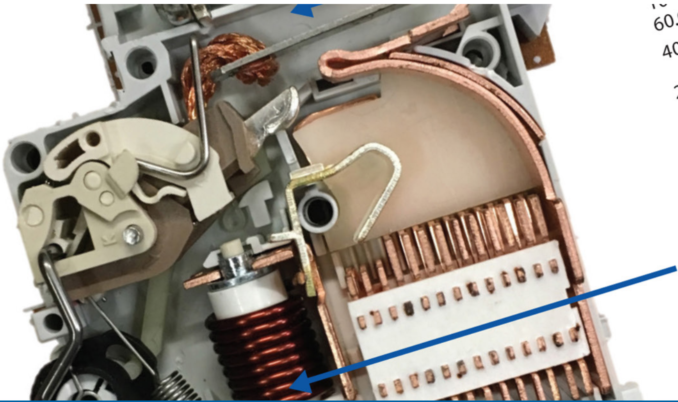
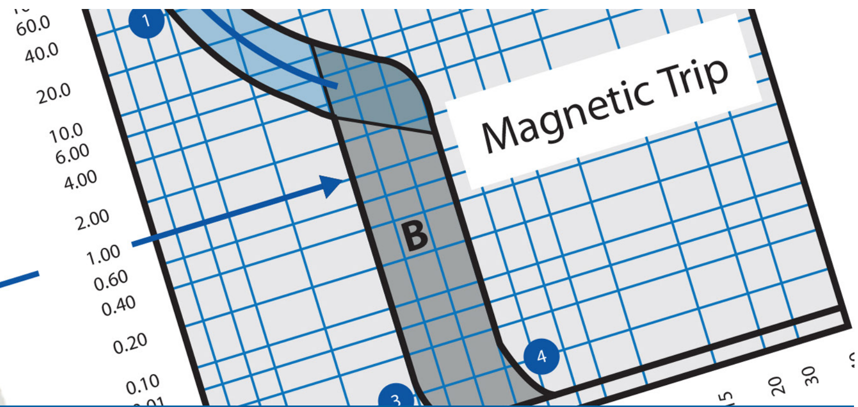




Understanding Trip Curves

Introduction to trip curves for UL 489 Miniature Circuit Breakers and UL 1077 Supplementary Protectors.

Trip Curves, aka Time Current Curves, can be an intimidating topic. The goal of this short paper is to introduce you to the concept of trip curves and explain how to read and understand them.

What is UL?

Underwriters Laboratories (UL) was established in 1894 as the Underwriters Electrical Bureau, a bureau of the National Board of Fire Underwriters. UL was founded primarily to provide independent testing and certification for the fire safety of electrical products. Those products include circuit protection devices discussed in this paper.

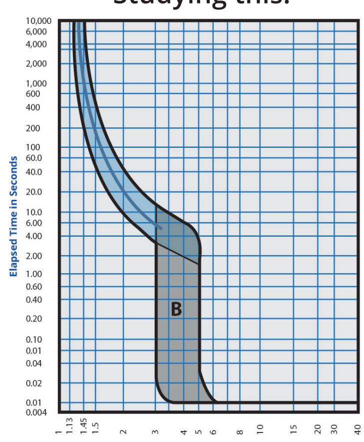
Circuit Protection Devices

Circuit protection is employed to protect wires and electrical equipment from damage in the event of an electrical overload, short circuit or ground fault. Lightning storms, overloaded power outlets, or a sudden electrical surge may result in a dangerous situation with the potential to cause fire, equipment damage or personal injury. Circuit protection is designed to eliminate this risk before it occurs by cutting off the power to the circuit.

What is a trip curve?

Simply put, a trip curve is a graphical representation of the expected behavior of a circuit protection device. Circuit protection devices come in many forms, including fuses, miniature circuit breakers, molded case circuit breakers, supplementary protectors, motor protection circuit breakers, overload relays, electronic fuses and air circuit breakers.

Studying this.



Tells you how this behaves.

Trip curves plot the interrupting time of overcurrent devices based on a given current level. They are provided by the manufacturers of circuit protection devices to assist users with selecting devices that provide proper equipment protection and performance, while avoiding nuisance tripping.

