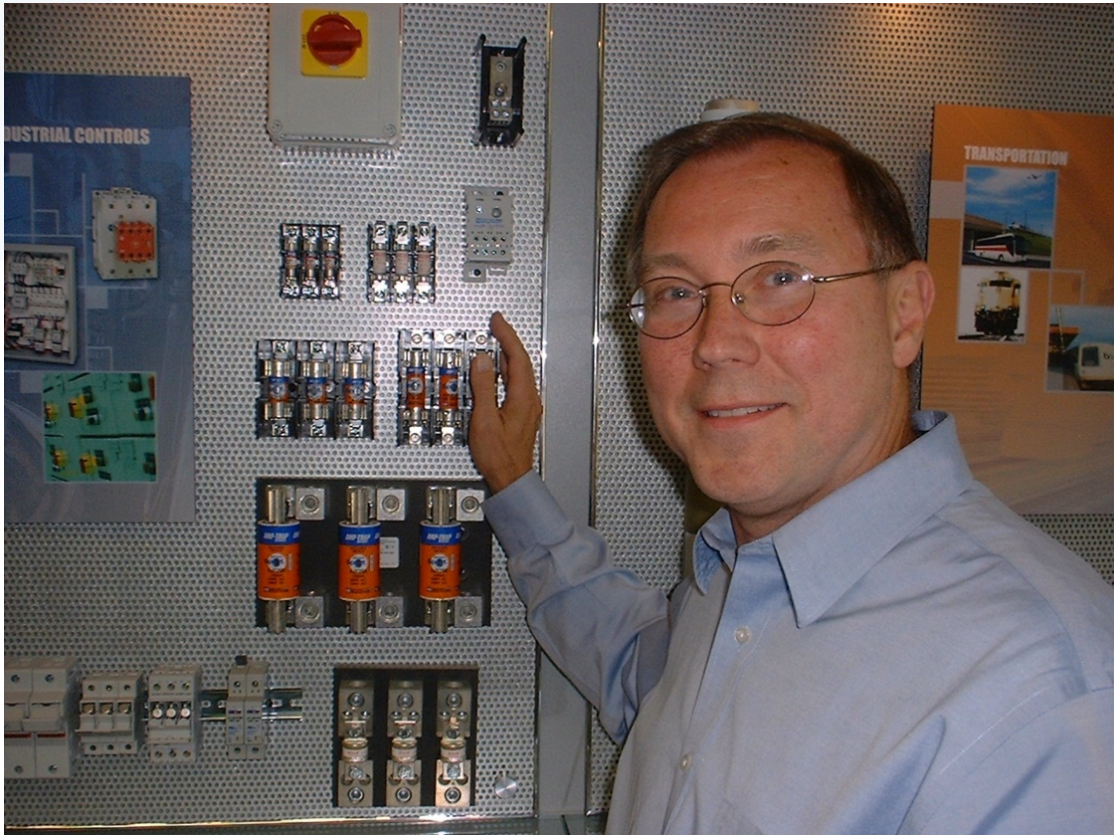
Arc Flash Mitigation with Fuses

Mersen



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- •Technical Committee Member of NFPA 111
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- •**Disclaimer- Speaking as individual and not giving an official position or interpretation from any Committee**

Overview

- Arc Flash Mitigation is easier with tools for various situations. Fuses can uniquely solve some challenges through current limitation. This webinar will review the concepts of using current limitation to reduce incident energy through low voltage UL and medium voltage E-Rated fuses. UL classifications will be correlated to their current limitation and arc flash reduction.
  - UL LV Fuse Standards
  - Current Limitation
  - Regions of TC Curve: Time Delay, No Time Delay, and Current Limitation
  - Medium Voltage –Transformer Primary Fusing to Reduce Arc Flash

Part 1. Common UL Fuse Types

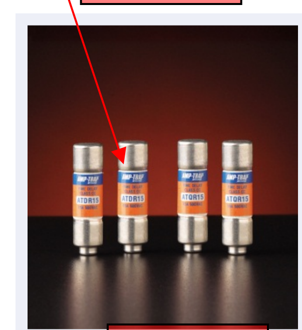
- UL Fuse Types
- Comparisons

Low Voltage Fuses
0 - 600 Volt
Branch Circuit

- Non -Current Limiting 0 - 600 Amp
  - Class H 250 Volt 600 Volt
  - Class K 250 Volt 600 Volt
- Current limiting 0 - 600 Amp
  - Class RK 250 Volt 600 Volt
  - Class J 600 Volt
- Current Limiting Other Amp ranges
  - Class T 300 Volt 600 Volt
  - Class L 600 Volt
  - Class CC 600 Volt
  - Class G 480 Volt

601-6000A

1/2-60A



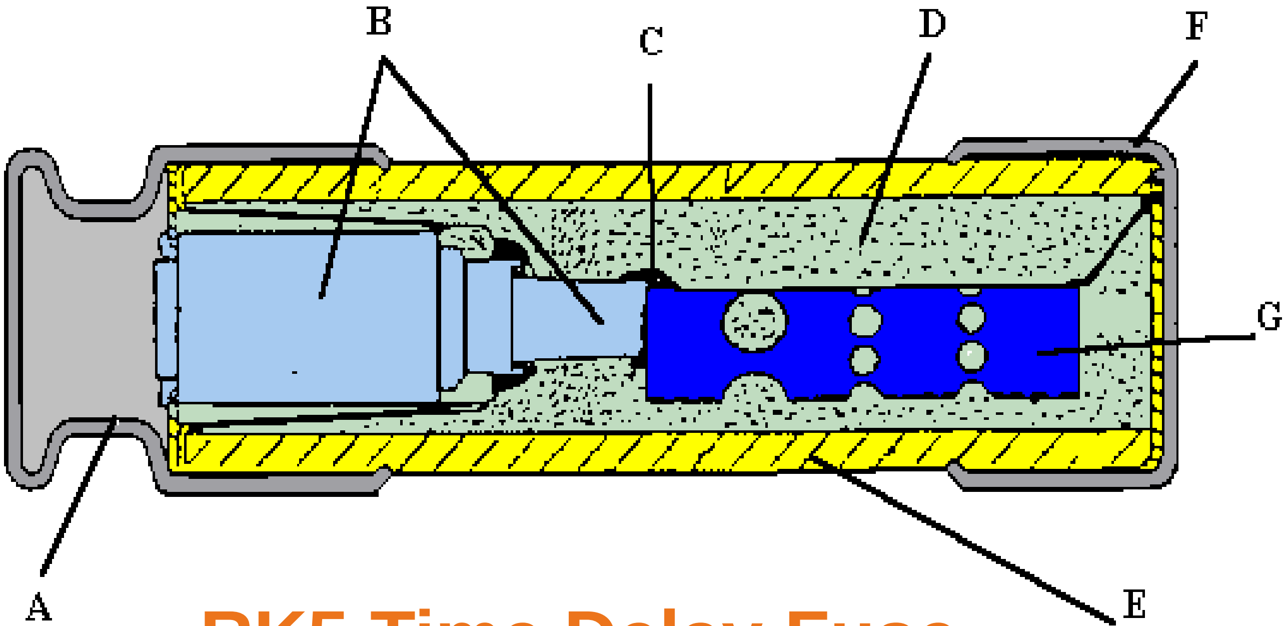
1/10-30A

Fuse Characteristics

- Amp Rating
- Voltage Rating
- Interrupting Rating AIC
- Time Delay or Not
- Degree of Current Limitation
- Mechanical Dimensions
- Manufacturer

Condensed UL Fuse Class Comparison

U/L Class	H	K-5	RK-5	RK-1	J	L
Ampere Rating	0-600	0-600	0-600	0-600	0-600	601-6,000
Amps IR	10kA	50kA	200kA	200kA	200kA	200kA
Current Limitation	None	Some	Some	Best	Best	Varies
Overload Region	0-10x	0-10x	0-10x	0-10x	0-10x	0-10x
Non-Time Delay Region	Over 10x	Over 10x	Over 10x	Over 10x	Over 10x	Over 10x
Current Limiting Region	None	Over 65x	Over 65x	Over 30x	Over 30x	30-40+x
Typical Fuse	RFS	OTS	TRS-R	A6D-R	AJT	A4BQ
						A4BY
						A4BT



