveness

ELIMINATION	SUBSTITUTION	ENGINEERING CONTROLS	WARNINGS	ADMINISTRATIVE CONTROLS	PERSONAL PROTECTIVE EQUIPMENT
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Life Cycle Value

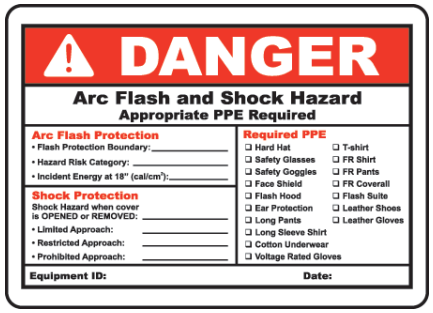
Conventional Approach to Arc Flash Safety

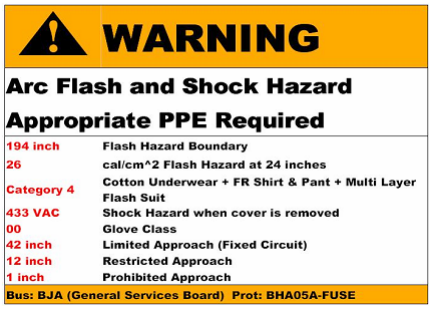
Undertake an arc flash study

Determine magnitude of arc flash hazard

Purchase appropriate levels of PPE

Apply and post warning labels specifying risk.





NFPA® has identified four FR hazardous risk category levels, which are numbered by severity from 1 to 4. Hazard Risk Category is the level of arc flash protection clothing you must wear to protect against a minimum level of incident energy.

HAZARD / RISK CATEGORY	CLOTHING DESCRIPTION (Typical number of clothing layers is given)	REQUIRED MINIMUM Arc Rating of PPE cal/cm²
1 HRC	Arc-rated FR shirt and FR pants or FR coverall **(1 layer)**	4
2 HRC	Arc-rated FR shirt and FR pants or FR coverall **(1 or 2 layers)**	8
3 HRC	Arc-rated FR shirt and FR pants or FR coverall, and arc flash suit selected so that the system arc rating meets the required minimum **(2 or 3 layers)**	25
4 HRC	Arc-rated FR shirt and FR pants or FR coverall, and arc flash suit selected so that the system arc rating meets the required minimum **(3 or more layers)**	40

ARC Rating - A value of the energy necessary to pass through any given fabric to cause with 50% probability a second or third degree burn. **This would not make me feel safe !**

Conventional Approach

Hierarchy of Hazard Control Measures from ANSI Z10

Control effectiveness

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Life Cycle Value

Doesn't reduce risk or lessen the hazard level.

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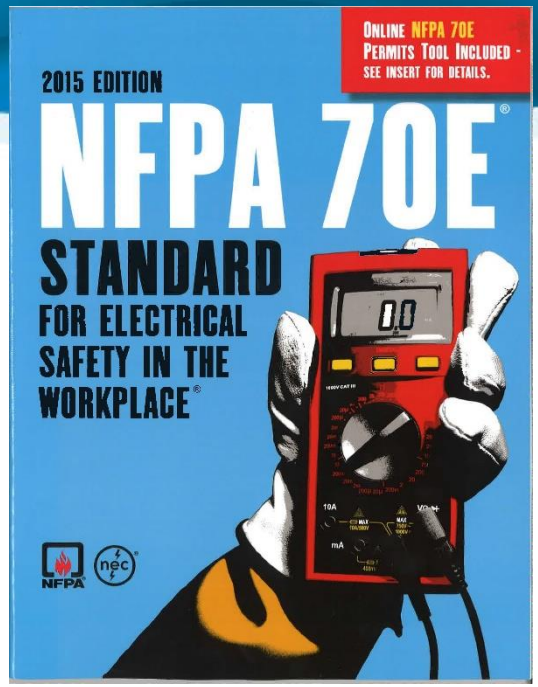

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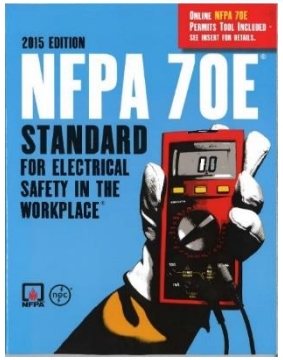


(3) High-resistance grounding.

