

# Motor Protection

Presented By  
Scott Peele PE



**Progress Energy**

# Motor Protection

- Overload on the motor load
  - ◆ Fuses
  - ◆ Heater
  - ◆ Magnetic relay
- Short Circuit on motor circuit
  - ◆ Fuses
  - ◆ Breakers
- Single Phasing

# Overload Protection

- NEC 430 Section
  - ◆ Part III
- Fuses
- Heater
- Magnetic Relays

# Motor Information Web Links

- <http://www.bussmann.com/services/training>
- <http://search.squared.com:8765/>  
**Search for: 9065PD9301.pdf**
- <http://www.cutler-hammer.eaton.com/unsecure/cms1/TB03305001E.PDF>

# Motor Protection

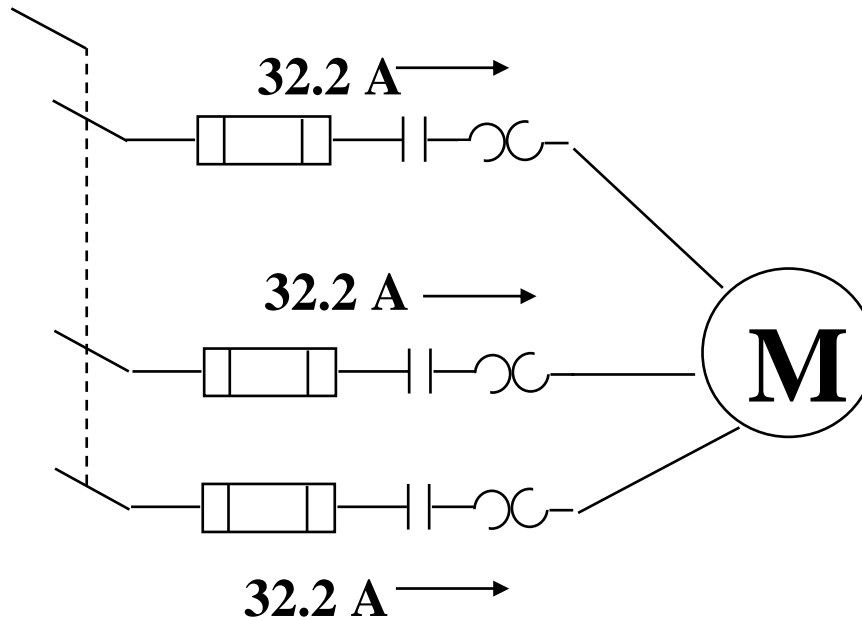
- Agenda
  - ◆ Motor Circuit Characteristics
  - ◆ Protection from Overcurrents
  - ◆ Motor Circuit Requirements
  - ◆ Sizing OCPD's
  - ◆ Single Phasing Protection

# Motor Protection

- How does a motor operate?
  - ◆ Starting
  - ◆ Normally
- What do we protect against?
  - ◆ Overload
  - ◆ Short-Circuit

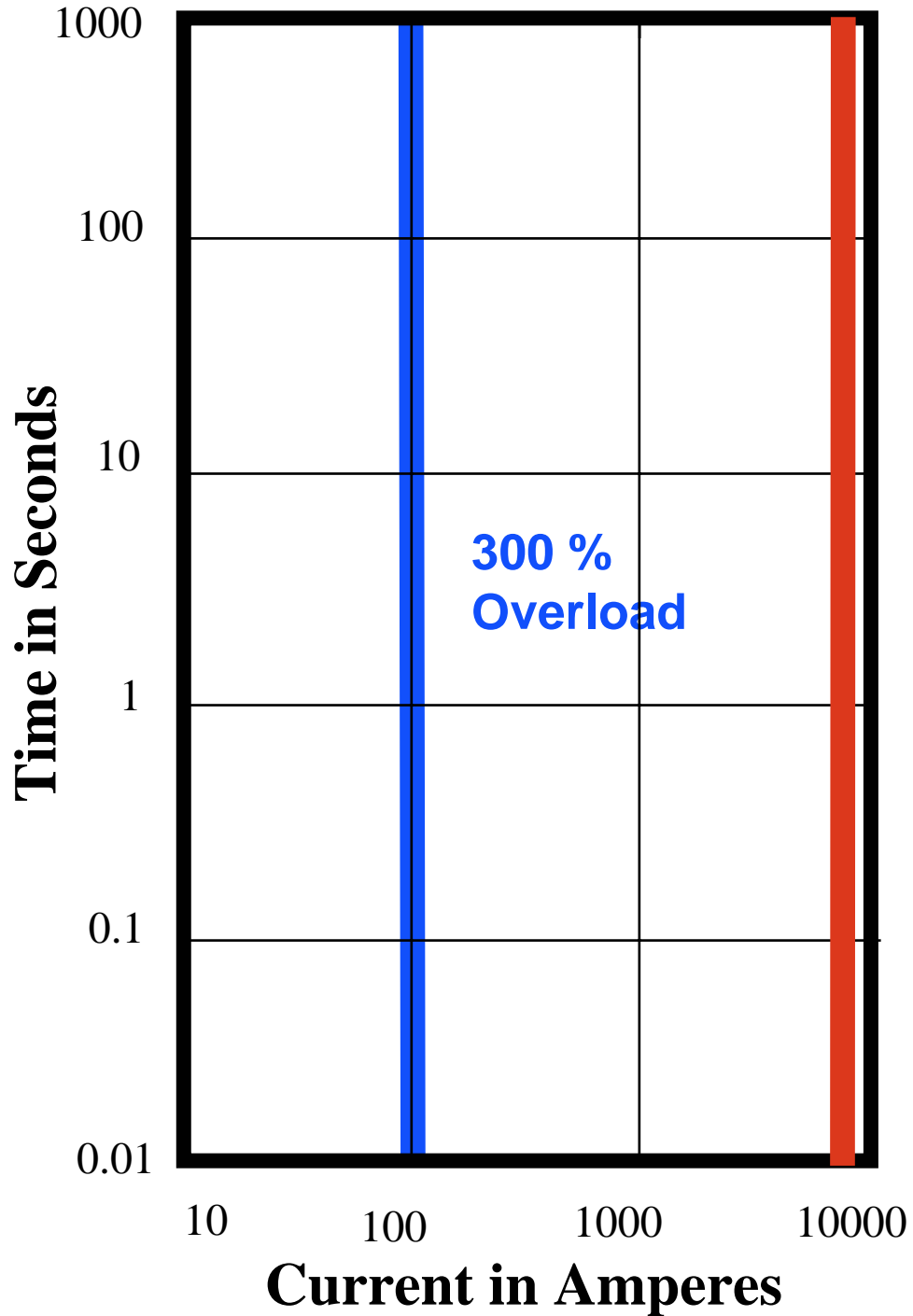
# Motor Circuit

## Normal Condition



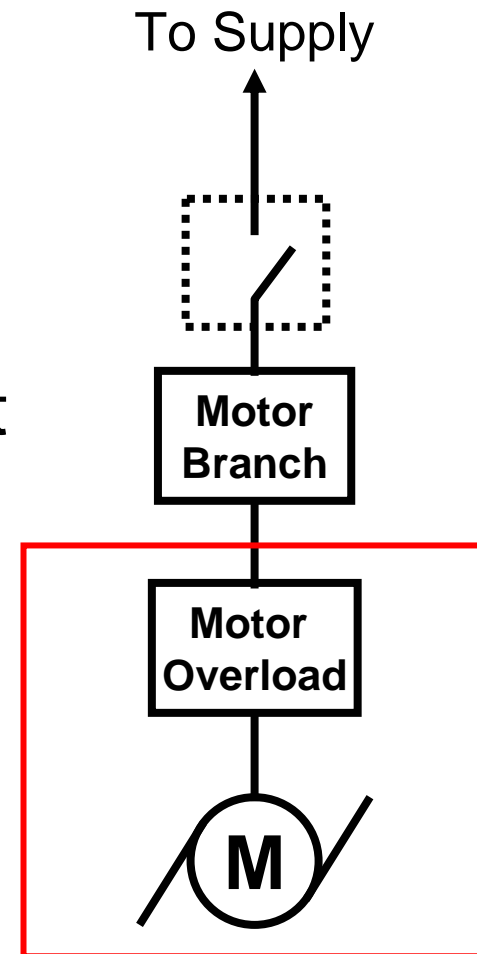
208 V 10 HP Motor 40°C

F.L.A. = 32.2 Amperes



# Motor, Motor Circuit, and Controllers (NEC<sup>®</sup>) Section 430

- Part IX
  - ◆ Disconnecting means
- Part IV
  - ◆ Branch-Circuit Short-Circuit
- Part III
  - ◆ Overload Protection