RK5 Time Delay Fuse

A - FERRULE (REJECTION FERRULE)

B - OVERLOAD ELEMENT (SPRING LOADED)

C - EUTECTIC SOLDER

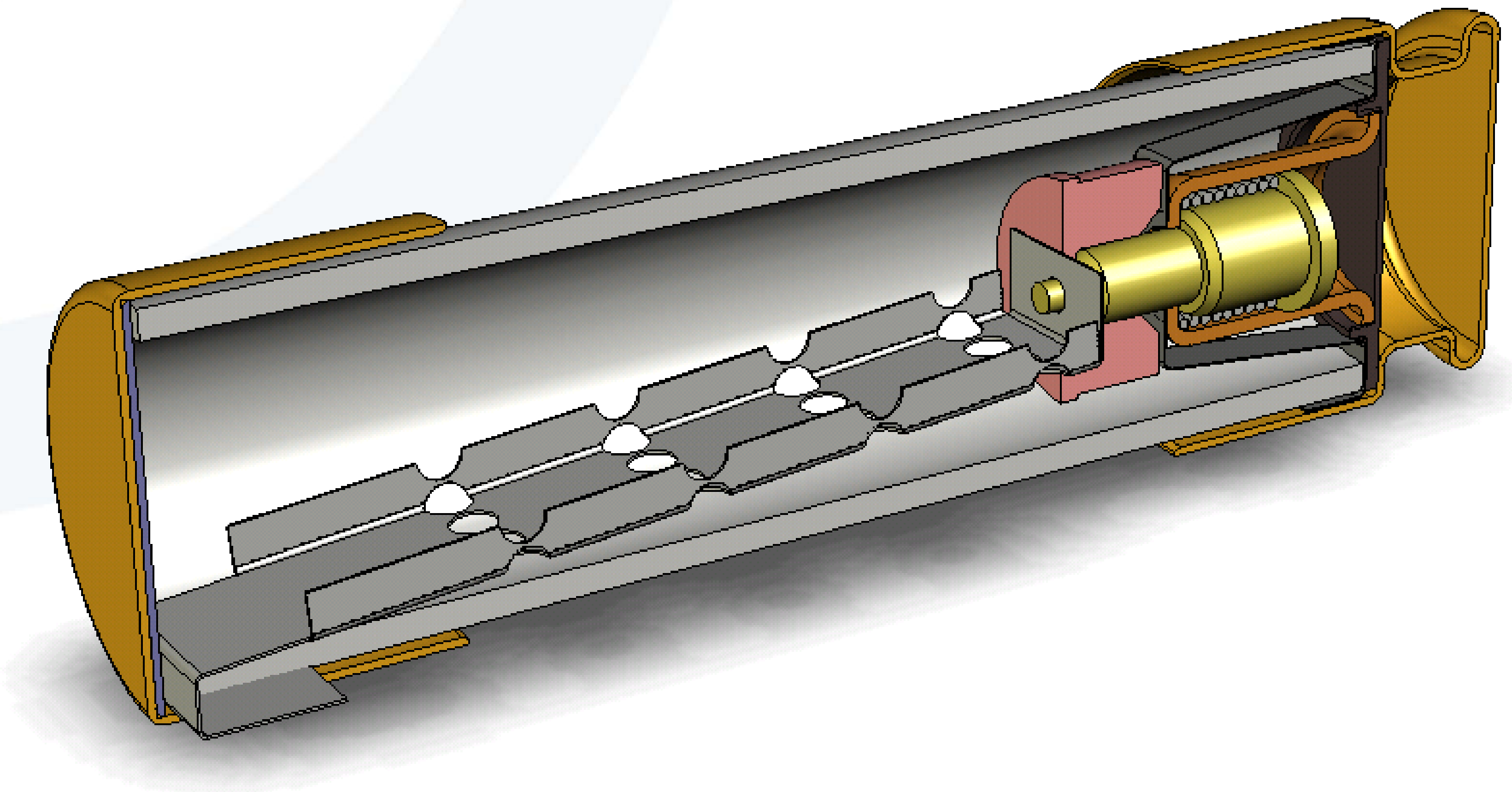
D - FILLER (QUARTZ SAND)

E - FUSE BODY

F - NON REJECTION FERRULE

G - SHORT CIRCUIT ELEMENT

RK1 Dual Element Fuse



Part 2. Current Limitation

- Concept of Current Limitation
- Affect on Incident Energy

NEC 240.2 Definitions.

- **Current-Limiting Overcurrent Protective Device**.
  A device that, when interrupting currents in its current-limiting range, reduces the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance.

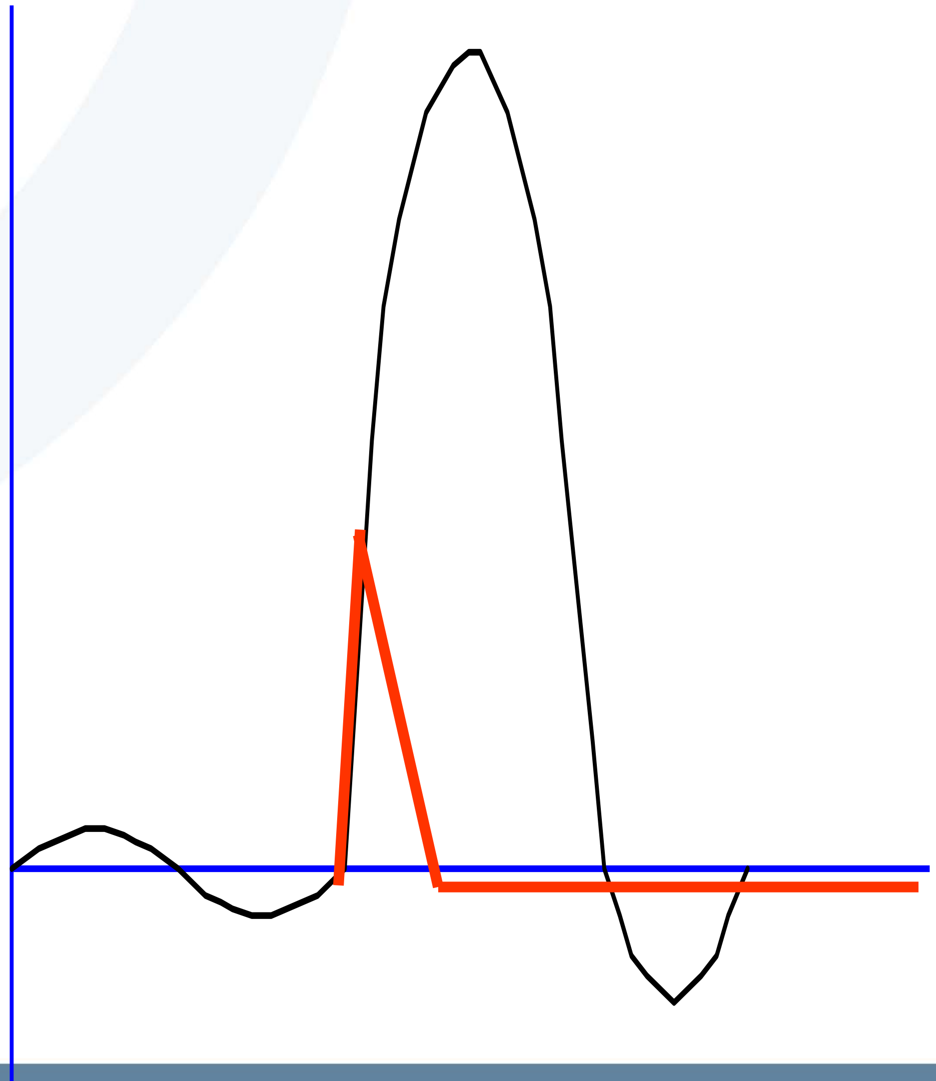
Incident Energy

- IE is proportional to $I^2 \times t$
- IE can increase with lower currents if the duration is extended