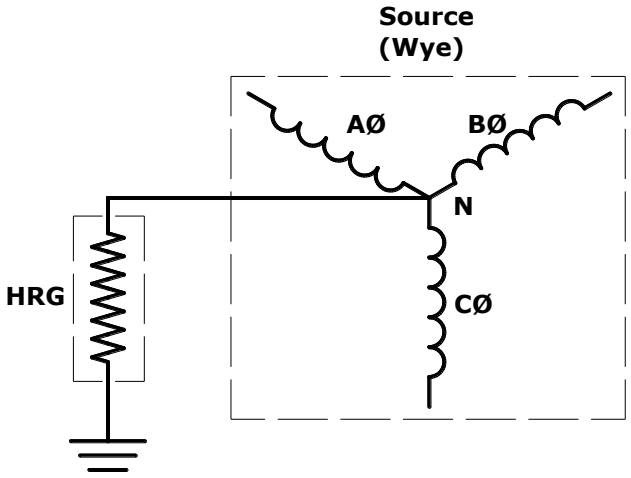
A great majority of electrical faults are of the phase-to-ground type. High-resistance grounding will insert an impedance in the ground return path and below (at 5 kV nominal or below), leaving **insufficient** fault energy and thereby helping reduce the arc flash hazard level.

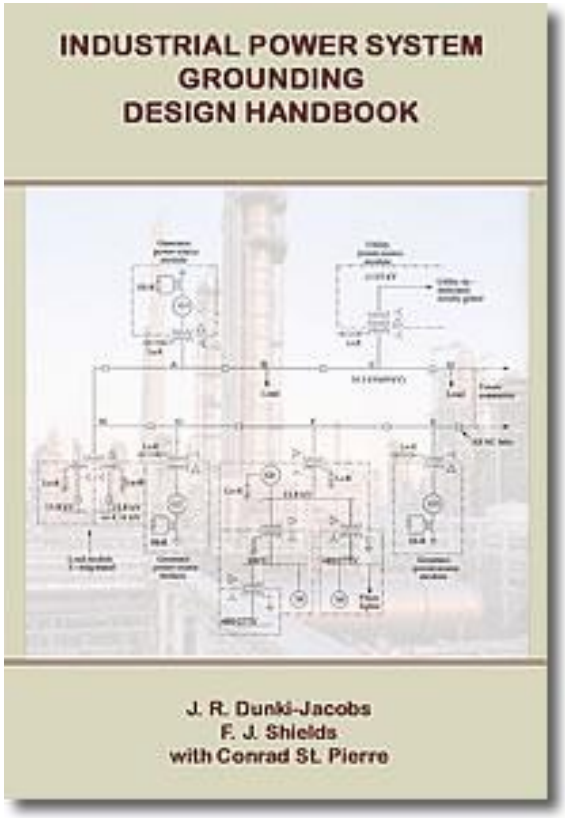
Reducing the Likelihood of Exposure
High Resistance Grounding

How Does HRG reduce Arc Flash?

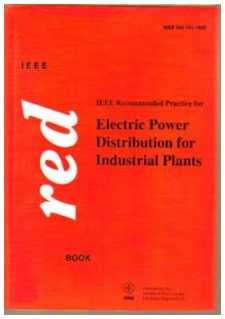
According to Industrial Power System Grounding Design Handbook - 95% of all electrical faults are phase to ground faults.

By limiting the fault current to a low level, 10 amps or less, there is **insufficient** current for the arc to re-strike and it self-extinguishes.



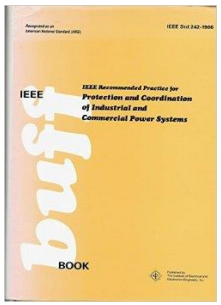


Reducing the Likelihood of Exposure
High Resistance Grounding



IEEE Std 141-1993 (Red Book)

7.2.2. High-resistance grounding provides the same advantages as ungrounded systems yet limits the steady state and severe transient over-voltages associated with ungrounded systems.



IEEE Std 242-1986 Recommended Practice for the Protection and Coordination of Industrial and Commercial Power Systems

7.2.5. Ungrounded systems offer no advantage over high-resistance grounded systems in terms of continuity of service and have the disadvantages of transient over-voltages, locating the first fault and burn-downs from a second ground fault. For these reasons, they are being used less frequently today than high-resistance grounded systems”

Reducing the Likelihood of Exposure
High Resistance Grounding

FM Global 5-18 Protection of Electrical Equipment Single Phase and Other Related Faults

- In ungrounded systems a phase to ground fault often produces dangerous overvoltage…
- Sustained arcing faults in low voltage apparatus are often initiated by a single-phase fault to ground which results in extensive damage to switchgear and motor control centers.