Different Types of Trip Curves

Most Common Trip Curves

B Curve	C Curve	D Curve
3-5X Instantaneous Tripping	5-10X Instantaneous Tripping	10-20X Instantaneous Tripping
Intended for resistive circuits	Intended for circuits with medium inductive loads	Intended for use in highly inductive and capacitive loads
Ex: Lighting, Control Circuits, Wire and Cable	Ex: Control Panels, Lighting, Coils	Ex: Motors, Transformers
UL 1077	UL 489, UL 1077	UL 489, UL 1077

More Specialized Trip Curves

S Curve	Z Curve	K Curve
13-17X Instantaneous Tripping	2-3X Instantaneous Tripping	10-14X Instantaneous Tripping
Intended for use in highly inductive loads	Intended for use in circuits that require a very low short circuit trip setting	Intended for use in highly inductive loads
Examples: Control Circuits, Light Filaments	Examples: Semiconductors and Control Circuits	Examples: motors and Transformers
UL 489, UL 1077	UL 489, UL 1077	UL 489, UL 1077

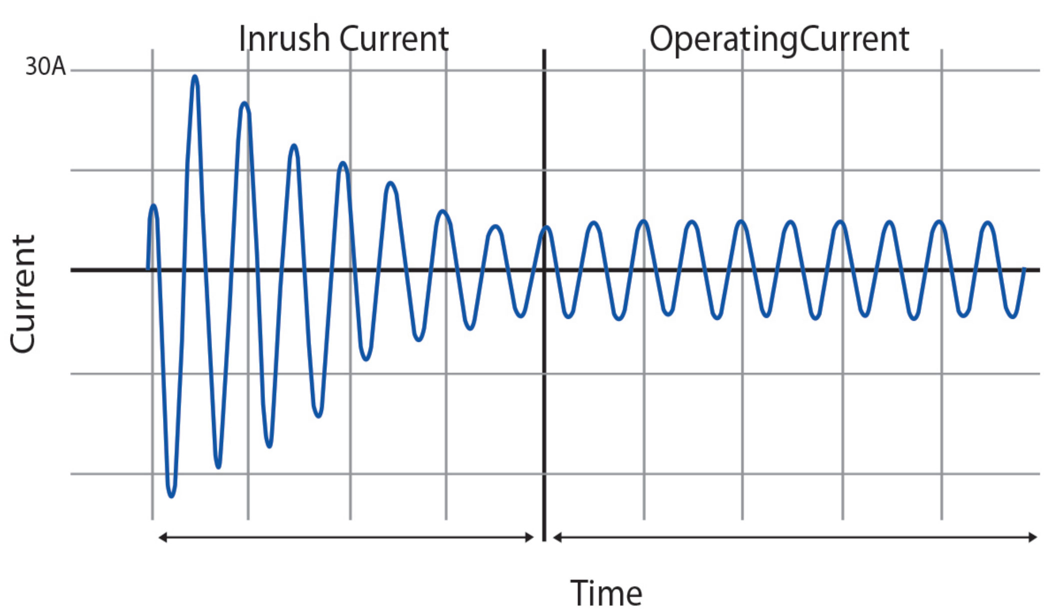
Why do we need different trip curves?

Circuit breakers must trip quick enough to avoid equipment or wiring failure, but not so fast as to give false, or nuisance trips.

To avoid nuisance trips, circuit breakers need to be sized appropriately to compensate for inrush current. NEMA defines instantaneous peak inrush *as the momentary current transient that occurs immediately (within half an AC cycle) after contact closure.*

Inrush current is what causes the lights to dim in a house when a motor, such as that on a clothes dryer or vacuum cleaner starts up.

Figure 2 (below) is an example of the inrush current for an AC motor.

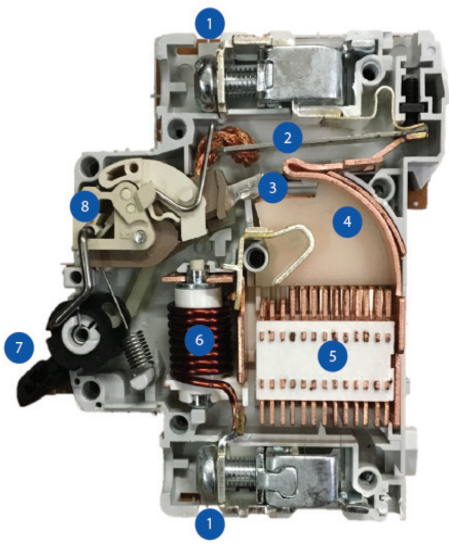


As the graph shows, the inrush current caused by switching the motor on is 30A. It is much higher than the operating, or steady state current. The inrush current peaks, then begins to decay as the motor spins up.