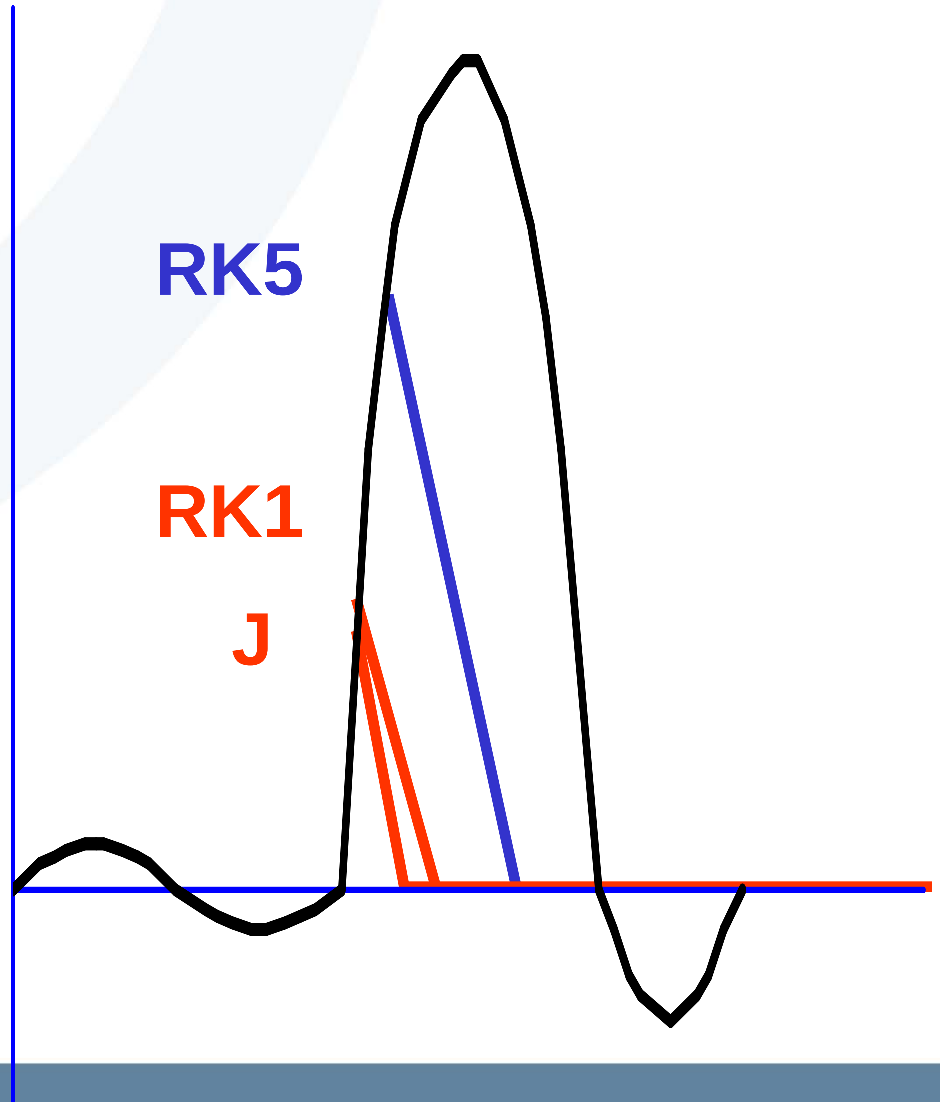
Fuse Mitigation Strategy

- Reduce incident energy by properly applied current limiting fuses
- Effective solution when fault levels are high

Current Limitation



Current Limitation Comparison



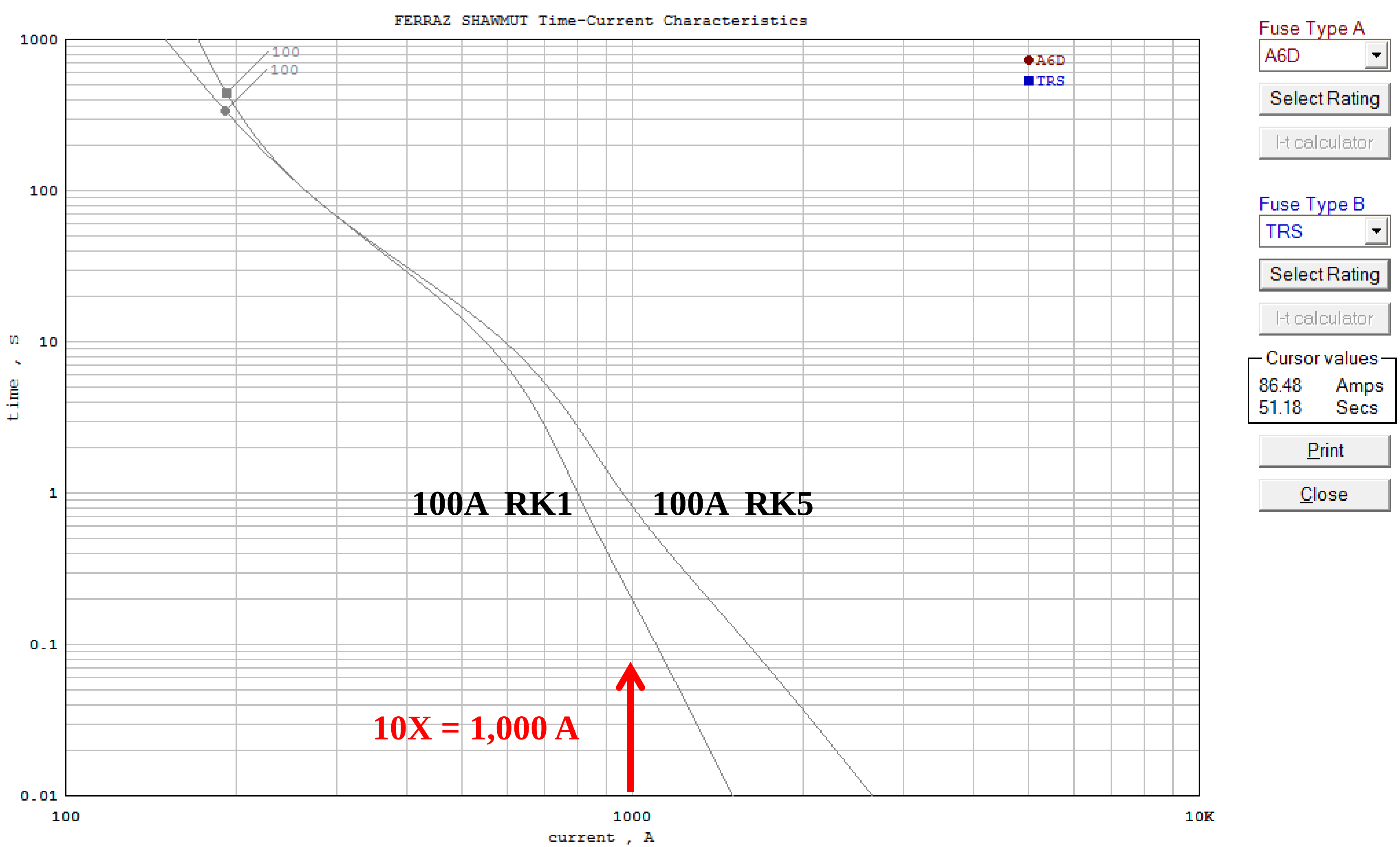
Fuse Energy Clearing I^2t Comparison

- 100A UL Class RK5 = 50,000 I^2t maximum rating
- 100A UL Class RK1 = 10,000 I^2t maximum rating
- 80% Reduction by Replacing RK5 with RK1 for high fault conditions