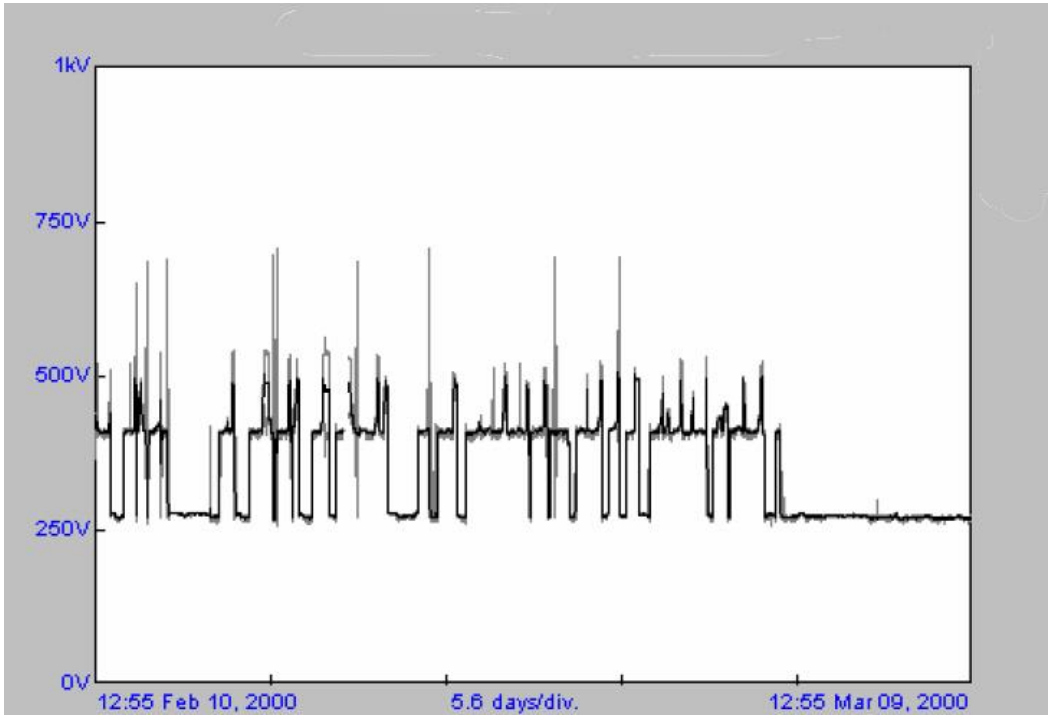
FM Global 5-10 Protective Grounding for Electric Power Systems and Equipment

- 2.3.3.1 Unlike the ungrounded system the high resistance grounded system prevents transient overvoltage which can cause potential failure of insulation.
- 2.3.4.1 Convert ungrounded systems to high resistance grounded systems.

Case Study

Automotive Facility **Troy Michigan**

- Phase to Ground voltage monitored for 4 weeks ungrounded and 4 weeks high resistance grounded.
- 485 events with peak voltage above 700 volts due to intermittent ground faults.
- Peak voltage 1050 volts
- Transients lead to insulation degradation.



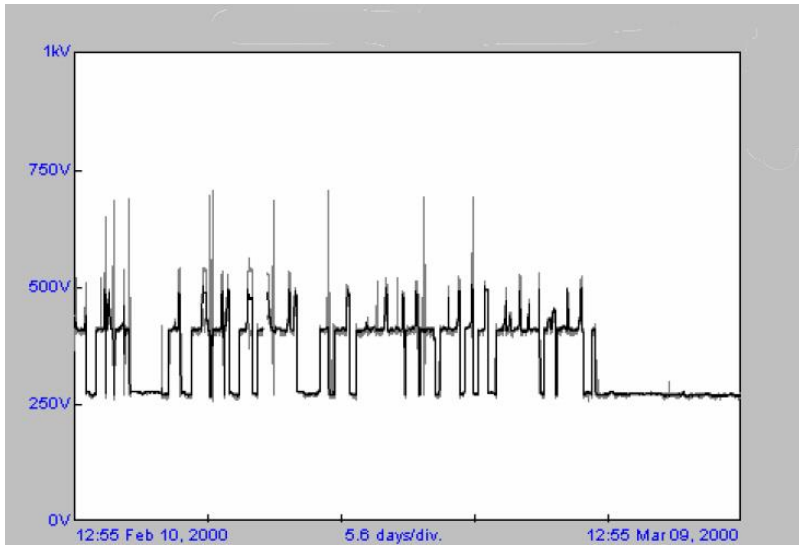
Impact of Transient Over-voltages

Insulation failure resulting in phase to phase fault and equipment damage in excess of $200k.

