Electrical Level 3

Overcurrent Protection 26305-14

Objectives

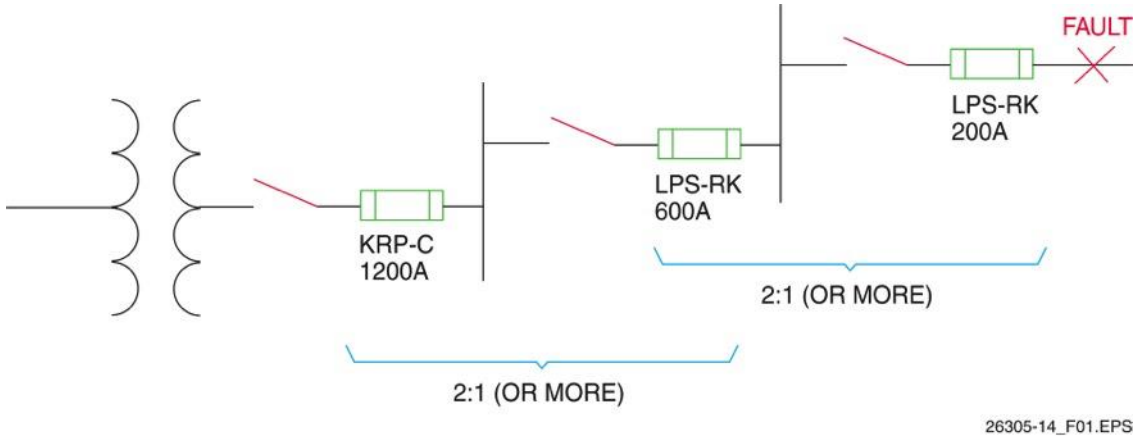
When trainees have completed this lesson, they should be able to do the following:

1. Apply the key *National Electrical Code®* (*NEC®*) requirements regarding overcurrent protection.
2. Check specific applications for conformance to *NEC®* sections that cover short circuit current, fault currents, interrupting ratings, and other sections relating to overcurrent protection.
3. Determine let-through current values (peak and rms) when current-limiting overcurrent devices are used.
4. Select and size overcurrent protection for specific applications.

This is a knowledge-based module; there are no Performance Tasks.

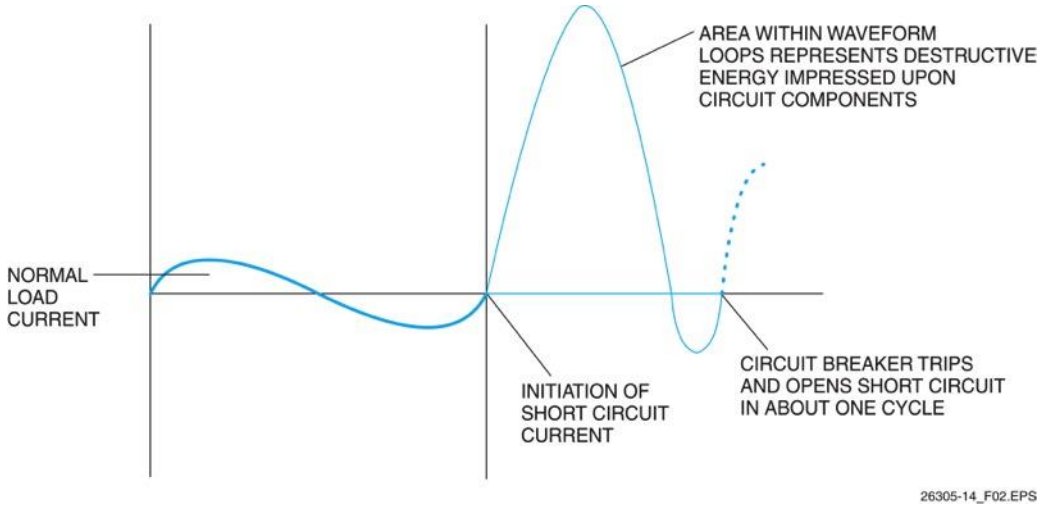
Fuses

- The coordination of protective devices prevents system power outages or blackouts caused by overcurrent conditions.
- A circuit's protective devices are selectively coordinated when only the protective device nearest a fault opens and larger upstream devices remain closed. This allows the rest of the circuit to continue operating.