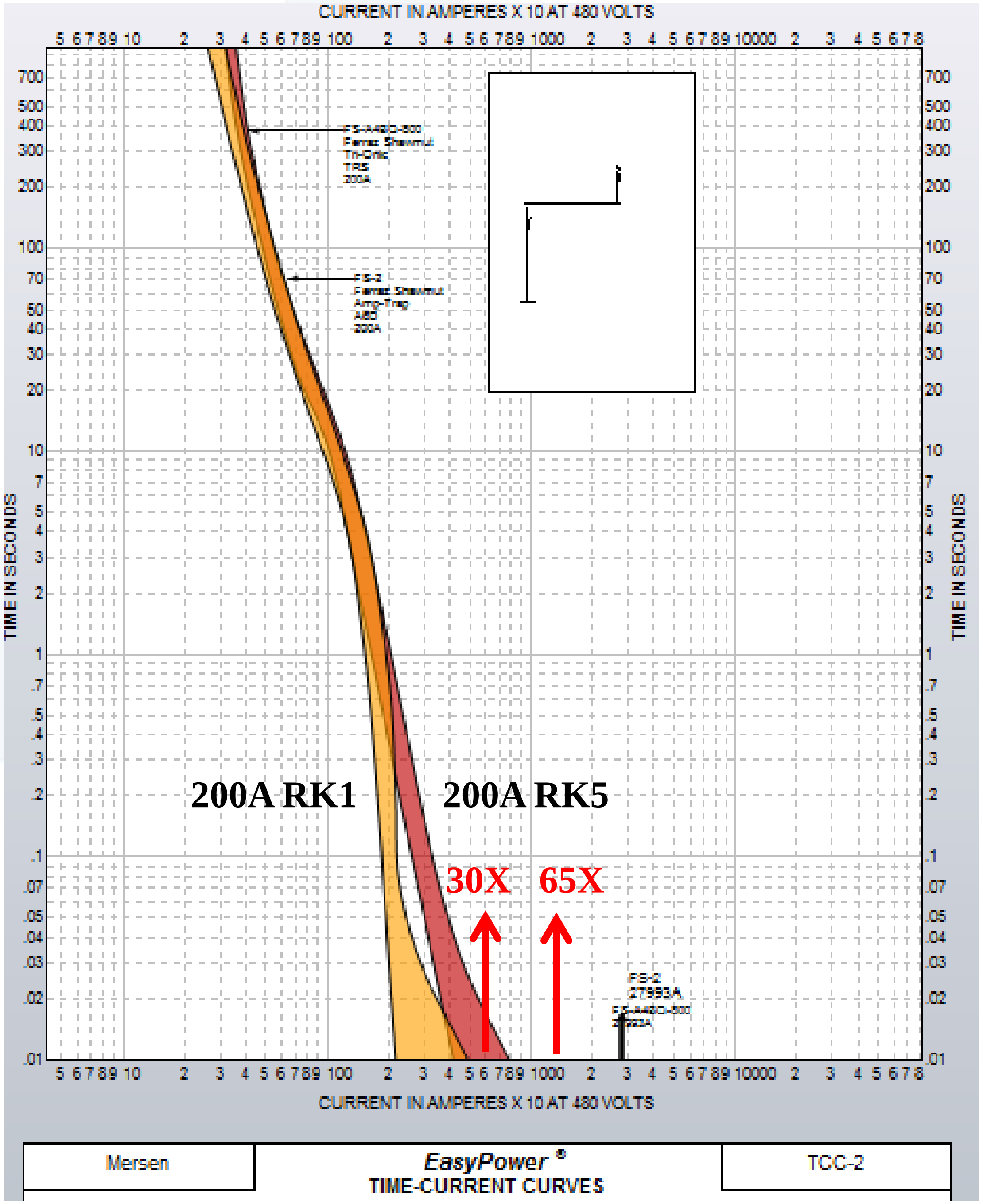
Part 3. Regions of the Fuse Time-Current Curve

- Time Delay Region
- No Intentional Time Delay Region
- Current Limitation Region