Case Study

Automotive Facility

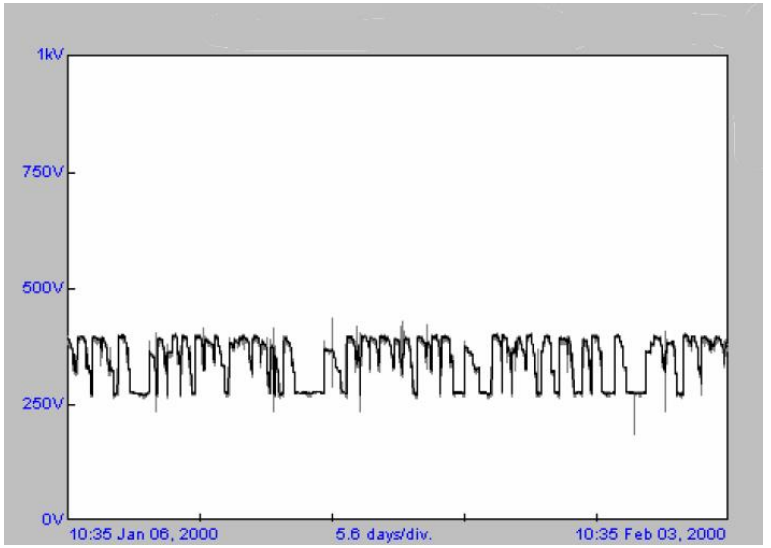
Phase voltage ungrounded



High level of transients
485 peak events over 700 volts
Peak voltage 1050 volts

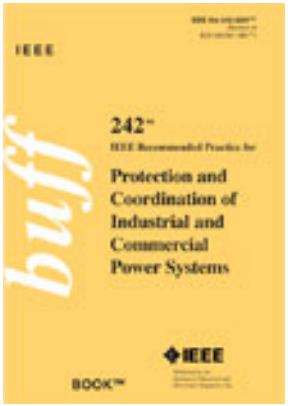
Troy Michigan

Phase voltage HRG



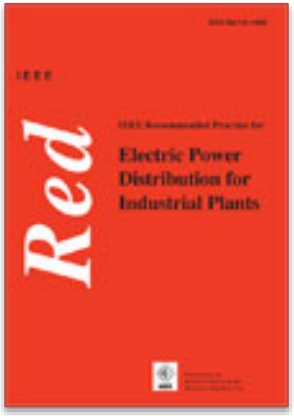
Transients controlled
0 peak events over 700 volts
Peak voltage 660 volts

Arc Faults of Solidly Grounded Systems



IEEE Std 242-2001 (Buff Book)

- 8.2.2. One disadvantage of the solidly grounded system involves the high magnitude of destructive, arcing ground-fault currents that can occur.



IEEE Std 141-1993 (Red Book)

7.2.4. The solidly grounded system has the high probability of escalating into a phase-to-phase or three-phase arcing fault, particularly for the 480V and 600V systems. The danger of sustained arcing for phase-to-ground fault…is also high for the 480V and 600V systems, and low or near zero for the 208V system.

7.2.2 There is no arc flash hazard, as there is with solidly grounded systems, since the fault current is limited to approximately 5A.

Another benefit of high-resistance grounded systems is the limitation of ground fault current to prevent damage to equipment.

Hierarchy of Hazard Control Measures from ANSI Z10

Control effectiveness

ELIMINATION	SUBSTITUTION	ENGINEERING CONTROLS	WARNINGS	ASMINISTRATIVE CONTROLS	PERSONAL PROTECTIVE EQUIPMENT
Eliminate the hazard during the design phase. Design or re-design the system to use High Resistance Grounding.	Substitute for a lower energy level. Reduce the impact of the hazard.	Design options that automatically reduce risk. Increase distance away from the hazard.	Automatic or manual, permanent or temporary, visible or audible warning systems, signs, barriers and labels.	Planning processes, training permits, safe work practices, maintenance systems, communications and work management	Available, effective, easy to use.
Reduces likelihood of arc flash by 95%.					

Life Cycle Value

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(1) Zone-selective interlocking. A method that allows two or more circuit breakers to communicate with each other so that a short circuit or ground fault will be cleared by the breaker closest to the fault with no intentional delay. Clearing the fault in the shortest time aids in reducing the incident energy.

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(3) Energy-reducing maintenance switching with a local status indicator. An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to operate faster while the worker is working within an arc flash boundary, as defined in NFPA 70E, and then to set the circuit breaker back to a normal setting after the work is complete.

O.2.4 Other Methods.

(1) 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.