# Motor and Motor Circuit Protection

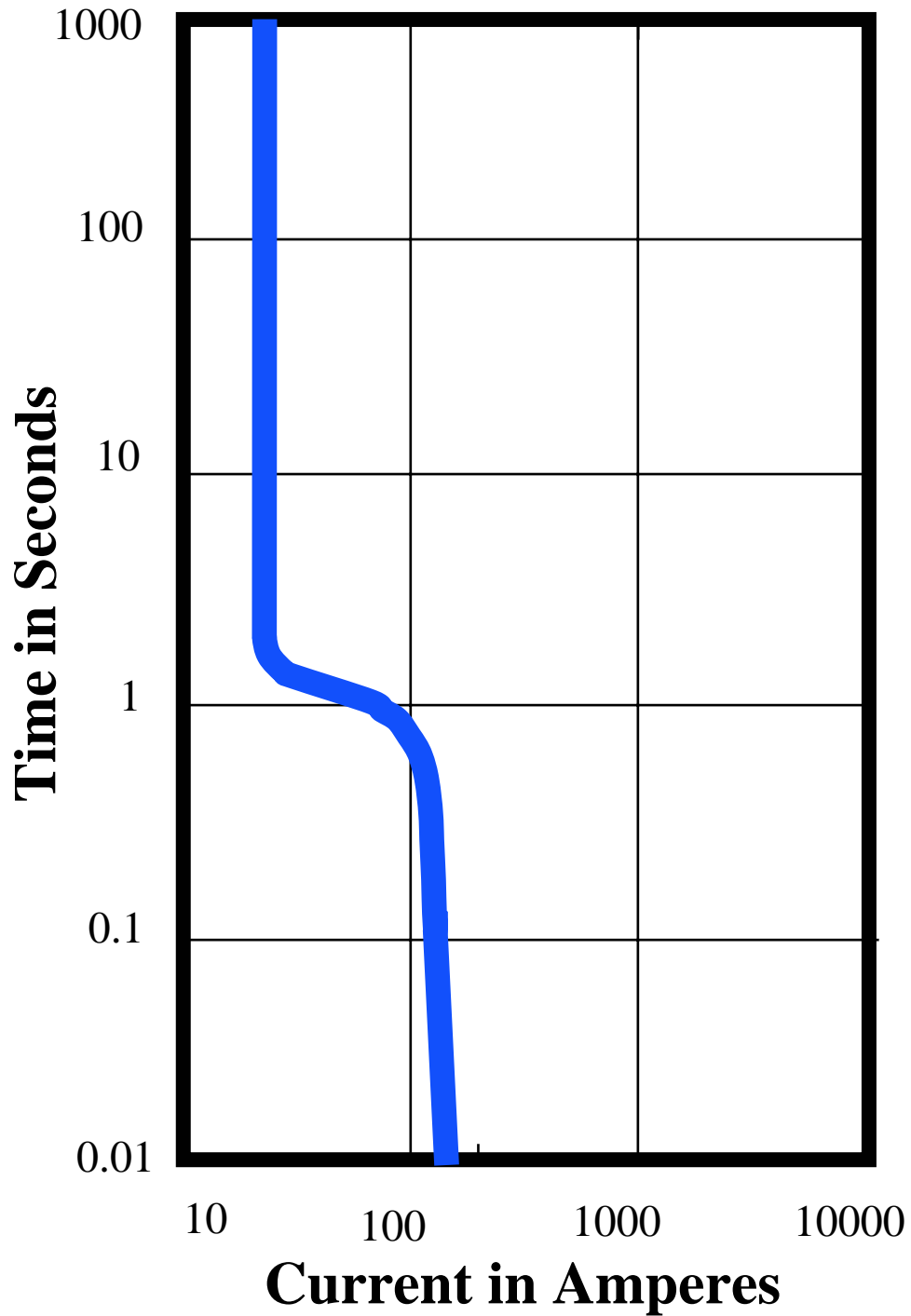
- NEC® 430.52
  - ◆ Branch-Circuit Short-Circuit Protection
  - ◆ (B) Must handle starting current
  - ◆ (C) Rating or Setting
    - ◆ (1) Table 430.52
      - ◆ Exception 1: Next Higher size is permitted if the values from table 430.52 do not correspond to a standard size

# Motor and Motor Circuit Protection

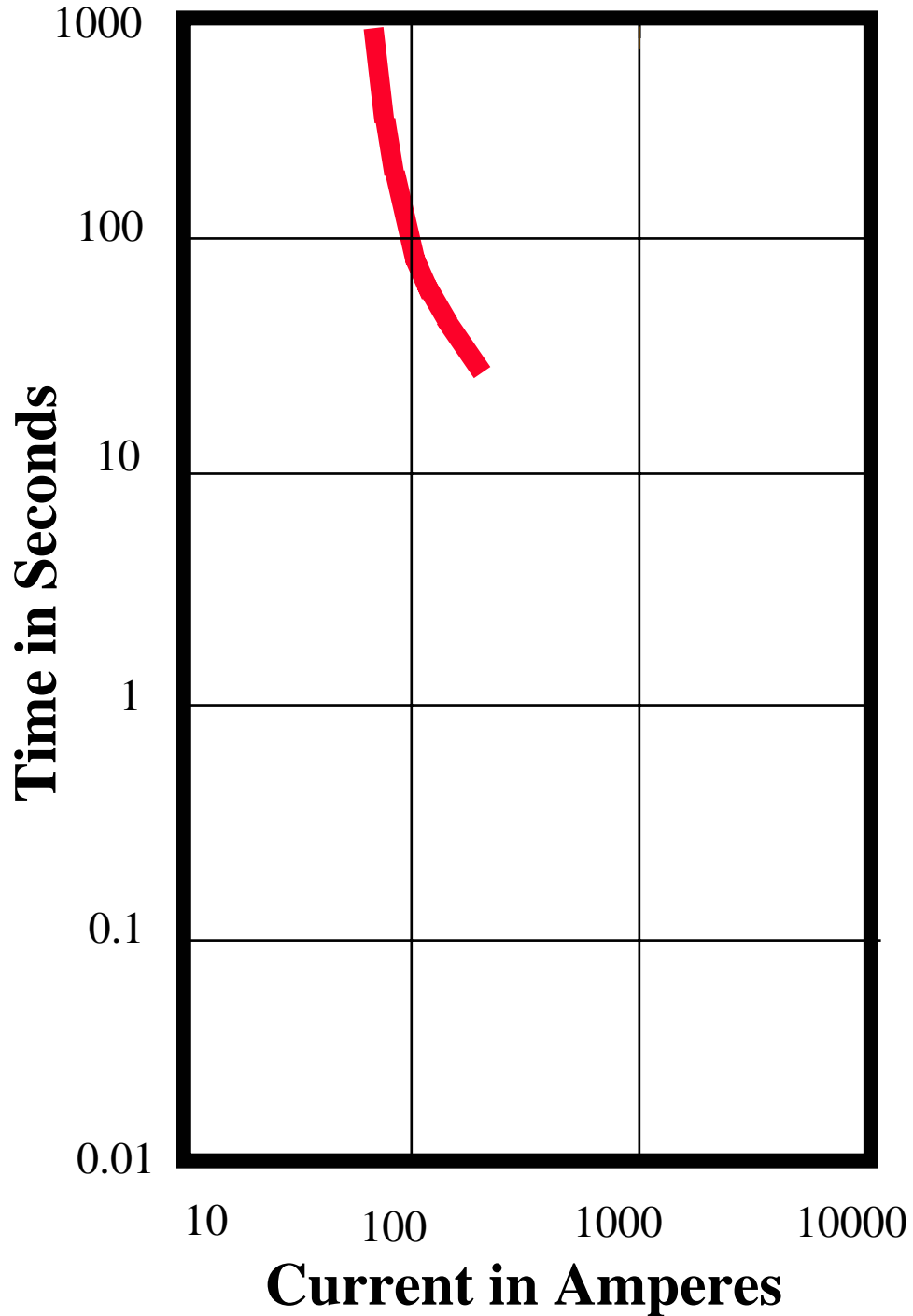
- NEC® 430.32 (Overload Protection)
  - ◆ (a) More than 1 Horsepower.
  - ◆ (1) A separate overload device that is responsive to motor current. This device shall be selected to trip or rated at no more than the following percent of the motor nameplate full-load current rating.
    - ◆ Motors with a marked service factor 1.15 or greater - 125%
    - ◆ Motors with a marked temperature rise 40 °C or less - 125%
    - ◆ All other motors - 115%