Transition Between TD and Non-TD



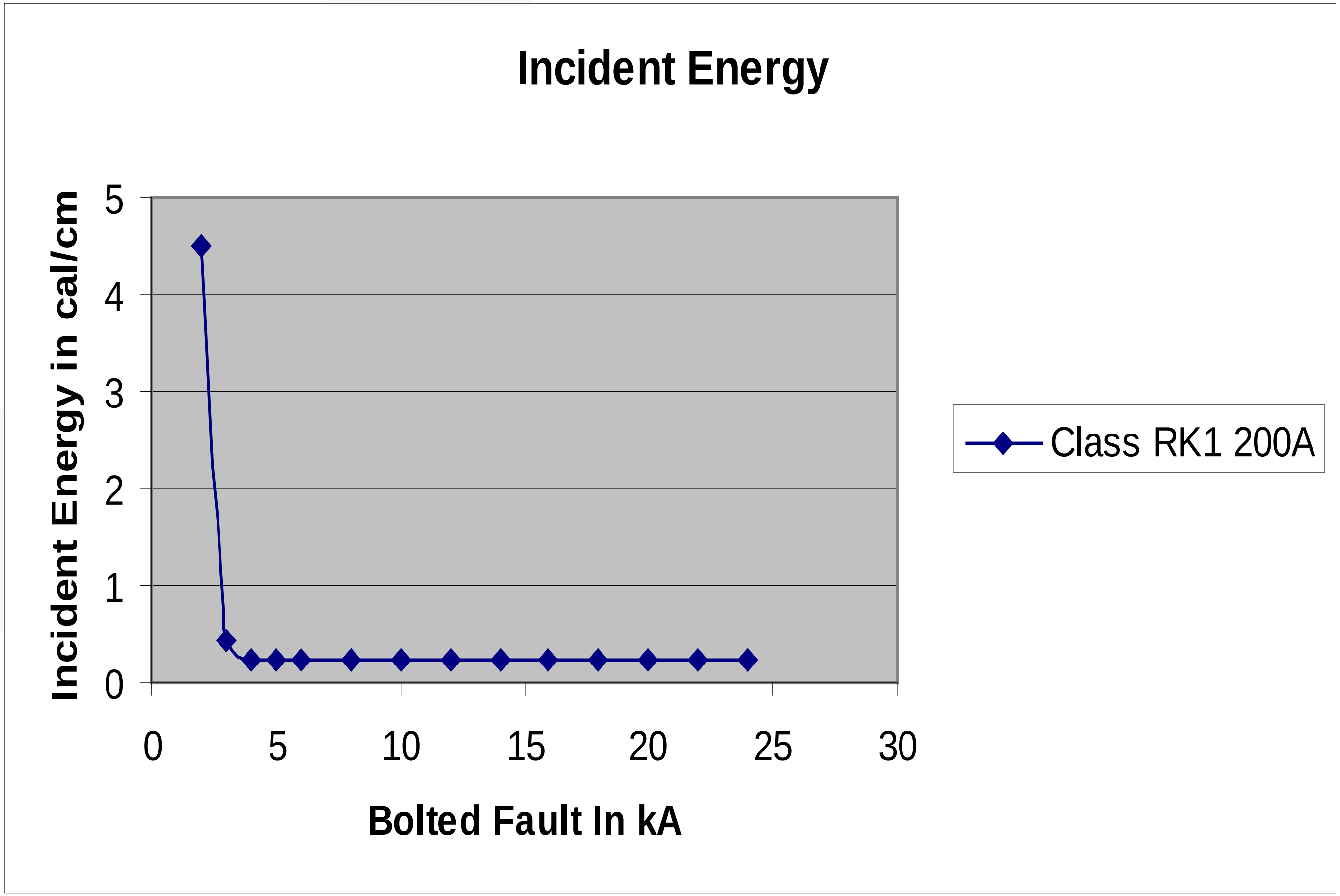
Transition to CL



30X200 = 6,000

65X200 = 13,000

Fuse Curve from IEEE-1584



Circuit Breaker Equation from IEEE-1584

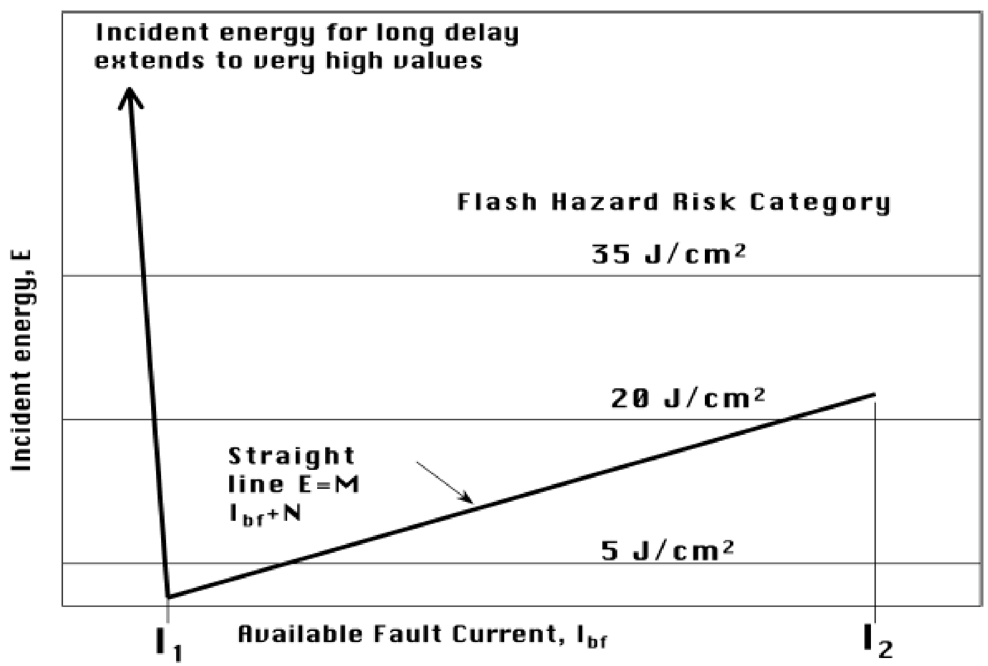
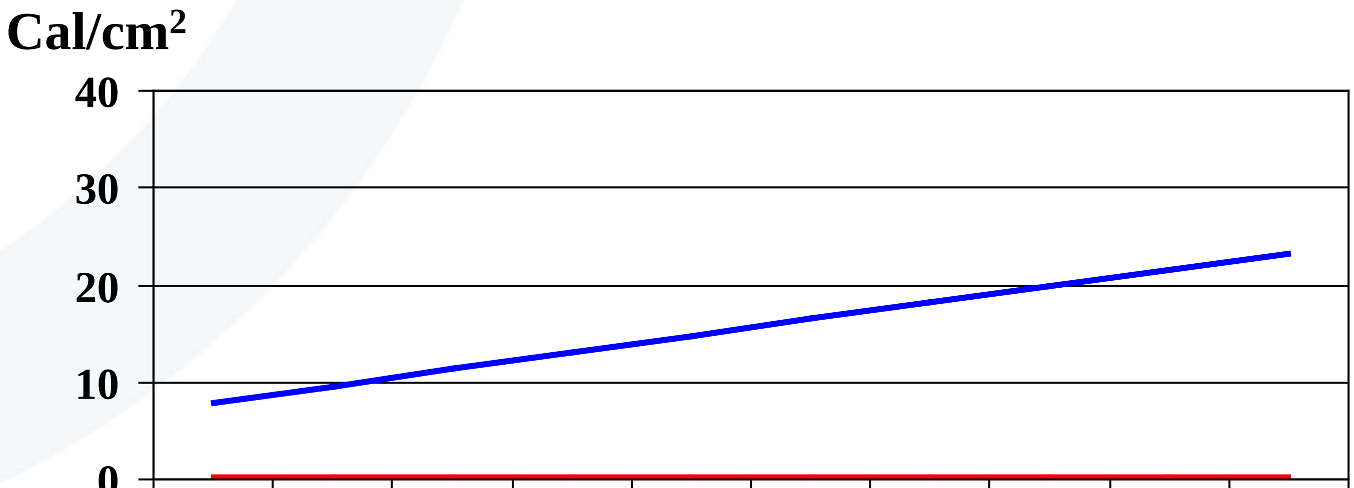


Figure 44—Incident energy vs available fault current generalized for circuit breakers

Current Limitation Can Reduce Arc Energy



Available Fault Current kA	20	25	30	35	40	45	50	55	60	65
6 Cycle	7.8	9.6	11.4	13.1	14.8	16.5	18.2	19.9	21.6	23.2
AJT200	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