We need different trip curves in order to balance the right amount of overcurrent protection against optimal machine operation. Choosing a circuit breaker with a trip curve that trips too soon can result in nuisance tripping. Choosing a circuit breaker that trips too late can result in catastrophic damage to machine and cables.

How does a MCB work?

To understand a trip curve, it is helpful to understand how a miniature circuit breaker, or overcurrent protection device, functions. Figure 3 below is a look at the inside of a Miniature Circuit Breaker (MCB).



1. Terminal for line/load power.
2. Bi-metallic strip. Bends with heat (current), separates contacts in response to smaller, longer term over currents, tripping breaker.
3. Contacts. Current flows through when closed. Breaks current when separated.
4. Arc Chamber. Channels plasma arcing to arc divider.
5. Arc divider/extinguisher. Breaks main arc into smaller arcs and extinguishes them.
6. Coil/Solenoid. Separates contacts in response to high overcurrents, such as a short circuit.
7. Actuator lever. Manually trips or resets breaker.
8. Actuator mechanism. Forces contacts together or apart.

With both a bi-metallic strip (2) and a magnetic coil/solenoid (6), a miniature circuit breaker can be two separate types of circuit protection device in one. The bi-metallic strip provides overload protection in response to smaller overcurrents, typically 10X the operating current. The metallic strip consists of two strips of different metals, formed together, which expand at different rates as they are heated. In an overload situation, the bimetallic strip bends and this movement actuates a trip mechanism and breaks (opens) the circuit. The strip converts a temperature change into mechanical displacement.

The magnetic coil or solenoid (6) reacts to fast, higher overcurrents caused by short circuits, typically greater than 10X the operating current – up to tens or hundreds of thousands of amperes. The high current causes a magnetic field to be generated by the coil, moving the internal piston quickly (within microseconds) to trip the actuator mechanism and break the circuit.