# Motor and Motor Circuit Protection

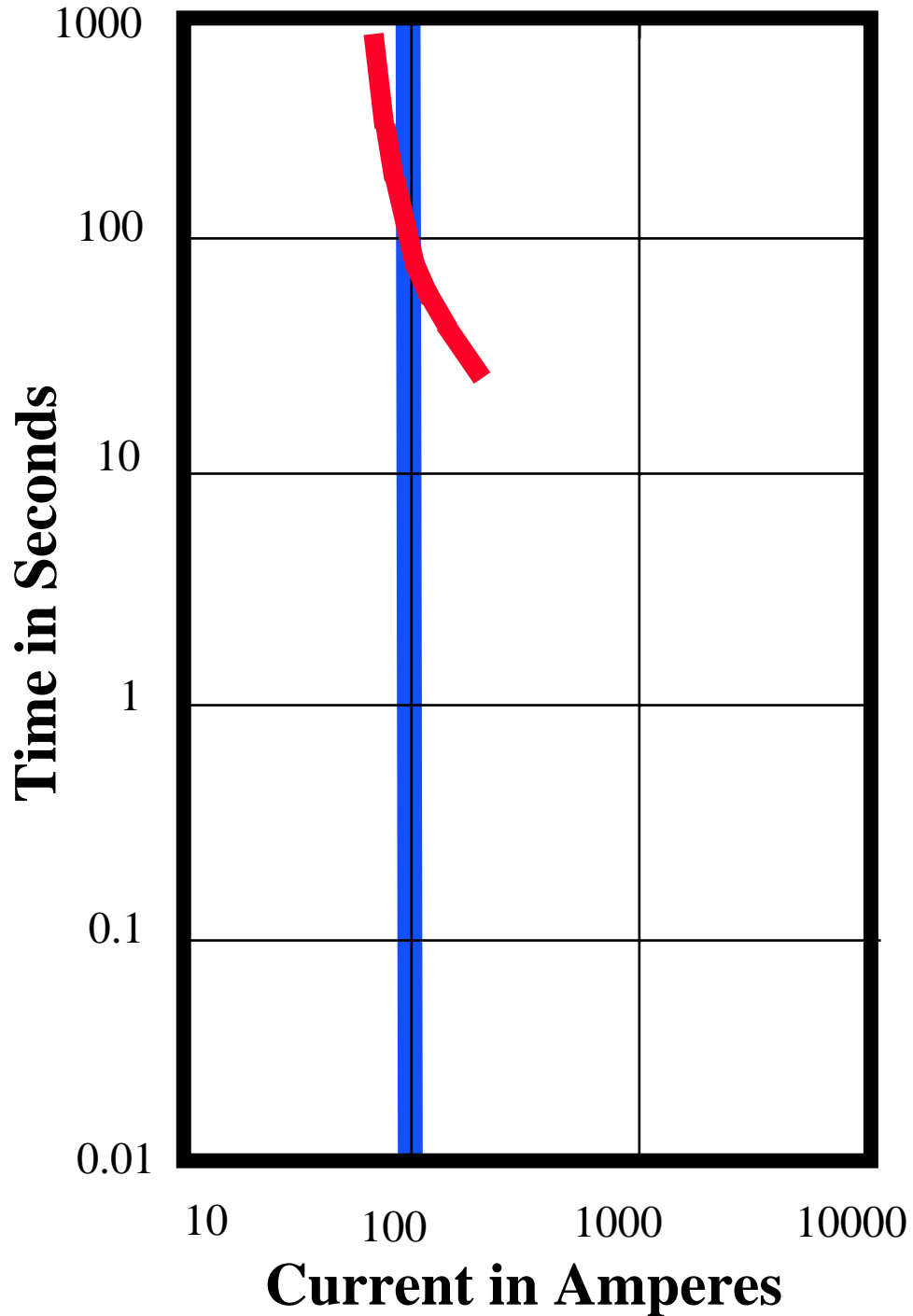
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**Motor Inrush  
Curve**



**Motor  
Damage  
Curve**

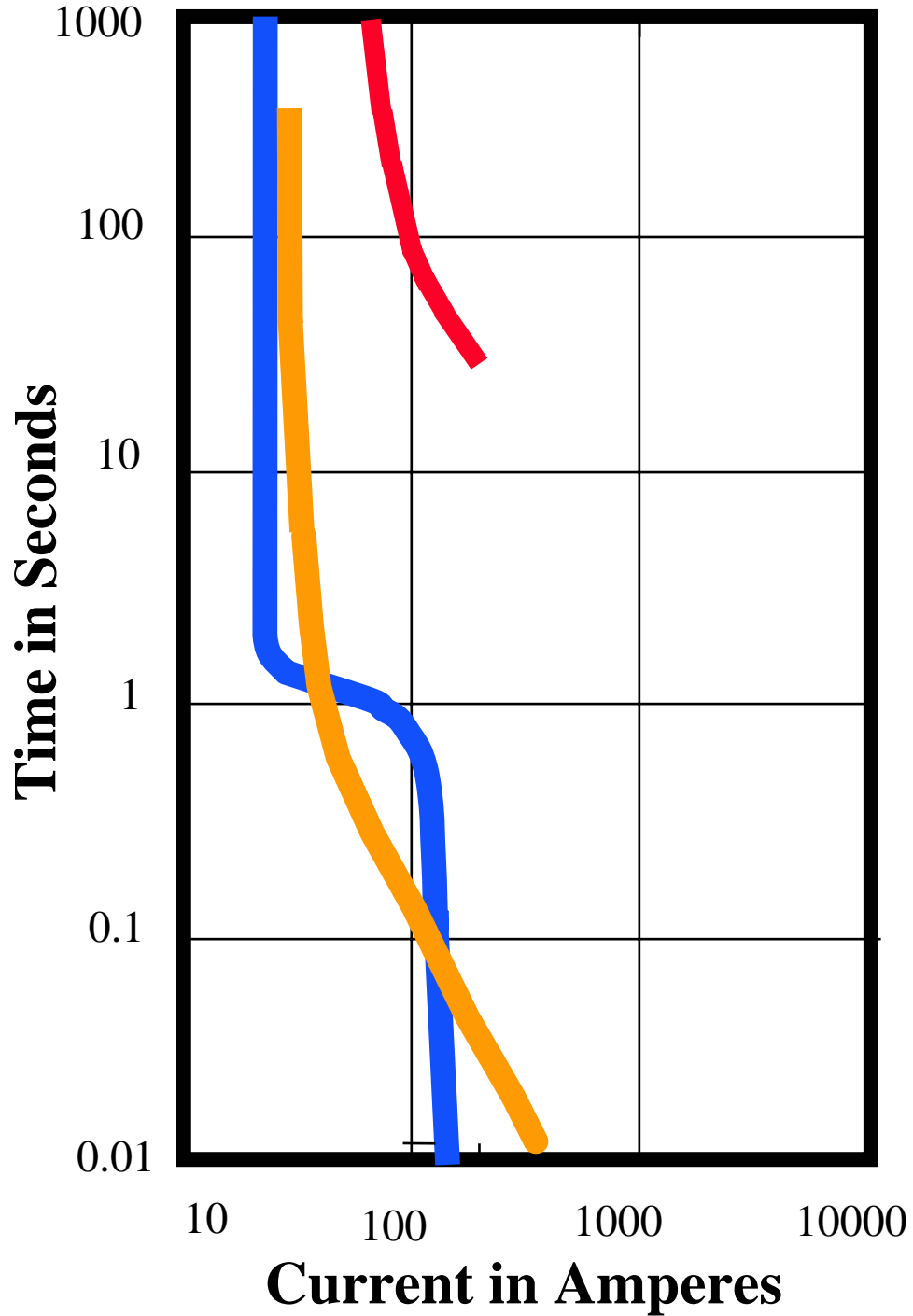


**Motor  
Damage  
Curve**

**300 %  
Overload**

# Over Load Protection Devices

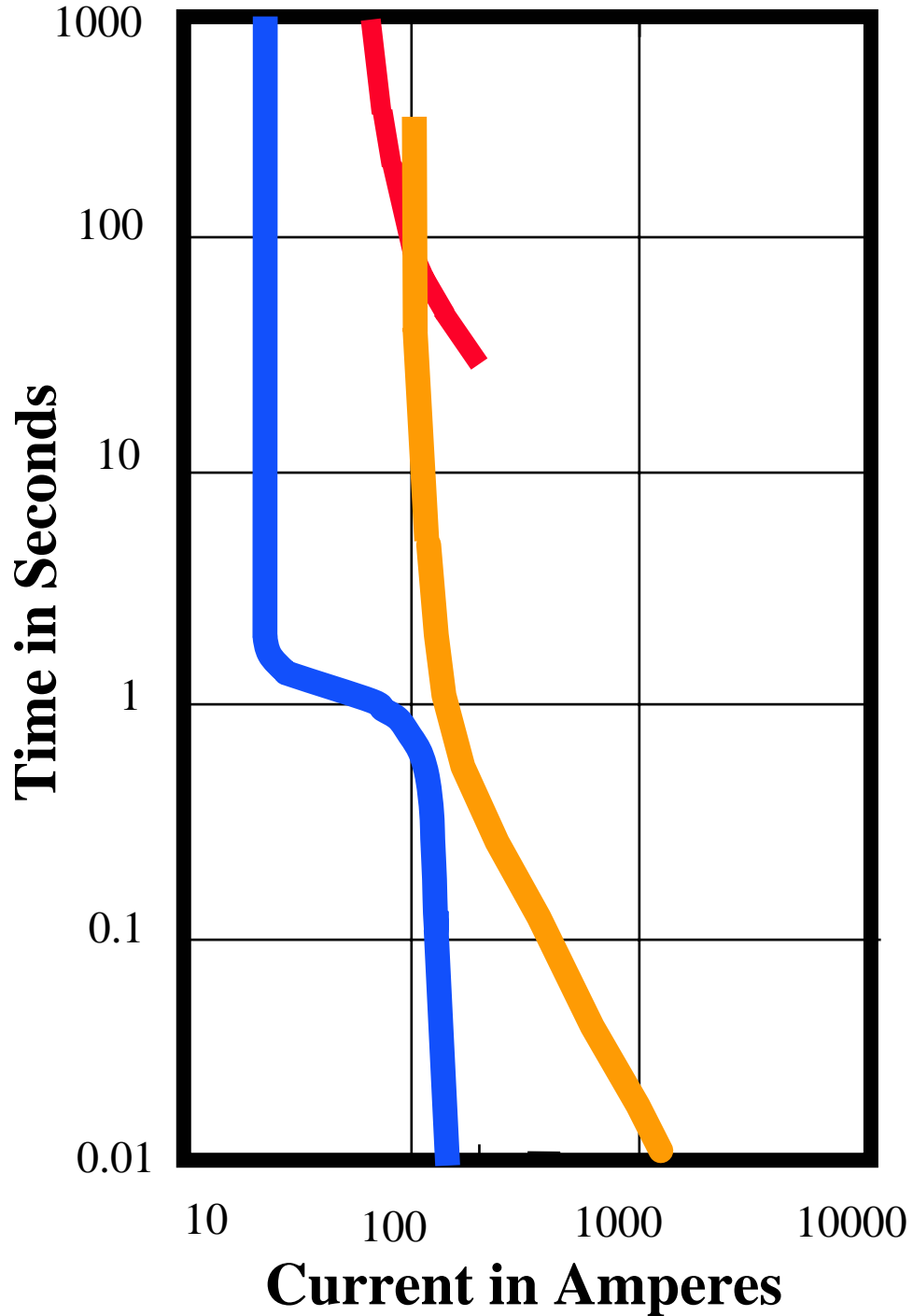
- Fuses
- Heater overload (Starters)
- Magnetic relays
- Thermal protector