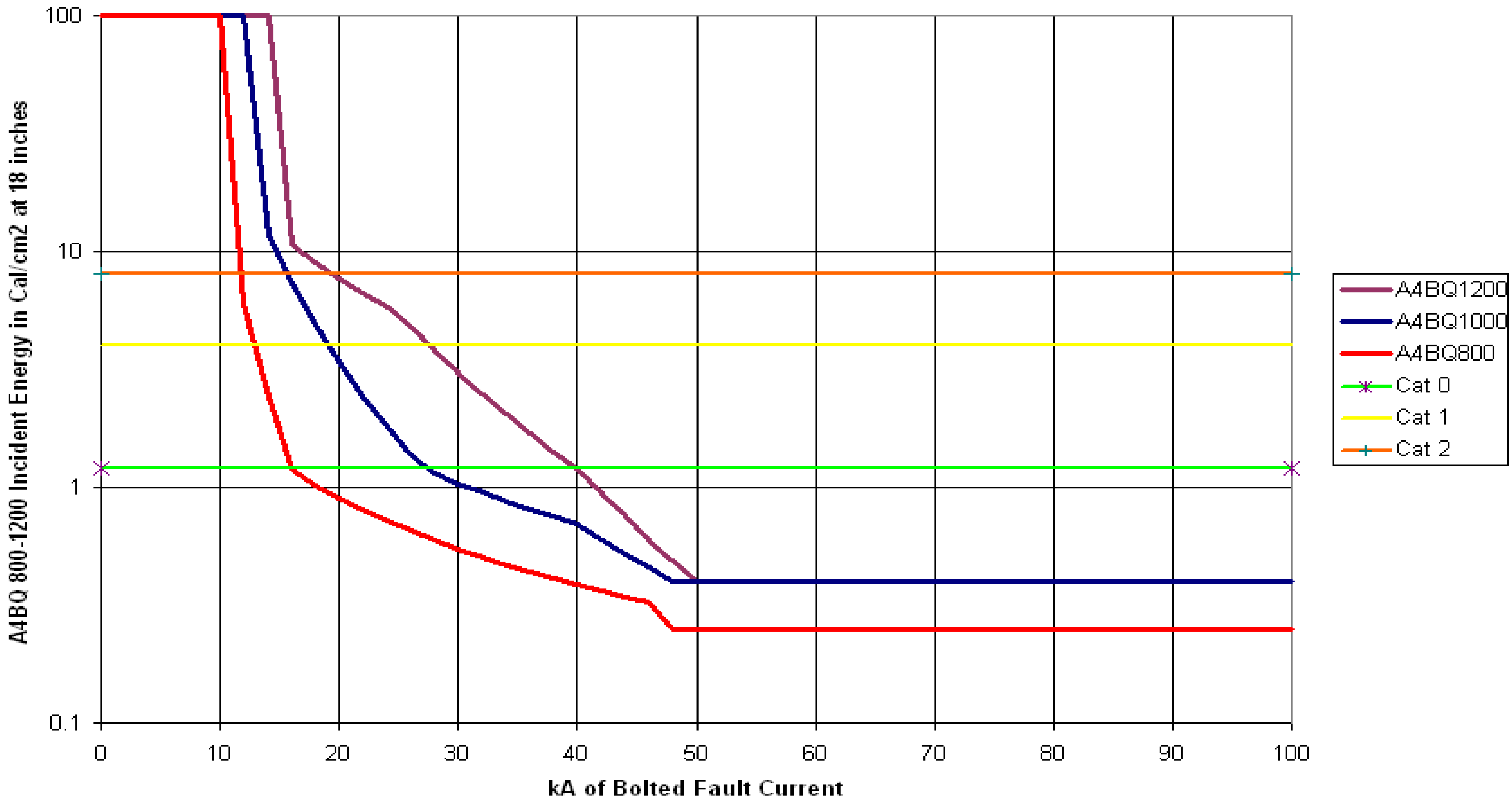
6 Cycle AJT200

Using IEEE 1584 (2002) equations

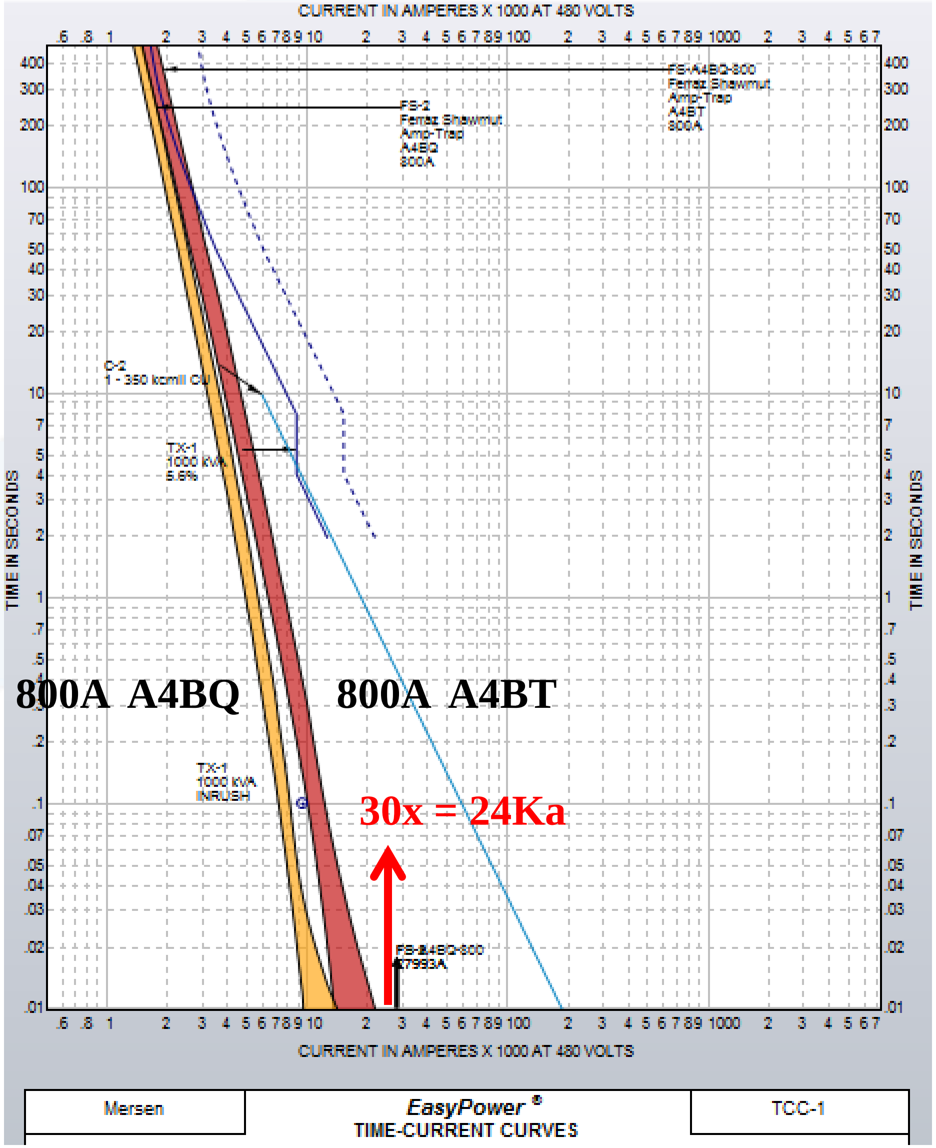
Arc Flash Design Example

- **600 V Motor Control Centers- If they are supplied by a maximum of a A4BQ800 fuse, many times the MCC is the safest category for Arc Flash (Incident Energy below 1.2 Cal/cm^3) because the minimum available fault current will operate the fuse quickly at low currents and current limitation will activate at high faults.**

Incident Energy vs. Minimum Bolted Fault Current at 600V



Transition to CL



Suggestion-Standardize on UL Class RK1 Fuses before Data Gathering for AF Study

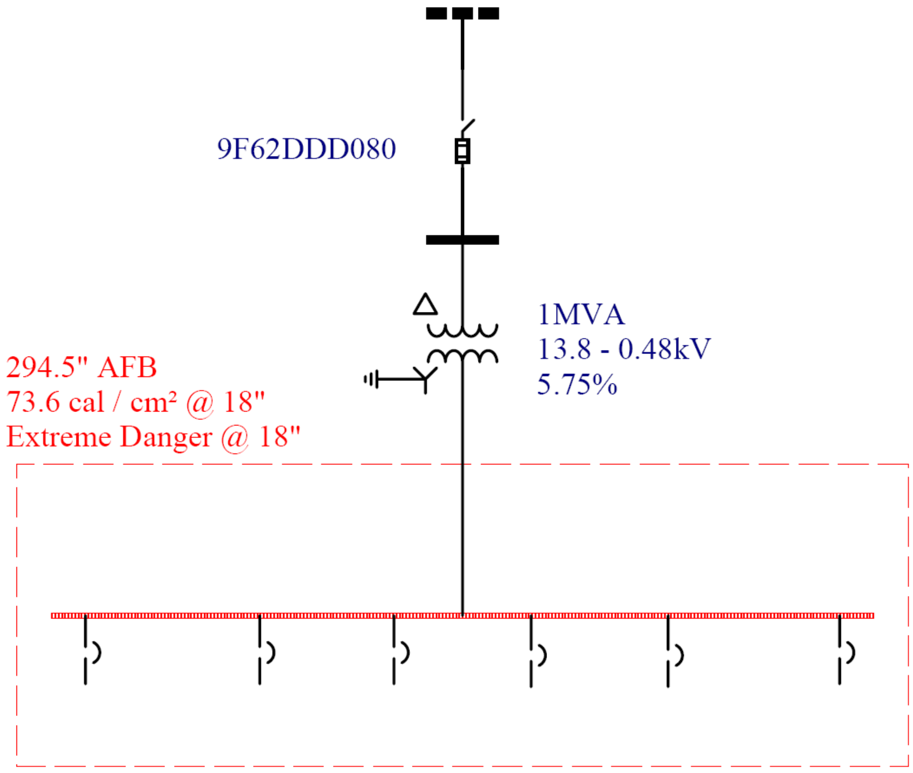
- Improved Energy Let Through Performance
- Easily input exact fuse characteristic without maintenance people substituting later
- Improved interrupting ratings