The Trip Curve

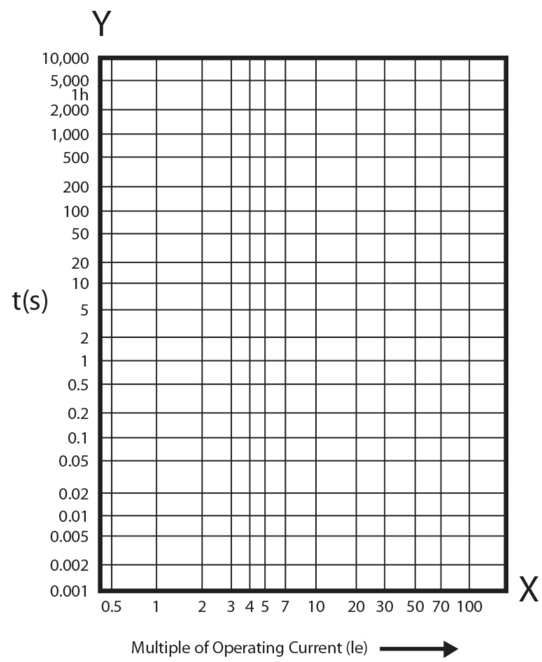


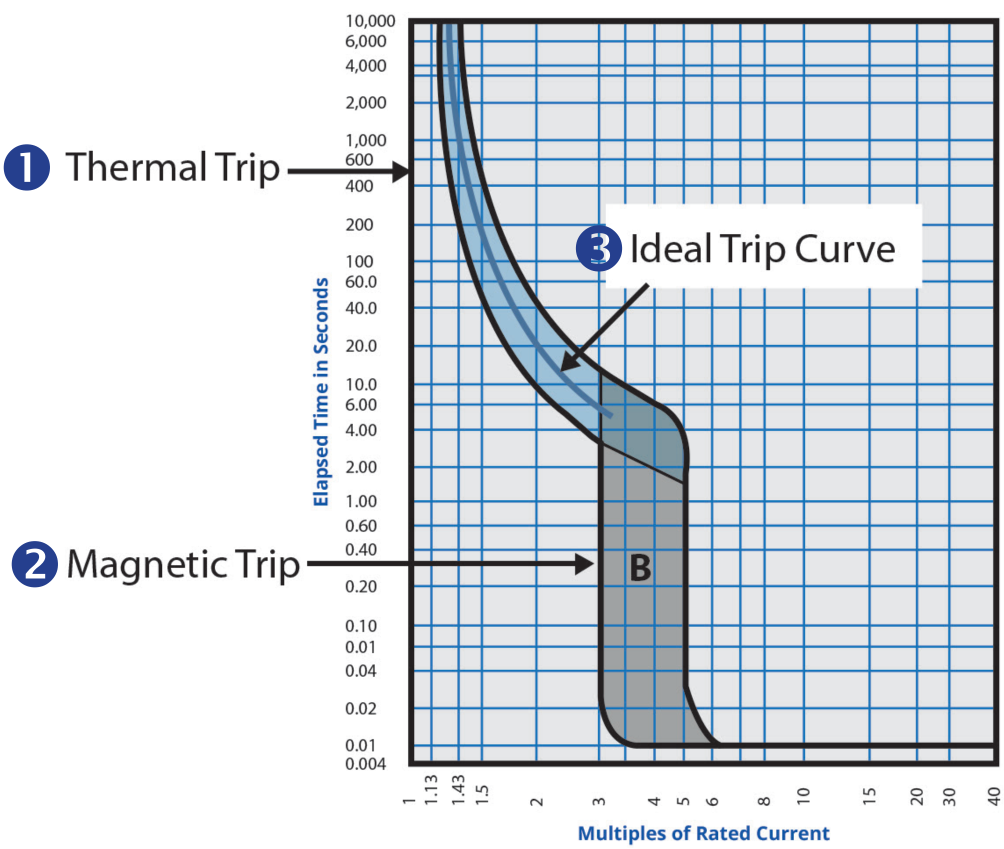
Figure 4 (on the right) is a Trip Curve chart.

- The X axis represents a multiple of the operating current of the circuit breaker.
- The Y axis represents the tripping time. A logarithmic scale is used in order to show times from .001 seconds up to 10,000 seconds (2.77 hours) at multiples of the operating current.

Figure 5 (below) shows a B Trip Curve overlaid onto the chart.

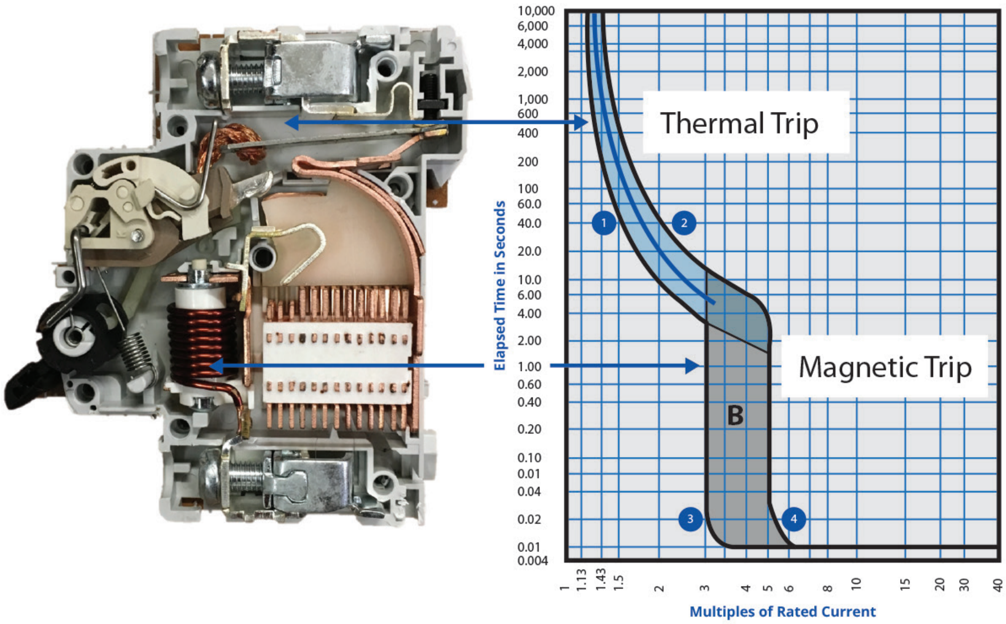
The three major components of the Trip Curve are:

1. Thermal Trip Curve. This is the trip curve for the bi-metallic strip, which is designed for slower overcurrents to allow for in rush/startup, as described above.
2. Magnetic Trip Curve. This is the trip curve for the coil or solenoid. It is designed to react quickly to large overcurrents, such as a short circuit condition.
3. The Ideal Trip Curve. This curve shows what the desired trip curve for the bi-metallic strip is. Because of the organic nature of the bi-metallic strip, and changing ambient conditions, it is difficult to precisely predict the exact tripping point.



How does a trip curve relate to an actual circuit breaker?

Figure 6 (below) shows how the internal components of the MCB relate to the trip curve.



The top of the chart shows the thermal trip curve for the bi-metallic strip. It tells us that at 1.5X the rated current the quickest the circuit breaker will trip is forty seconds (1). Forty seconds at 2X the rated current is the slowest the circuit breaker will trip (2).

The bottom of the chart is for the magnetic trip of the coil/solenoid; 0.02 to 2.5 seconds at 3X the rated current is the soonest the circuit breaker will trip (3). The same duration, 0.02 to 2.5 seconds, at 5X the rated current, is the longest it will take the circuit breaker to trip (4).

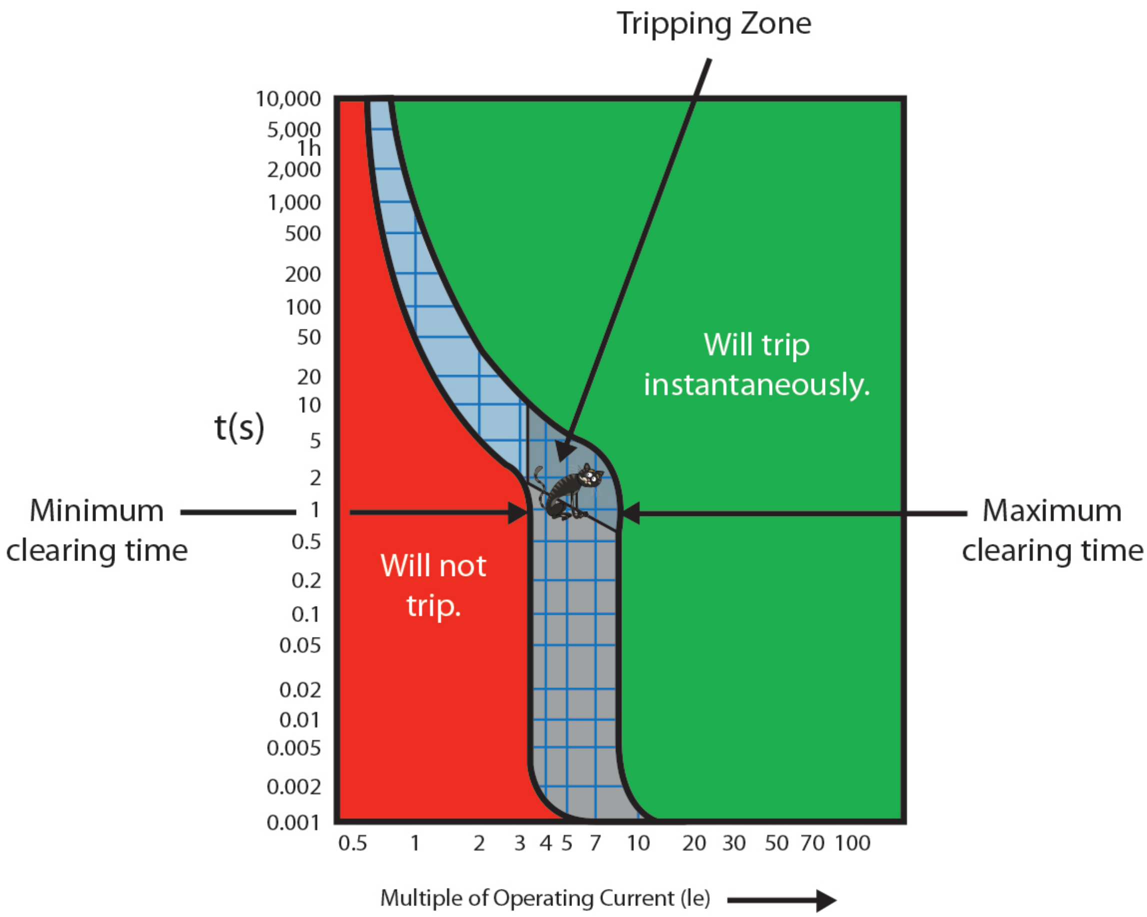
The area shaded in between is the Tripping Zone.