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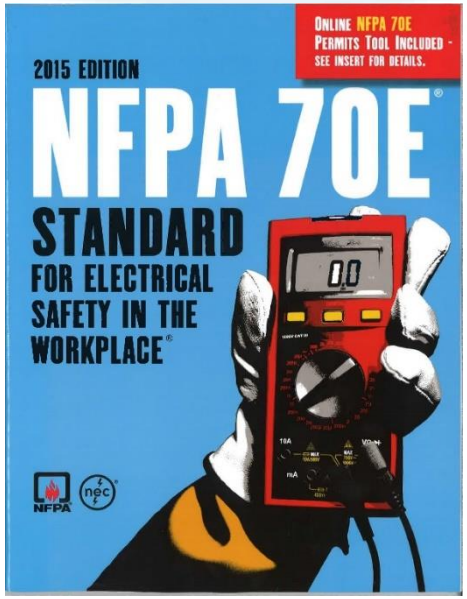

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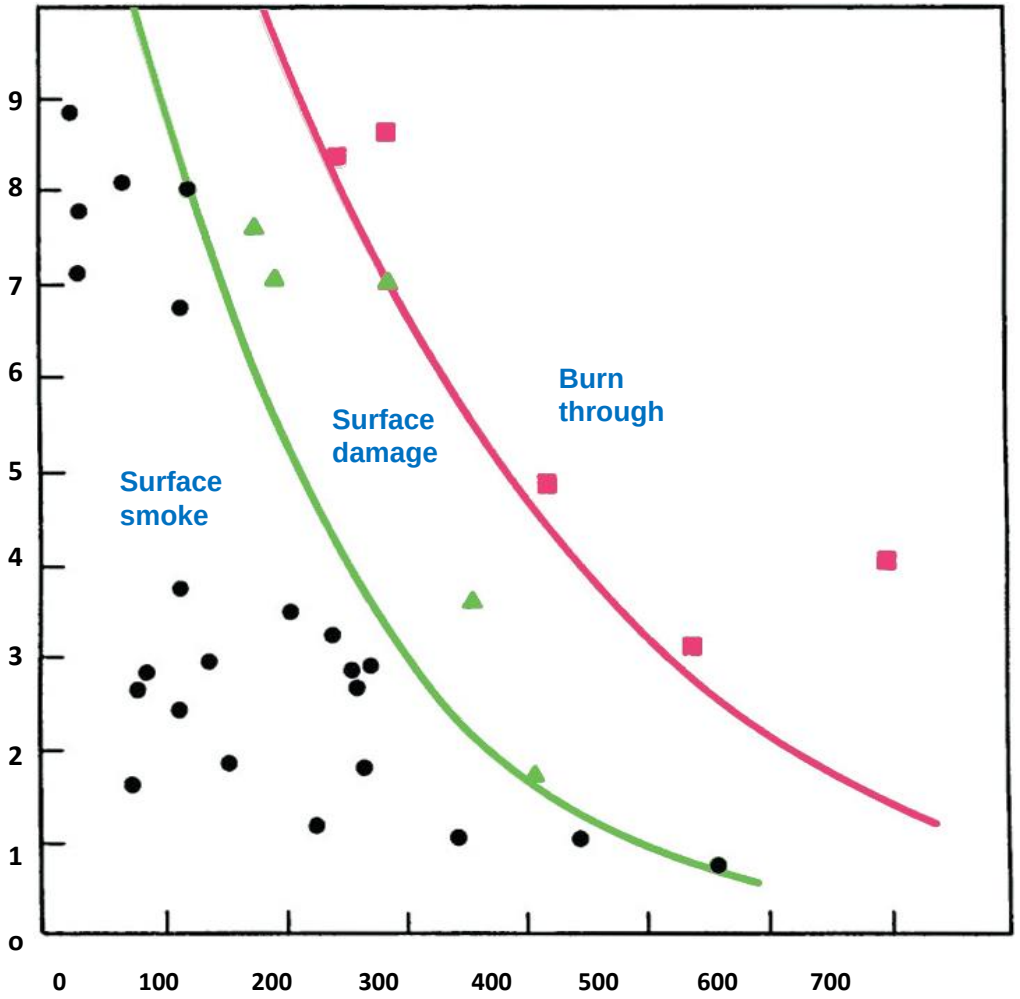
Arc Damage versus Arc Duration



An arc is developed within milli-seconds and leads to the discharge of enormous amounts of destructive energy. The energy in the arc is directly proportional to the square of the short-circuit current and the time the arc takes to develop.

Reduce the Time,

Reduce the Damage,

Reduce the Incident Energy.