Part 4. Primary Fuse Selection to Mitigate Secondary Incident Energy

- Example Application
- Considerations
- Results

Figure 1

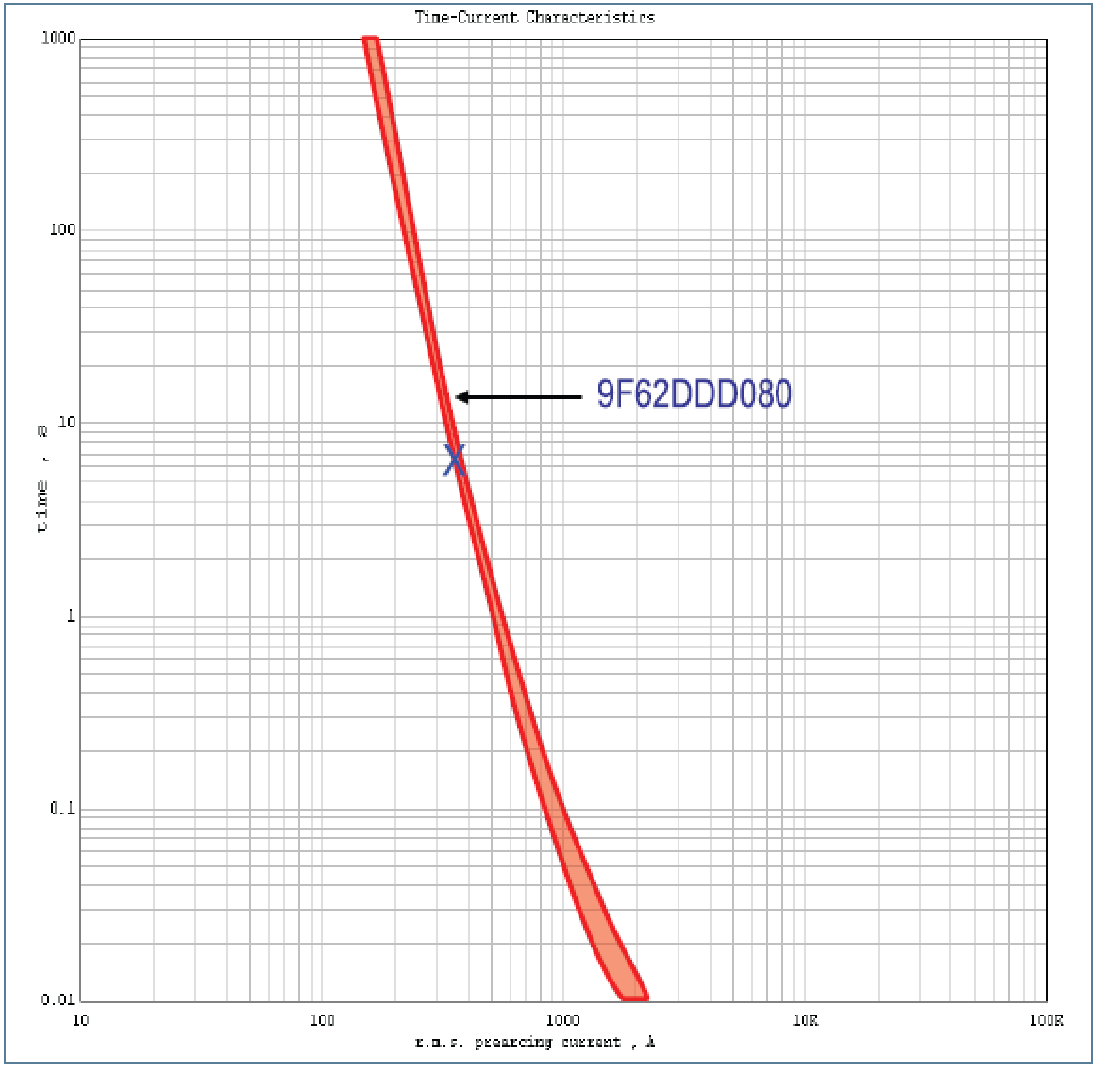
Switchgear with no main switch fed by 1,000kVA Transformer. Short circuit protection for switchgear bus is provided by primary fuse.



Incident Calculation Results

9F62DDD080				
Percent of I_{arc}	**I_{arc} Secondary**	**I_{arc} Primary**	**Total Clearing Time**	**Incident* Energy**
100%	11,322 A	394 A	6.7 Seconds	73 cal/cm^2
85%	9,624 A	335 A	16 Seconds	61 cal/cm^2

Figure 2 Time current curve for original primary fuse.



If It Were a Relay,
You Would Adjust the Curve

- Some fuses can have different curves but still meet the other application requirements
- Selecting different fuse curves can reduce the Arc Flash Incident Energy

Factors and Considerations for the Selection of a Transformer Primary Fuses

- To reduce arc flash hazards and maintain reliable operation of the primary fuse, an arc flash energy objective must be added to the protection objectives of the primary fuse. Before changing the fuse to get a faster clearing time for the I_{arc} values, it is essential to review the other factors that affect selection of a transformer primary fuse. These factors include:

    - System considerations
    - Transformer characteristics
    - NEC requirements
    - Fuse characteristics

System Considerations

- Source Impedance-Fault current
- System Voltage
- Cable type and Length
- Coordination

Transformer Characteristics

- Inrush at 25X at 0.01 seconds (½ cycle)
- Inrush at 8X or 10X at 0.1 second
- Damage Curve by ANSI C57.109
- Transformer Ratings for full load
- Percent Impedance Z%
- Turns ratio
- Connection, i.e. Delta-Wye

NEC Requirements

- Article 450.3 controls the maximum fuse size
- Articles 110.9 and 490.21(B) require adequate interrupting rating
- Article 490.21(B)3 require adequate voltage rating
- Article 240.100(C) requires adequate short circuit protection of cables feeding the transformer primary

Fuse Characteristics

- ANSI/IEEE C37-40 Covers service conditions
- ANSI/IEEE C37.41 Specifies tests that prove the compliance to the standard
- ANSI/IEEE C37.46 Specifies fuse characteristic and ratings

Figure 5

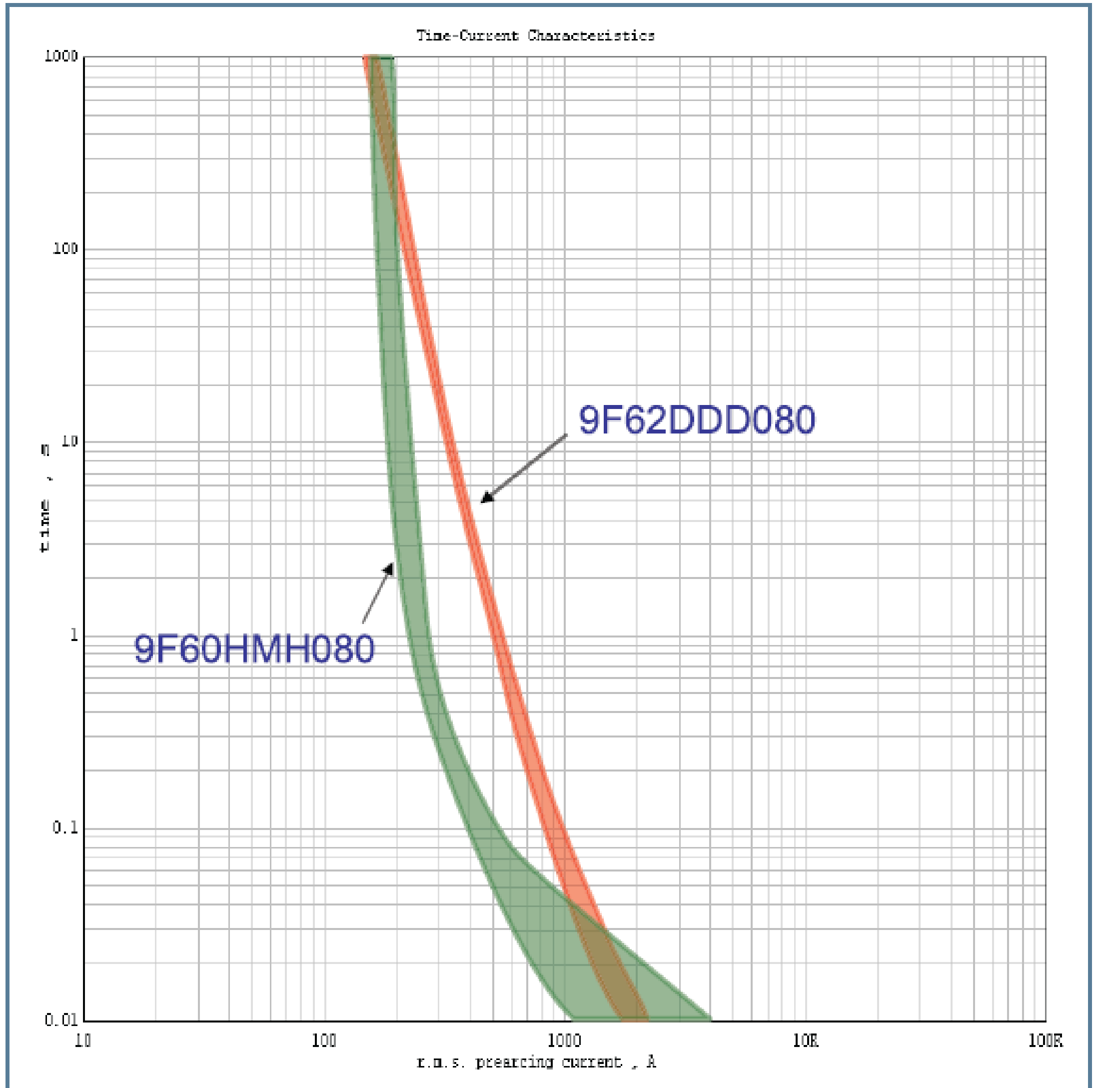


Figure 5. *Time current curves for two different 15.5kV 80E fuses.*

Other Considerations

- Even if the new fuse is great electrically, it still has to fit physically
- In addition to having enough space, mounting can be an issue