IMPORTANT: Trip curves represent the predicted behavior of a circuit breaker in a cold state (ambient room temperature). A cold state is when the bimetallic strip is within the specified ambient operating temperature for the breaker. If the breaker has experienced a recent thermal trip, and has not cooled down to the ambient temperature, it may trip sooner.

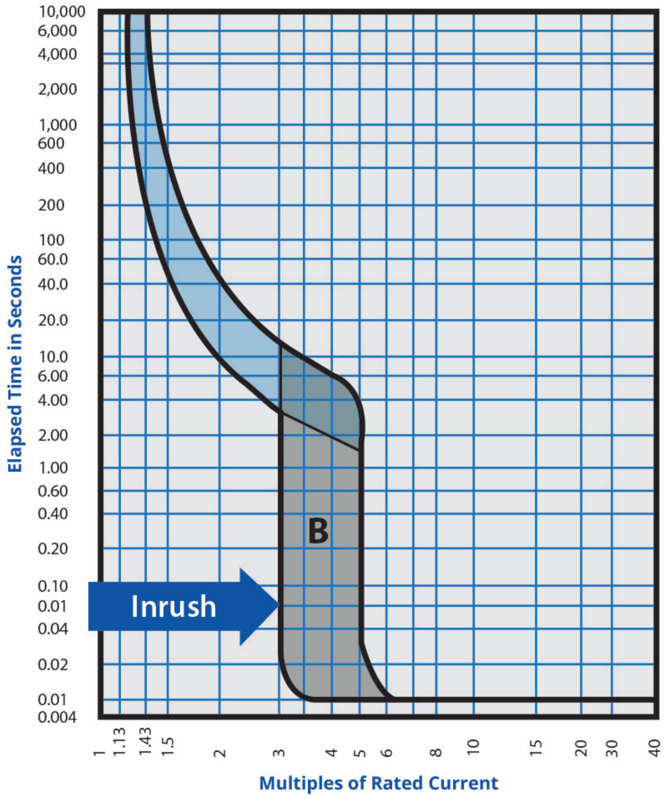
Putting it all together

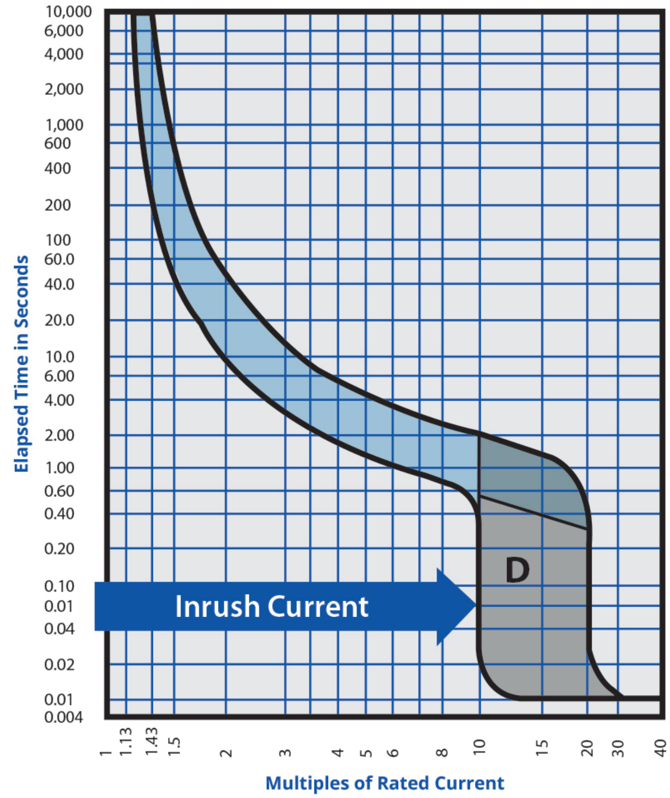
Figure 7 (below) puts these concepts into a clearer picture.