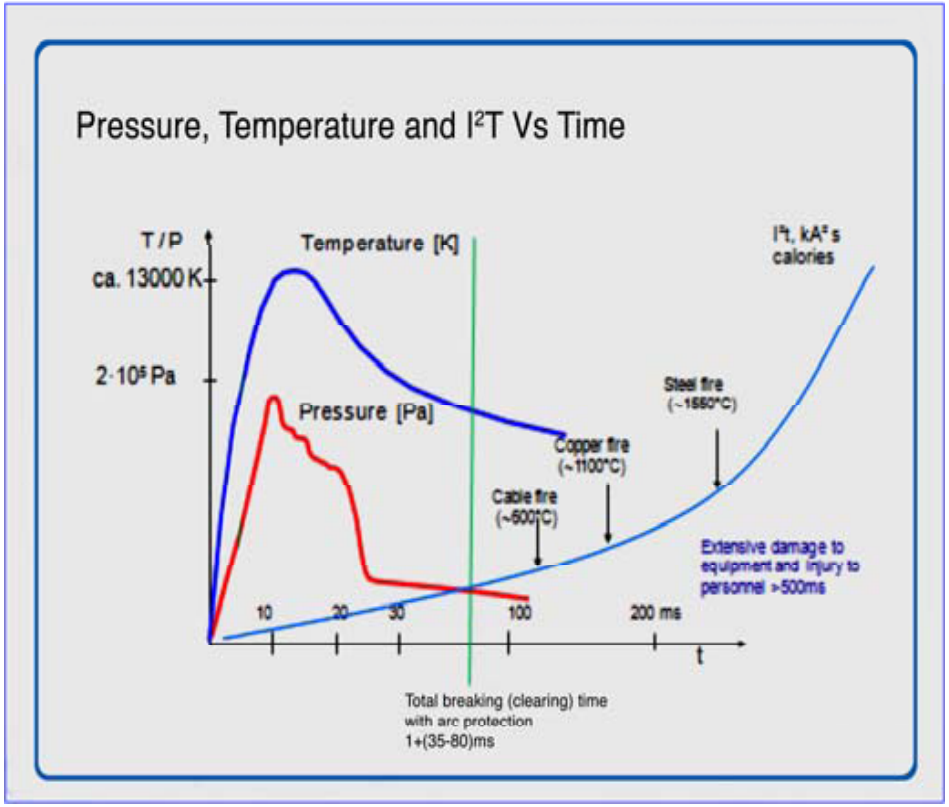
Total Clearing Time is Critical

Reduce the Time	Reduce the Damage	Reduce the Incident Energy
-35 ms:	no significant damage to persons or Switchgear, which can often be returned to use after checking the insulation resistances	2.9 Cal /cm2
- 100ms:	small damage, requires cleaning and possibly some minor repair likely	8.31 Cal/cm2
- 500ms:	large damage both for persons and the switchgear, which must be partly replaced.	41.58 Cal/cm2

The arc burning time is the sum of the time to detect the arc and the time to open the correct breaker.

***Based on 50kA maximum bolted fault current on a 480 volt solidly grounded system @ 18 " Working distance.**

Optical Arc Detection Relays



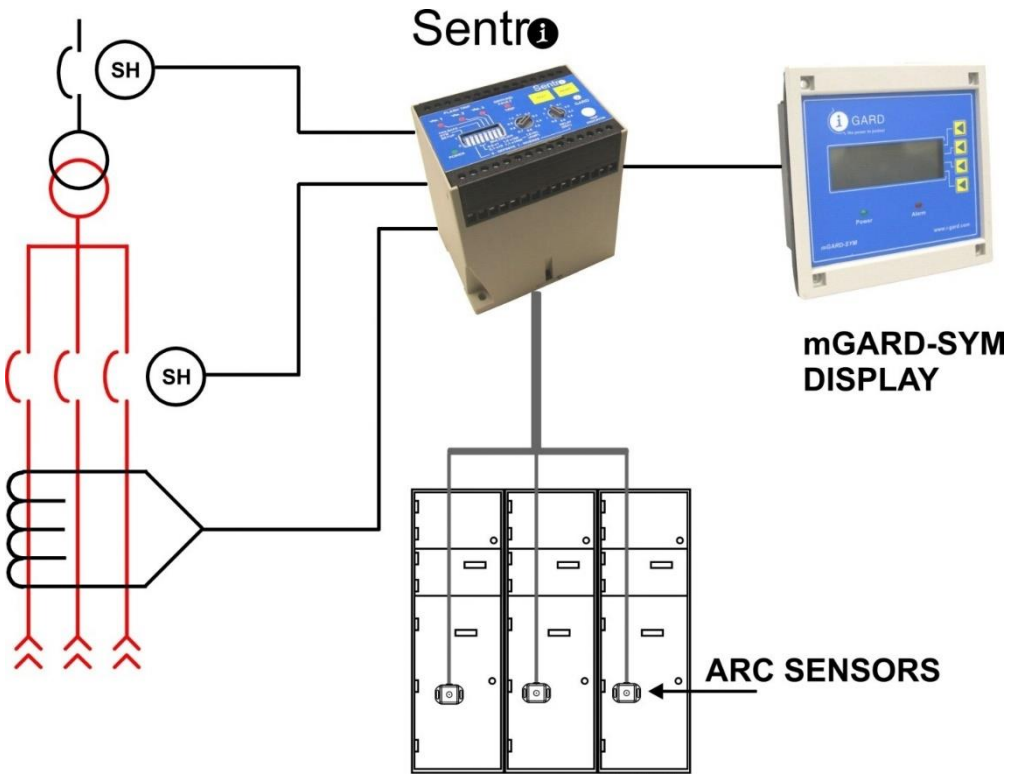
An arc is accompanied by radiation in the form of light, sound, and heat.