**40 Amp Fuse  
Single  
Element**

**Motor  
Damage  
Curve**

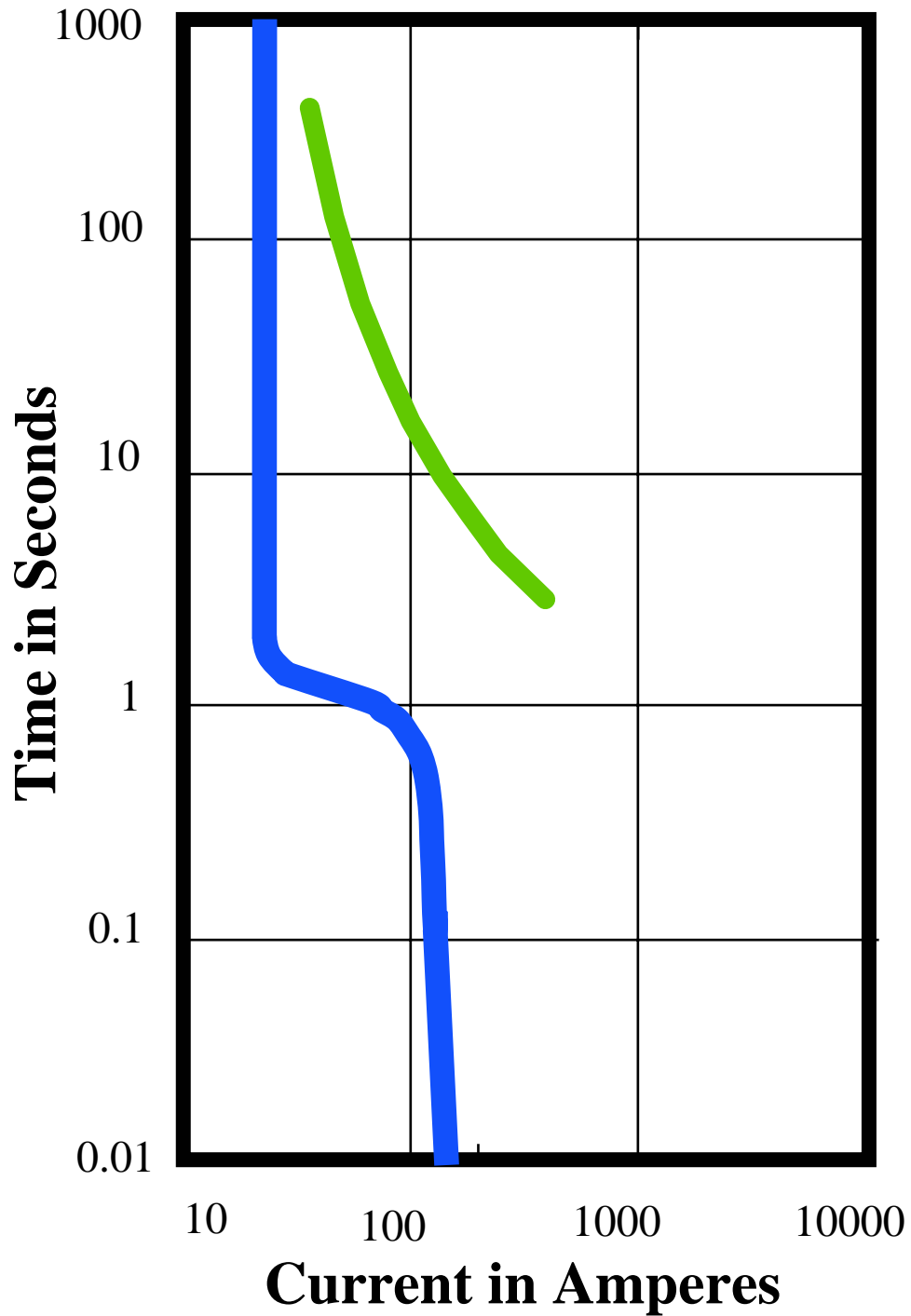
**Motor Inrush  
Curve**



**100 Amp Fuse  
Single  
Element**

**Motor  
Damage  
Curve**

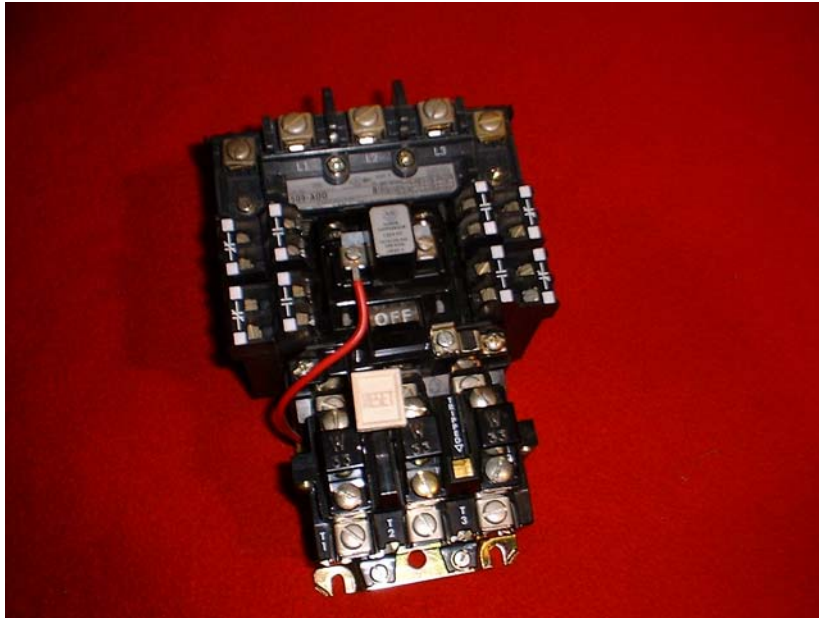
**Motor Inrush  
Curve**



**Motor Inrush  
Curve**

**Overload  
Heater Relay**

# Starter with Heaters



January 2003  
YES, Ref. No. [229]

Citation

## Replacement Capabilities (Continued)

### Overload Relay Heater Selection Tables

**Table 13-6. Type ST Standard Trip Eutectic Alloy**

For Replacement in Existing Applications Only; For Motors with 1.15 Service Factor

Table ST-1	Table ST-2	Table ST-3	Table ST-4	Table ST-5	Heater Catalog Number
NEMA Sizes 00, 0, 1, 1-1/2	NEMA Sizes 00, 0, 1, 1-1/2	NEMA Size 2	NEMA Size 2	NEMA Size 3	
For <i>Open</i> Type Catalog Prefix A10, A50, A700, B10, B50, C300 For <i>Enclosed</i> Type Catalog Prefix B10, B50, C300	For <i>Enclosed</i> Type Catalog Prefix A10, A50, A460 ①, A490 ②, A700	For <i>Open</i> Type Catalog Prefix A10, A50, A700, B10, C300 For <i>Enclosed</i> Type Catalog Prefix B10, C300, A30, A40, A70, A80, A800-A803	For <i>Enclosed</i> Type Catalog Prefix A10, A50, A460 ①, A490 ②, A700	For <i>Open</i> Type Catalog Prefix A10, A50, A700, B10, C300 For <i>Enclosed</i> Type Catalog Prefix A70, A80, A800-A803, A808-A809, B10	
Heater Ampere Range					
—	24.2 – 27.0	28.0 – 32.0	28.5 – 28.7	29.5 – 33.5	H1045
—	—	32.1 – 36.6	28.8 – 32.5	33.6 – 37.8	H1046
—	—	36.7 – 41.8	32.6 – 36.6	37.9 – 42.8	H1047
—	—	41.9 – 45.0	36.7 – 41.0	42.9 – 48.5	H1048
—	—	—	41.1 – 45.0	48.6 – 55.1	H1049
—	—	—	—	55.2 – 62.3	H1050
—	—	—	—	62.4 – 69.5	H1051
—	—	—	—	69.6 – 79.1	H1052
—	—	—	—	79.2 – 90.0	H1054
—	—	—	—	—	H1055
—	—	—	—	—	H1056
—	—	—	—	—	H1057
—	—	—	—	—	H1058

① For A460 controllers, select heaters at 50% of rated full load current.

② For A490 controllers, select heaters at 58% of rated full load current.