Take special note of the Tripping Zone where the breaker may or may not trip. Think of this as the Schrödinger's Cat area. Within the zone, until an overcurrent event happens, we do not know exactly when/if the breaker will trip (Schrödinger's Cat = dead) or if the breaker will not trip (Schrödinger's Cat = alive).

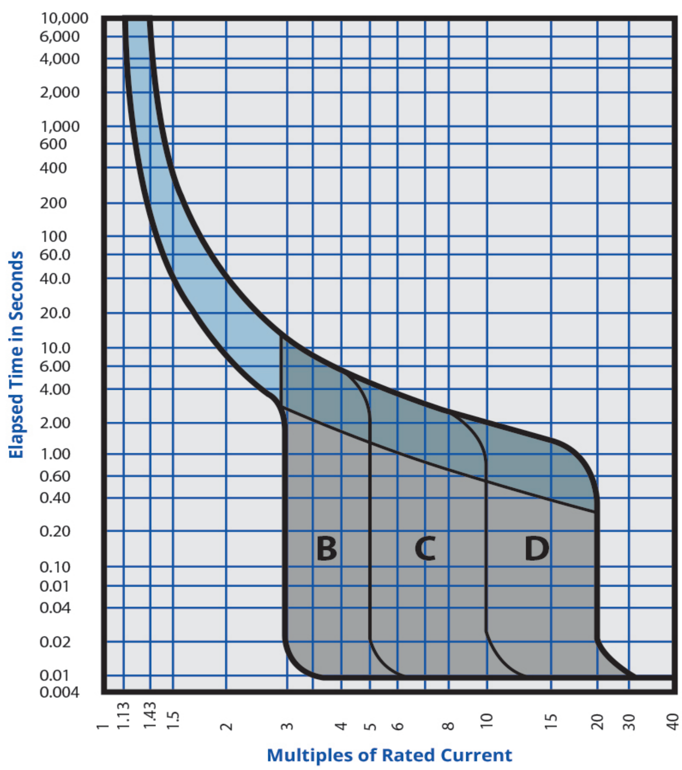


Now that we have put it all together, it is clear that choosing a 10A, B Curve circuit breaker could result in nuisance trips since the breaker enters the tripping zone at 30A. (See figure 8, below.) D Curve breakers are the most common choice for electric motors, although sometimes a C Curve breaker can be chosen for applications that have mixed loads on the same circuit.





The three most common trip curves for Miniature Circuit Breakers are B, C and D. By putting all three on one chart (Figure 9, below), we can see how the thermal portion of the curves are similar to each other, but there are differences on how the magnetic (coil/solenoid) curve, and thus the circuit breaker functions.



In Summary:

Circuit protection is employed to protect wires and electrical equipment from damage in the event of an electrical overload, short circuit or ground fault. Lightning storms, overloaded power outlets, or a sudden electrical surge may result in a dangerous situation with the potential to cause fires, equipment damage or personal injury. Circuit protection is designed to eliminate this risk before it occurs by cutting off the power to the circuit.

- Circuit protection devices include fuses, miniature circuit breakers, molded case circuit breakers, supplementary protectors, motor protection circuit breakers, overload relays, electronic fuses and air circuit breakers.
- Trip Curves predict the behavior of circuit protection devices in both slower, smaller overcurrent conditions, and larger, faster over current conditions.
- Choosing the correct trip curve for your application provides reliable circuit protection, while limiting nuisance or false trips.

This paper is a brief overview of trip curves. It is not intended to be the final answer on this topic. There is a lot more to learn, including other types of trip curves and circuit breaker coordination. With the basics now covered, one can confidently approach those topics.