Figure 6- Common Fuse Mounting Types

Time Curves

A. Magnetizing Inrush Current at 0.1 sec (8 x Transformer primary FLA)

B. Magnetizing Inrush Current at 0.01 sec (25 x Transformer primary FLA)

C. ANSI C57 Transformer Damage Curve shifted for phase to ground through faults

D. Cable Damage Curve

E. Largest feeder breaker time current curve

F. Original fuse curve

G. 9F60HMH080 (80E) time current curve.

T1. Clearing time for 100% I_{arc} (11,322A;0.2 seconds)
T2. Clearing time for 85% I_{arc} (9,624A;0.3 seconds)

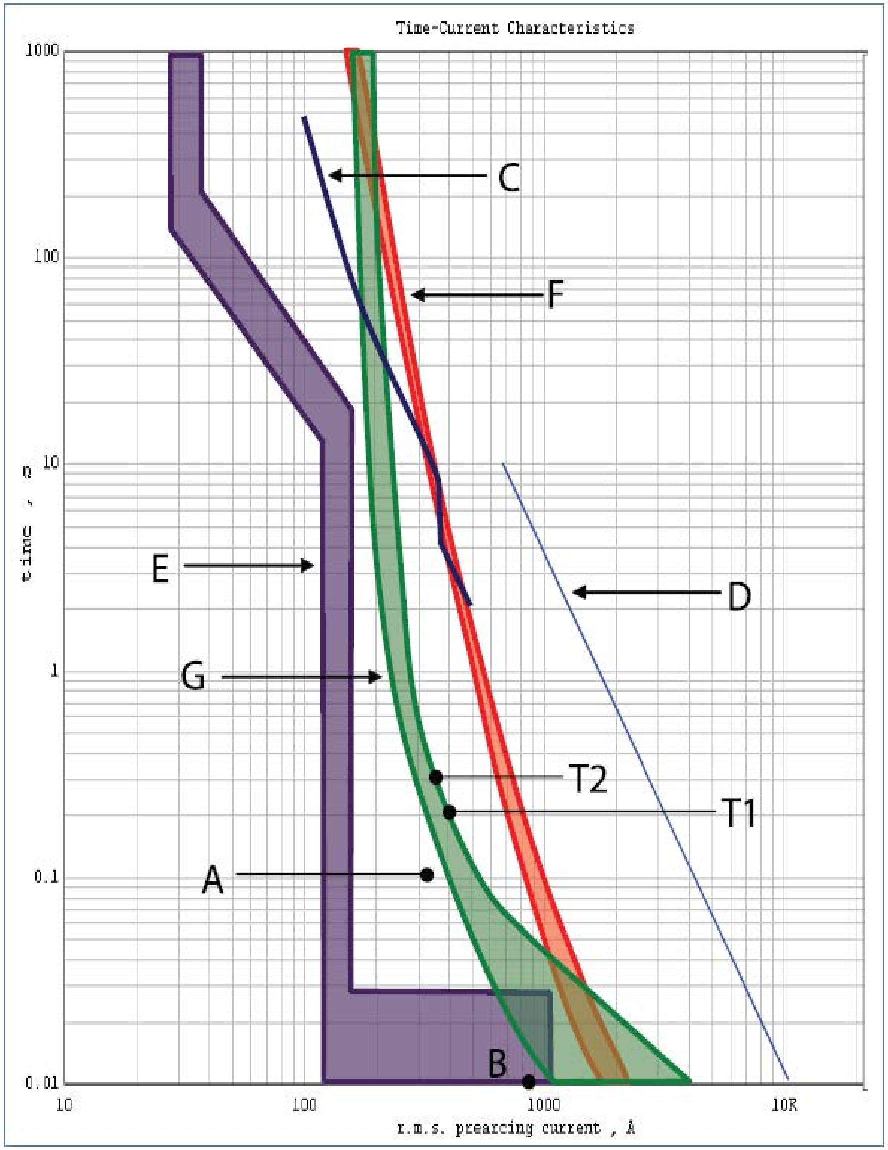


Figure 7 Time Current Curve evaluation for replacement fuse.

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Final Results

Incident energy calculations using the time current curves of the replacement fuse.

			9F62DDD080		9F62HMH080	
Percent of I_{Arc}	I_{Arc} Secondary	I_{Arc} Primary	Total Clearing Time	Incident Energy	Total Clearing Time	Incident Energy
100%	11,322 A	394 A	6.7 Seconds	73 cal/cm^2	0.2 Seconds	7.8 cal/cm^2
85%	9,624 A	335 A	16 Seconds	61 cal/cm^2	0.3 Seconds	11 cal/cm^2

Summary - Questions?

- Arc Flash Mitigation is easier with tools for various situations. Fuses can uniquely solve some challenges through current limitation. This webinar reviewed the concepts of using current limitation to reduce incident energy through low voltage UL and medium voltage E-Rated fuses. UL classifications were correlated to their current limitation and arc flash reduction.
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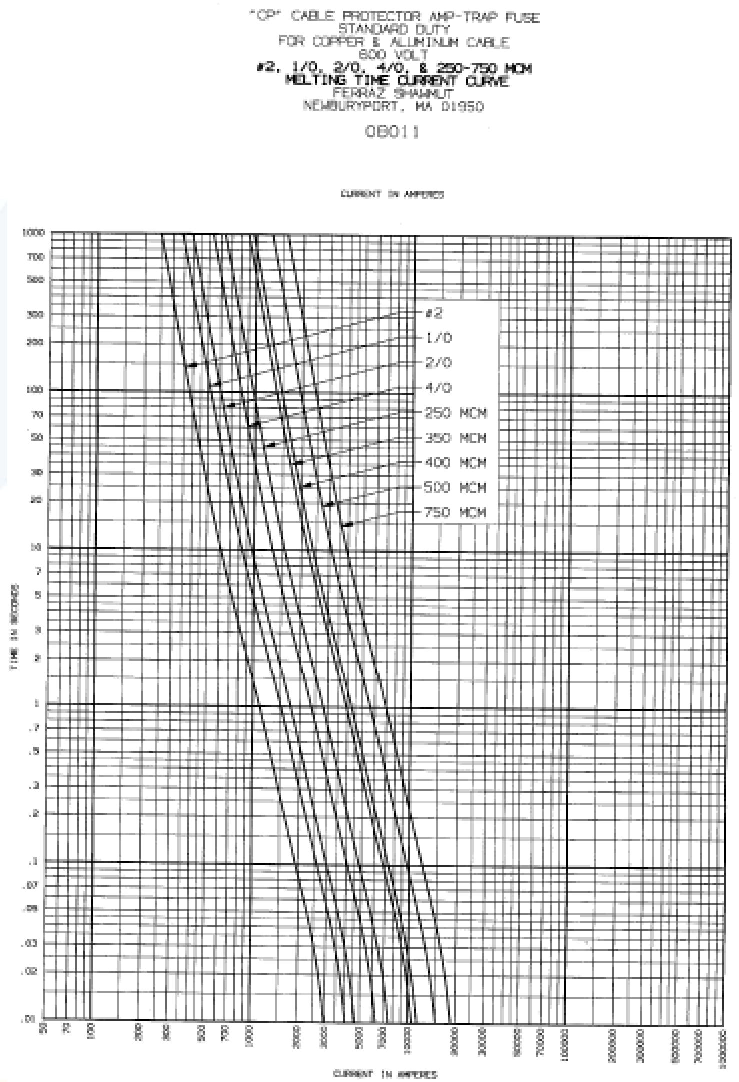
Question: I would like to find out if cable protectors can be used on the secondary side of transformers such to lower the incident energy available on the line side of the secondary main disconnecting device?

Cable Limiter Impact

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