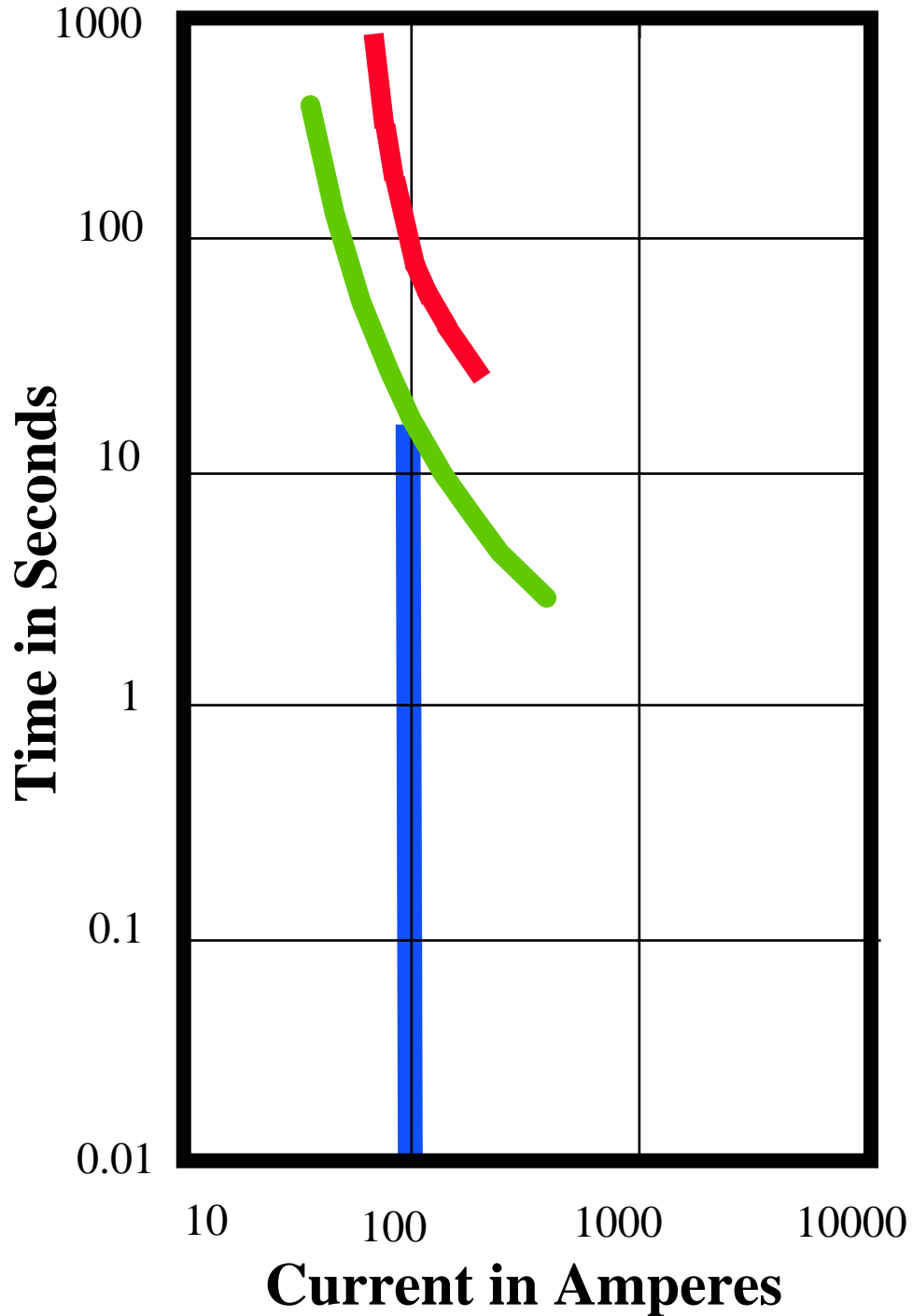
**Note:** Individually boxed heaters master packed 10 per carton.

CA08105001E

For more information visit: [www.cutler-hammer.eaton.com](http://www.cutler-hammer.eaton.com)

# Service Factor Note

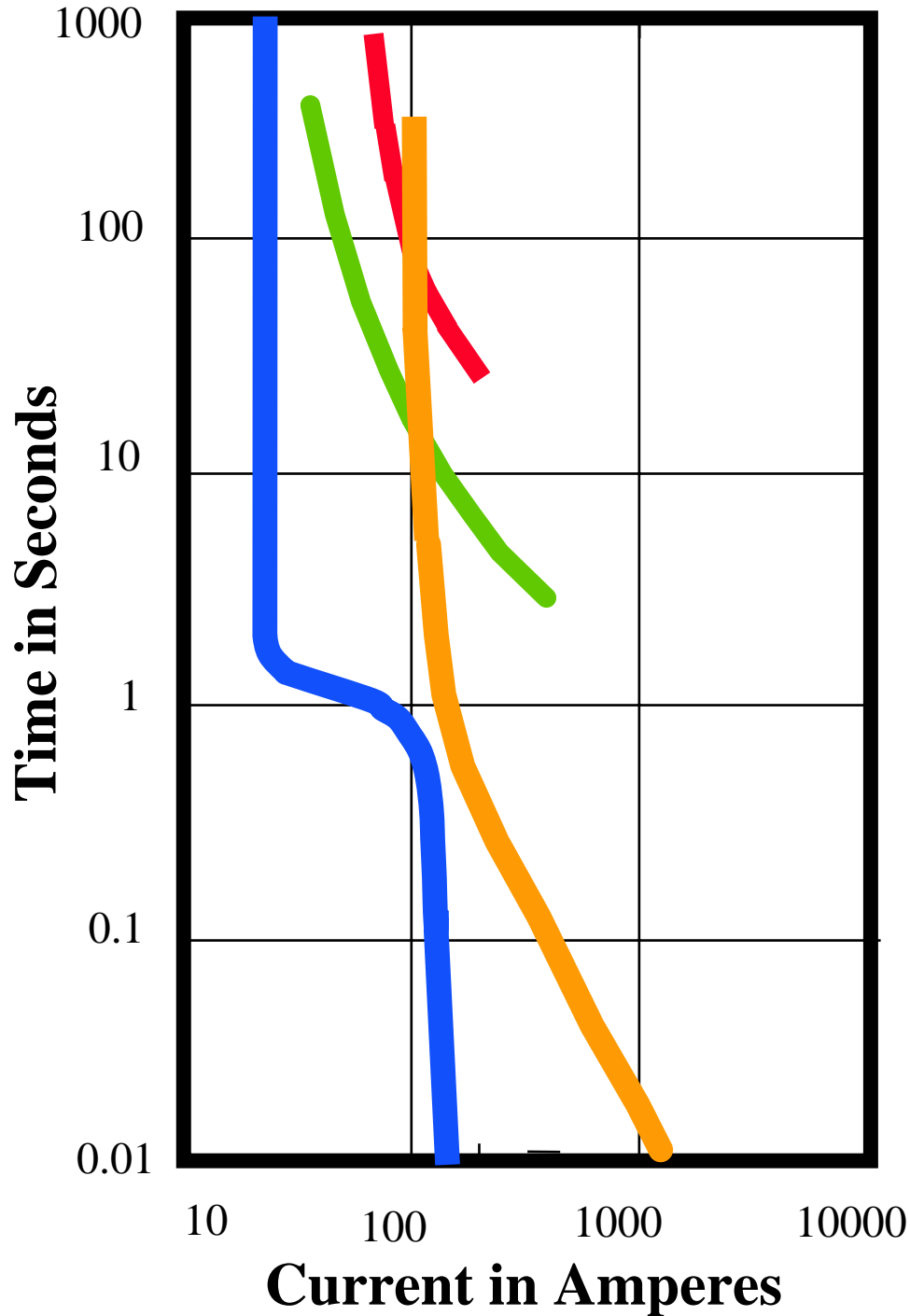
When motor and overload relay are in the same ambient and the service factor of the motor is 1.15 to 1.25, select heaters from the heater application table. If the service factor of the motor is 1.0, or there is no service factor shown, or a maximum of 115% protection is desired, select one size smaller heater than indicated.