Therefore, the presence of an arc can be detected by analyzing visible light, sound waves, and temperature change.

To avoid erroneous trips, it is normal to use a short-circuit current detector along with one of the aforementioned arc indicators.

The most common pairing in North America is current and light.

Optical Arc Detection Relays



The light from an arc flash is detected by specially calibrated optical sensors based on lux intensity and wavelength, a signal is then sent to a tripping device in under 1 millisecond.

(it takes 300 milliseconds to blink).

Optical Arc Detection Relays

Protection Type	Clearance Time	Incident Energy
MCGG Over-Current	2.0 seconds	211 Cal / cm2
MCGG Instantaneous	0.45 seconds	47 Cal / cm2
Optical Arc Detection	0.084 seconds	9.0 Cal / cm2

- Assumes circuit breaker interrupting time of 5 cycles
- Assumes 480V and 65kA bolted fault current, 18 inches

Hierarchy of Hazard Control Measures from ANSI Z10

Control effectiveness

ELIMINATION	SUBSTITUTION	ENGINEERING CONTROLS	WARNINGS	ASMINISTRATIVE CONTROLS	PERSONAL PROTECTIVE EQUIPMENT
Eliminate the hazard during the design phase. Design or re-design the system to use High Resistance Grounding.	Substitute for a lower energy level. Reduce the impact of the hazard.	Design options that automatically reduce risk. Increase distance away from the hazard.	Automatic or manual, permanent or temporary, visible or audible warning systems, signs, barriers and labels.	Planning processes, training permits, safe work practices, maintenance systems, communications and work management	Available, effective, easy to use.
Reduces likelihood of arc flash by 95%.	**Lowers the HRC to category 0 or 1 – safer levels.**				

Life Cycle Value

Informative Annex O Safety-Related Design Requirements

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

O.1 Introduction. This informative annex addresses the responsibilities of the facility owner or manager or the employer having responsibility for facility ownership or operations management to perform a risk assessment during the design of electrical systems and installations.

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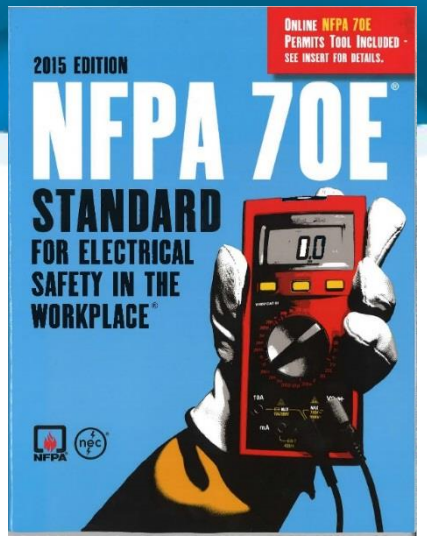