**Motor  
Damage  
Curve**

**300 %  
Overload**

**Overload  
Heater Relay**

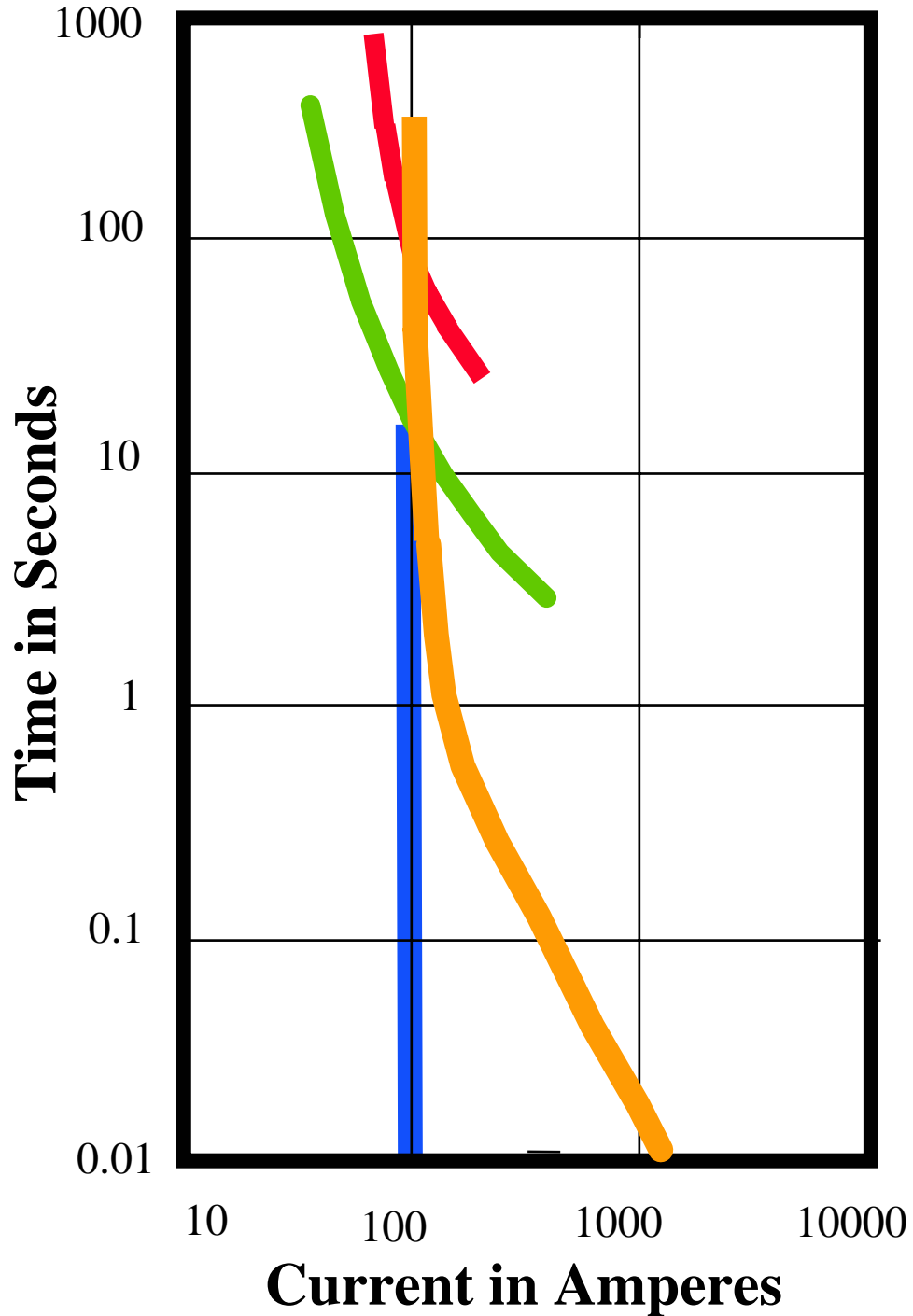


**100 Amp Fuse  
Single  
Element**

**Motor  
Damage  
Curve**

**Motor Inrush  
Curve**

**Overload  
Heater Relay**

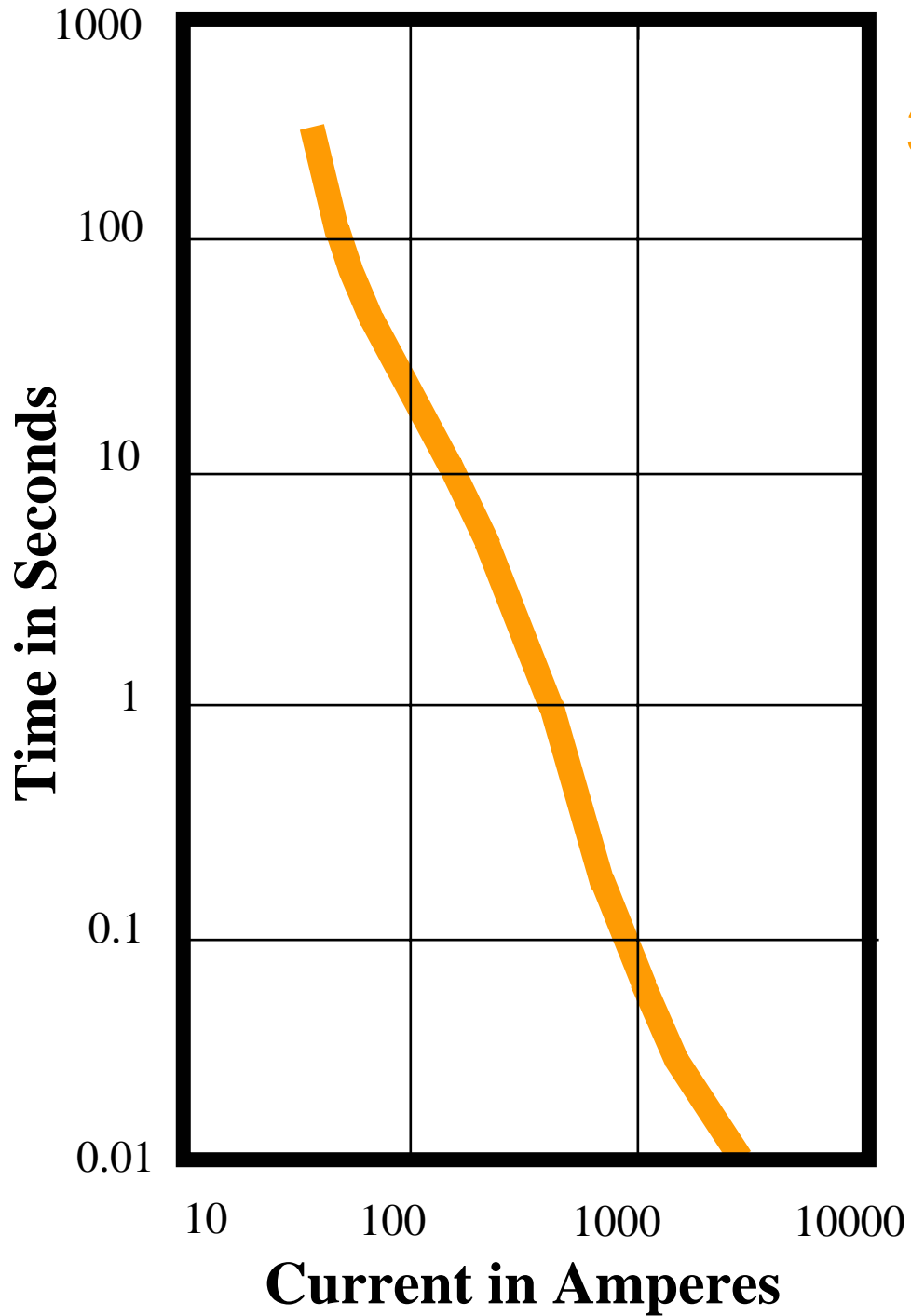


**100 Amp Fuse**  
**Single Element**

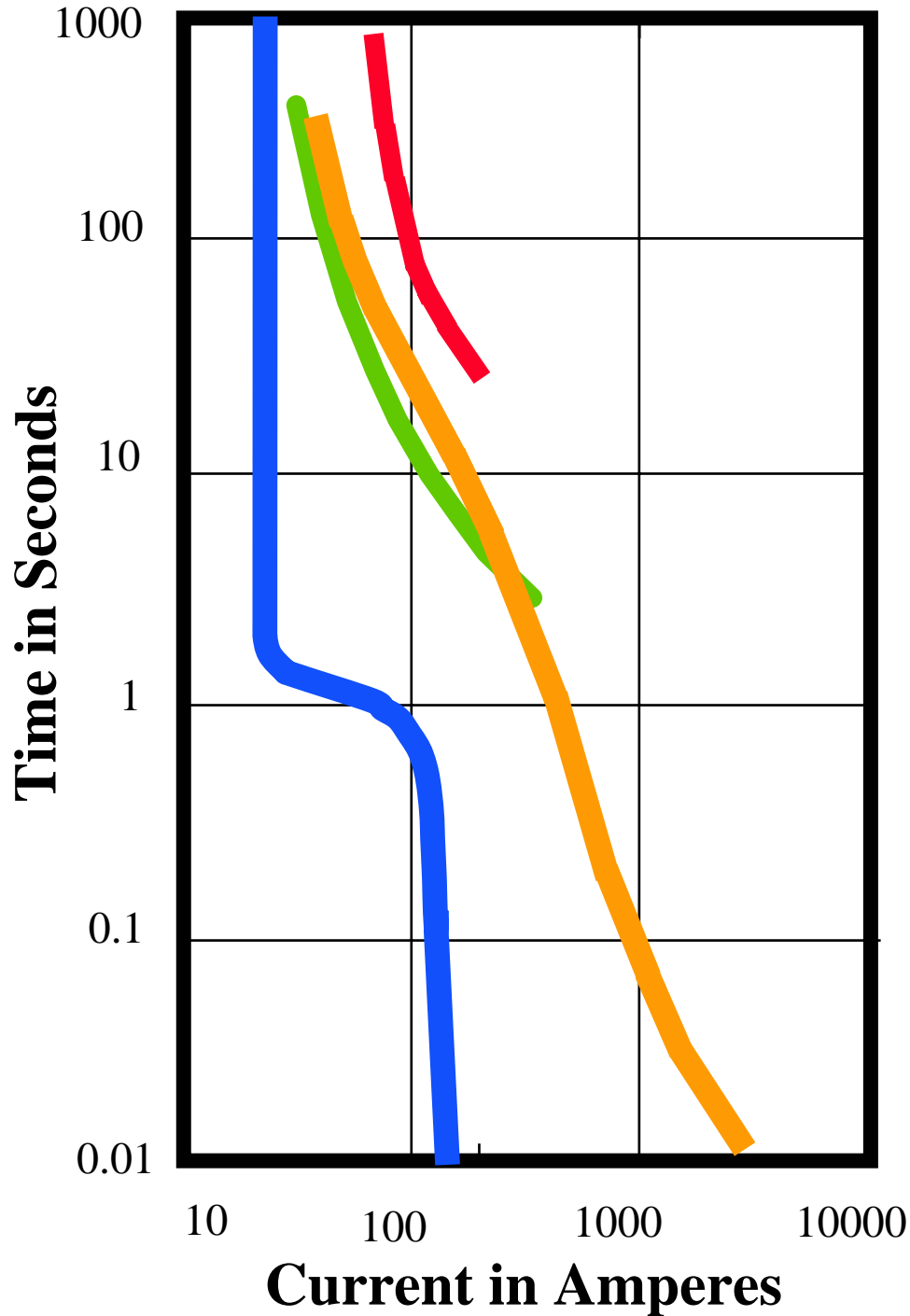
**Motor Damage Curve**

**300 % Overload**

**Overload Heater Relay**



**35 amp Fuse**  
**Dual Element**

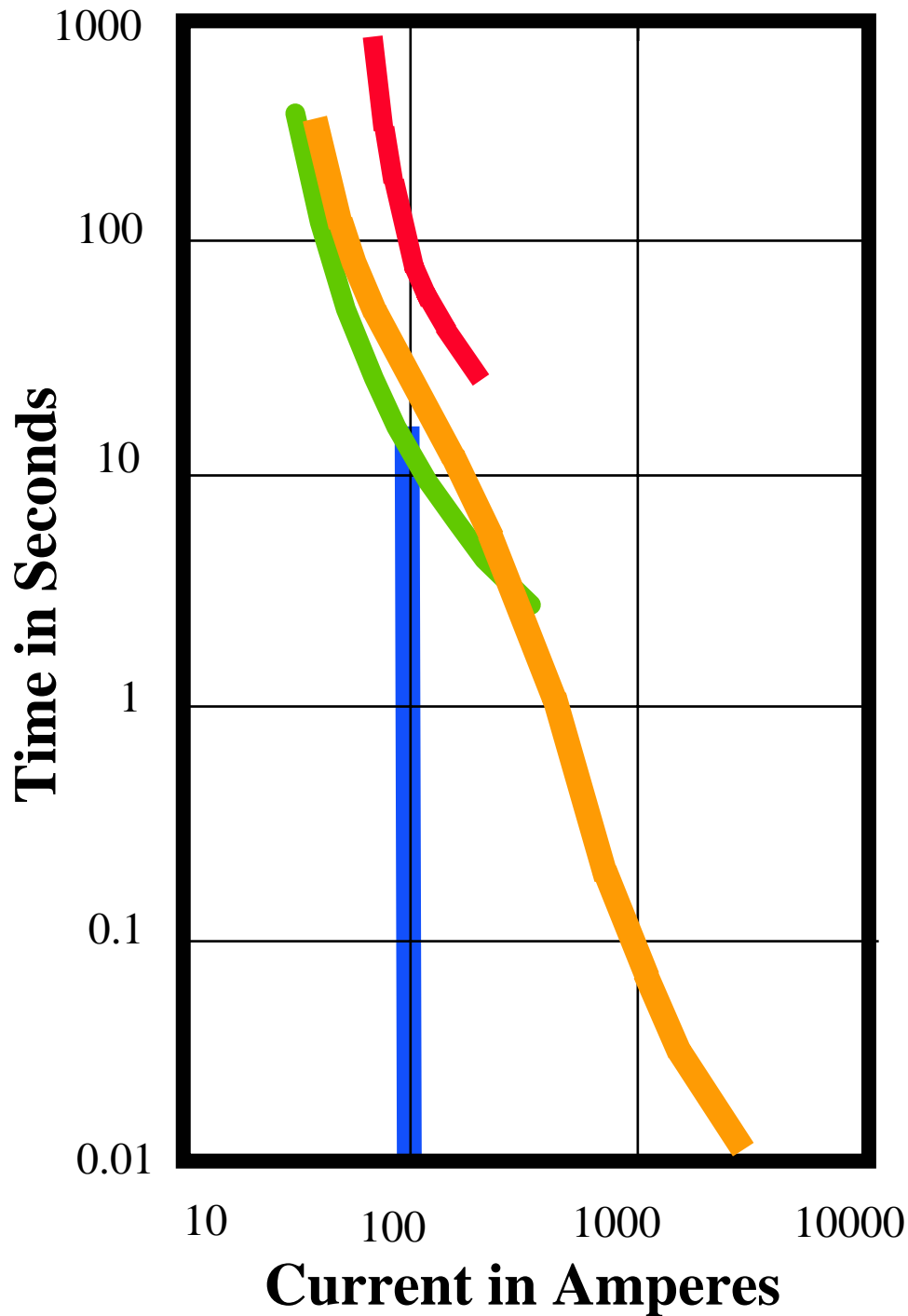


**35 Amp Fuse  
Dual Element**

**Motor  
Damage  
Curve**

**Motor Inrush  
Curve**

**Overload  
Heater Relay**



**35 Amp Fuse  
Dual Element**

**Motor  
Damage  
Curve**

**300 %  
Overload**

**Overload  
Heater Relay**

# Single-Phasing

- Single phasing is the opening of one phase of a three phase circuit.
  - ◆ Primary Open
  - ◆ Secondary Open

# Primary vs Secondary

- Primary or Secondary refers to the side of the transformer serving the load.
- Primary single phasing occurs when one phase of the primary side of the transformer serving the load is open.
- Secondary single phasing occurs when one phase of the circuit feeding the load is open.

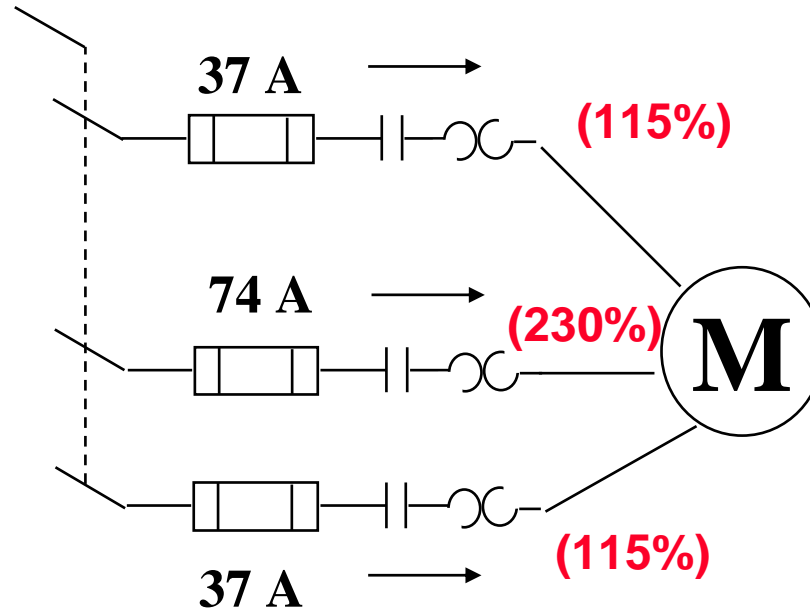
# Primary Single Phasing

- Primary wire broken by:
  - ◆ Storm - Wind - Ice - Sleet - Hail - Lightning
  - ◆ Vehicle or Plane Striking Pole
  - ◆ Falling Tree Limbs
  - ◆ Construction Mishaps
- Primary Fault
  - ◆ Bad Cable, Bad Transformer winding
  - ◆ Temporary Fault or Overload Causing Fuse to Blow

# Primary Single Phasing

## Single Phase Condition

Assume one phase lost on the primary side of transformer.



**208V 10 HP Motor 40 °C**

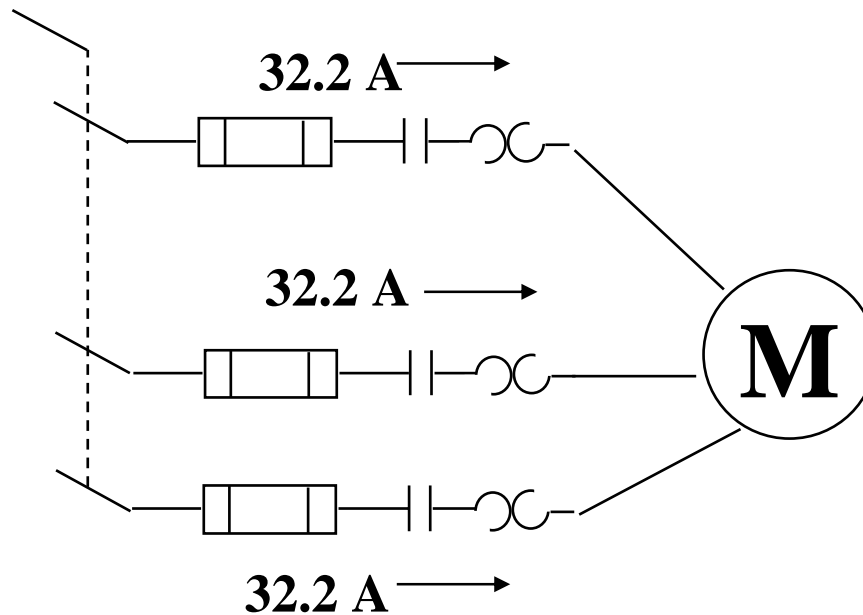
**F.L.A. = 32.2 Amperes**

# Secondary Single Phasing

- Damaged Motor Starter Contact - One Pole Open
- Burned open overload relay (heater)
- Damaged switch or circuit breaker on the main, feeder, or branch circuit.
- Open fuse or open pole in breaker on main, feeder, or branch circuit.
- Open cable or bus on secondary of transformer terminals