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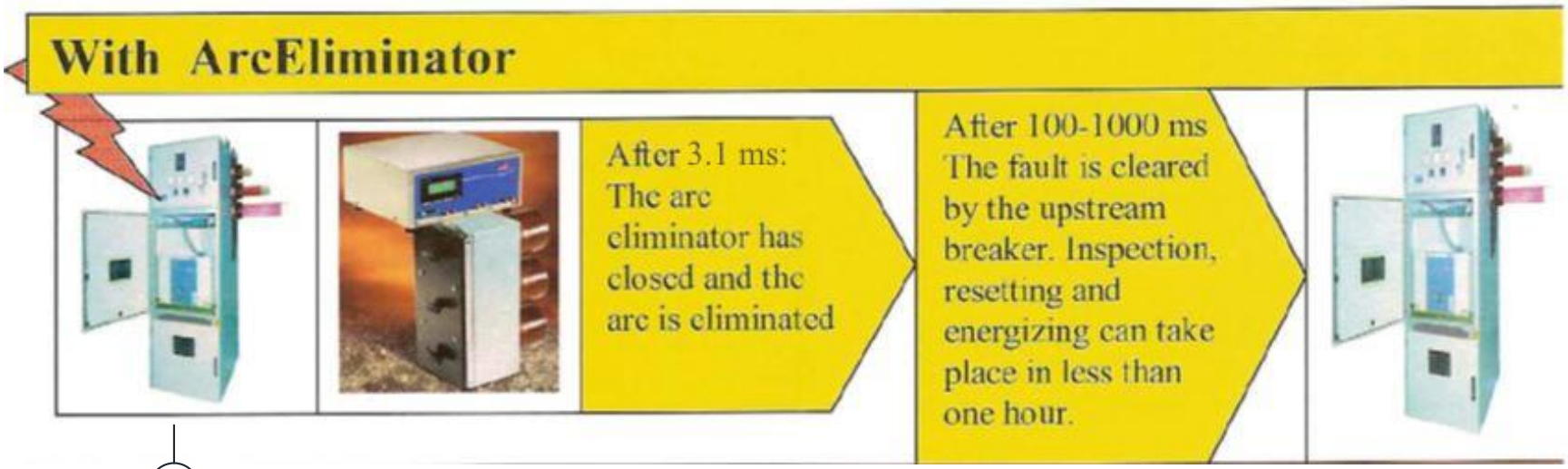
Incident Energy without Arc Mitigation

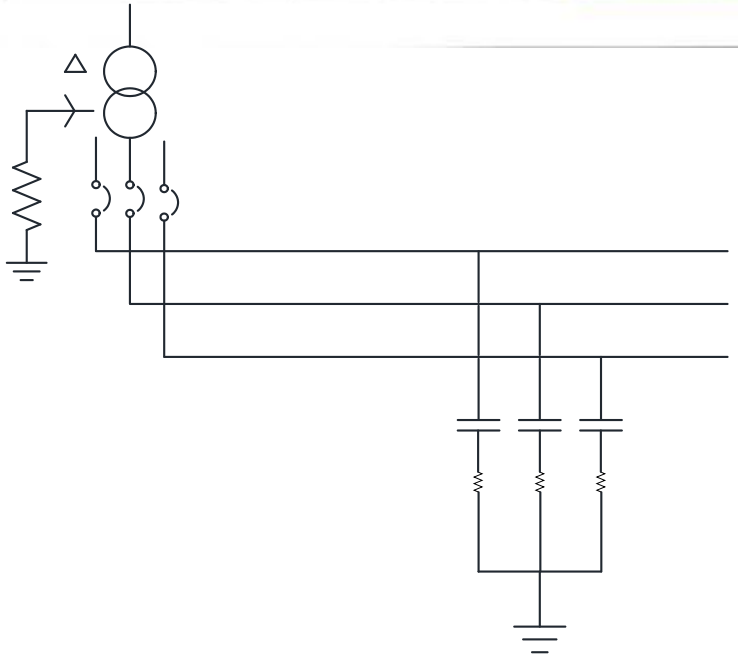
Without ArcEliminator

After 100-1000 ms:
Cubicles, apparatus and sometimes the building are damaged and have to be repaired.

After 100-1000 ms
The fault is cleared by the upstream breaker. During the arcing period the hot gases and melted material is a threat to operator's life. Inspection, repair and replacement might require several weeks.

Incident Energy with Active Arc Mitigation





Fault clearing time: 3.1 ms ~ 1.17 cal/cm^2

Introduction of an impedance controls the fault energy eliminating concern over mechanical stresses

Reducing the Magnitude of Exposure

Active Arc Mitigation

Protection Type	Clearance Time	Incident Energy
Over-Current	2.00 seconds	211 Cal / cm^2
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Optical Arc Detection	0.084 seconds	9 Cal / cm^2
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Hierarchy of Hazard Control Measures from ANSI Z10

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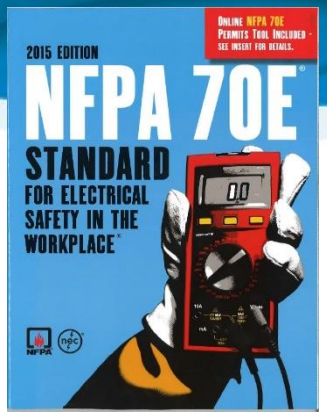

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0.2.2 Design option decisions should facilitate the ability to eliminate hazards or reduce risk by doing the following:

(1)Reducing the likelihood of exposure = **High Resistance Grounding**

(2) Reducing the magnitude or severity of exposure **= arc flash relays or active arc mitigation.**

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Hierarchy of Hazard Control Measures from ANSI Z10

Recommended Approach

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Life Cycle Value

Thank You

Questions?

For comments or product information, please contact: marketing@i-gard.com