# Secondary Single Phasing

## Normal Condition



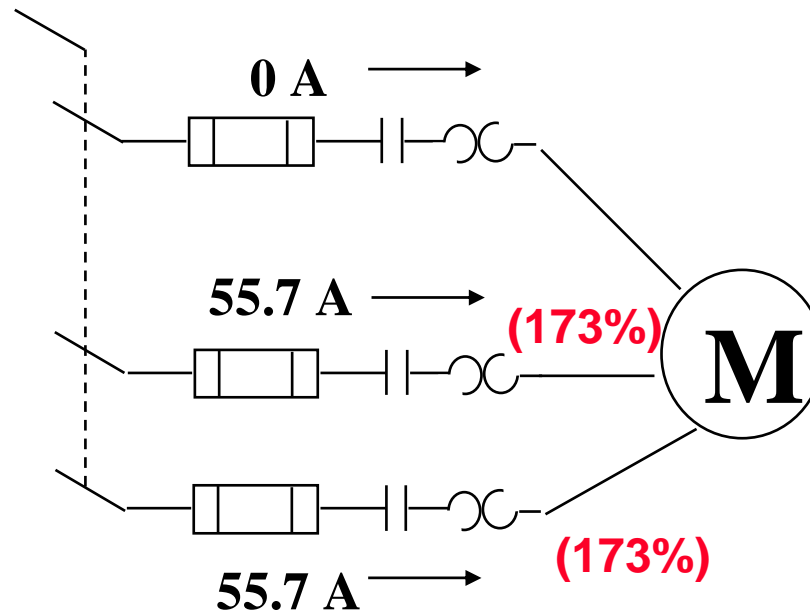
**208V 10 HP Motor 40 °C**

**F.L.A. = 32.2 Amperes**

# Secondary Single Phasing

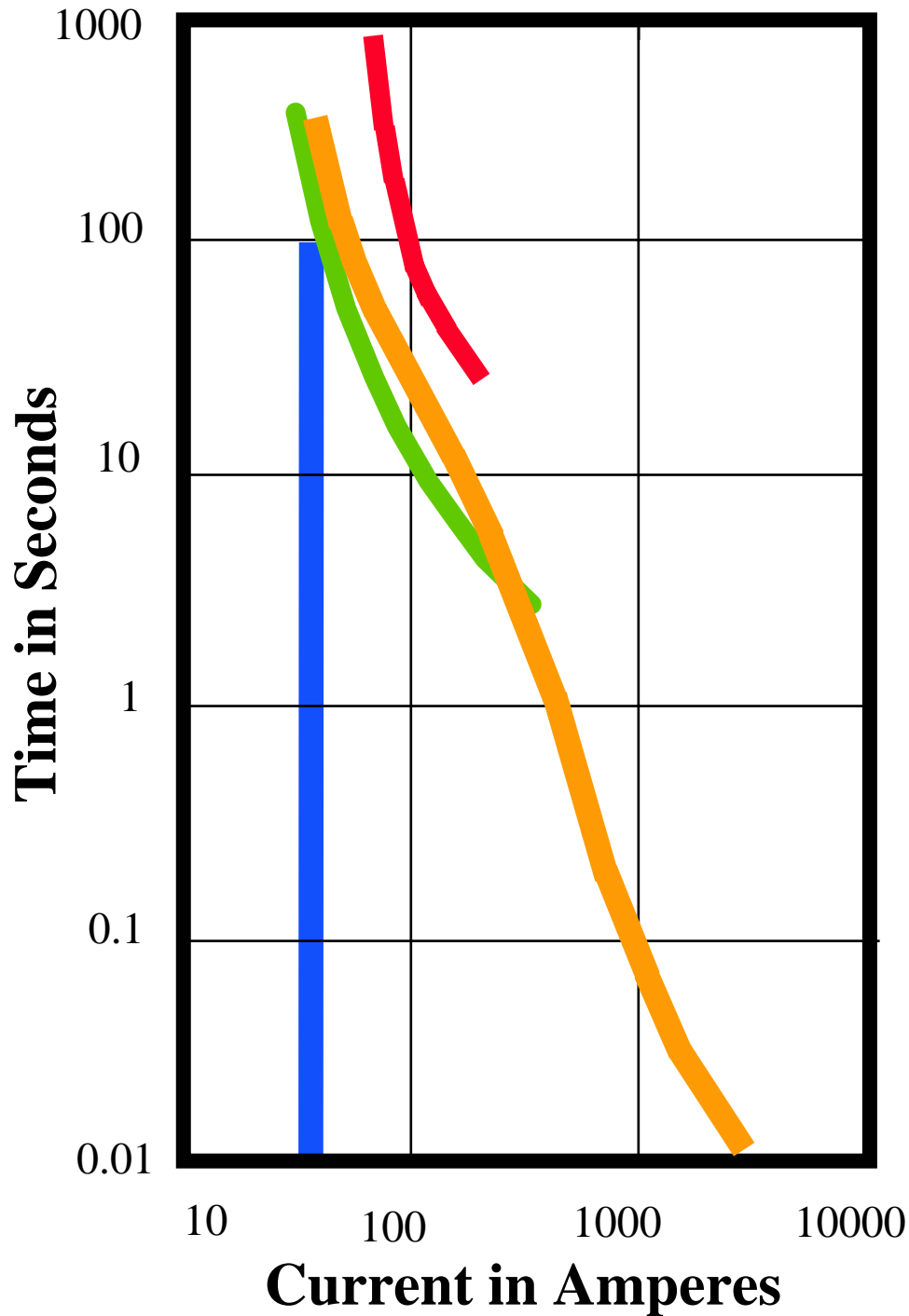
## Single Phase Condition

Assume one phase lost on the 208 V side of transformer.



**208V 10 HP Motor 40 °C**

**F.L.A. = 32.2 Amperes**



**35 Amp Fuse  
Dual Element**

**Motor  
Damage  
Curve**

**Secondary  
Single  
Phasing**

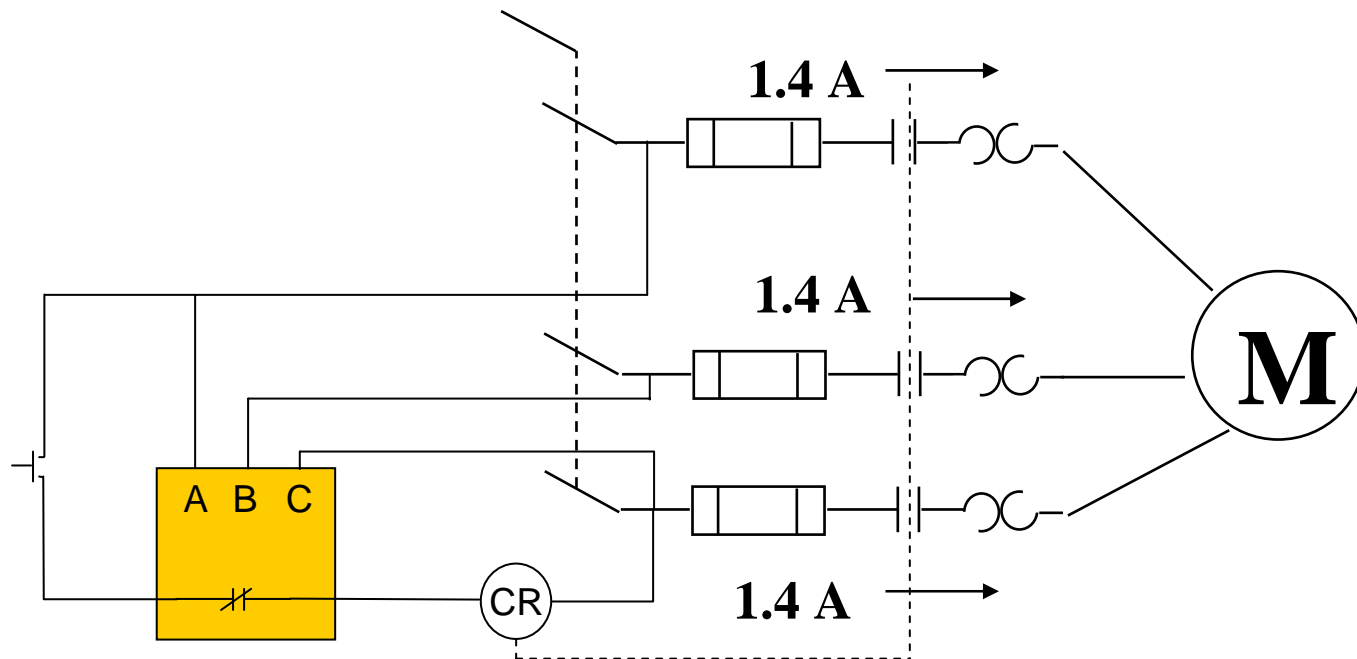
**Overload  
Heater Relay**

# Relay or Electronic Single Phasing Protection

- This system identifies voltage unbalance
- It will react faster than fuse or overloads.
- Better protection for single phasing events than overload devices.
- Higher Cost for protection

# Single Phasing Protection

## Normal Condition



Phase Monitor    208V 1/3 HP Motor    40 C°

F.L.A. = 1.4 Amperes

# Voltage Unbalance =

$$\frac{\text{Maximum Deviation for Average Voltage}}{\text{Average voltage}} \times 100 \text{ (for Percent)}$$

## EXAMPLE

	243 Volts	
Measured	241 Volts	239 Average Volts
Voltages	233 Volts	

$$\frac{6}{239} \times 100 = 2.5\% \text{ voltage unbalance}$$

# Part X Adjustable-Speed Drive System

- NEC® 430.124 (Overload Protection)
- Overload protection of the motor shall be provide.
  - ◆ **Included in Power Conversion Equipment** Where the power conversion equipment is marked to indicate that motor overload protection is included, additional overload protection shall not be required.
  - ◆ **Bypass Circuits** Article 430 Part III applies.

# Part X ASD Cont.

- NEC® 430.126 (Motor Overtemperature Protection)
  - ◆ ASD shall protect against motor overtemperature conditions
    - ◆ Motor Thermal protector
    - ◆ ASD controller with load and speed-sensitive overload protection and thermal memory retention upon shutdown or power loss.
    - ◆ Overtemperature protection relay with embedded sensors.
    - ◆ Thermal sensor embedded in motor for ASD to act upon

# Food for Thought

- You Must Provide Protection on All Motors
- >25HP install Phase Monitors
- Adjustments on Monitor
- Nuisance trips for short term events
- Whole Plant Protection

# Motor Protection

**Questions?**