Characteristics of a Noncurrent-Limiting Protective Device

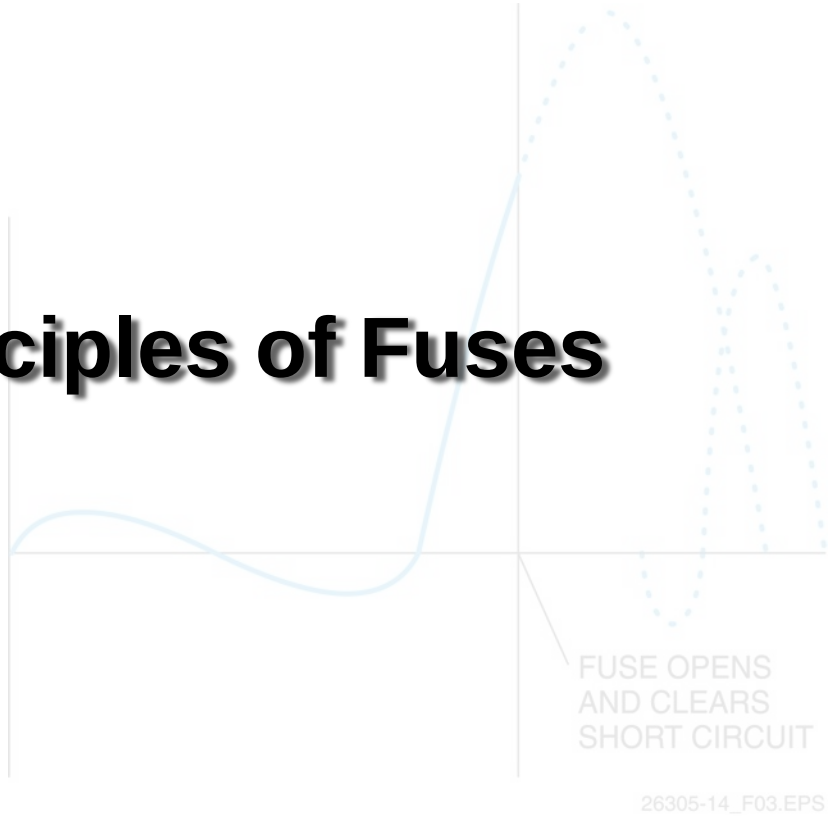
- Short circuit currents can reach levels of 30,000A to 40,000A or higher in the first half cycle after the start of a short circuit.
- Noncurrent-limiting devices can permit a short circuit current to build up to this full value before opening the circuit, resulting in a tremendous amount of destructive heat energy.



Next Session…

Characteristics of a Current-Limiting Fuse

- A current-limiting device has such a high speed of response that it cuts off a short circuit before it can build up to its full peak value.
- Current-limiting devices permit breakers with lower interrupting ratings to be used and can reduce bracing of bus structures.



Operating Principles of Fuses

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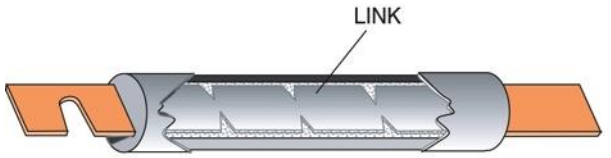
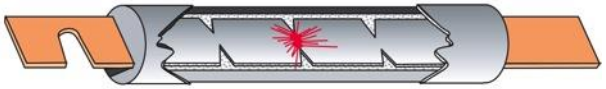
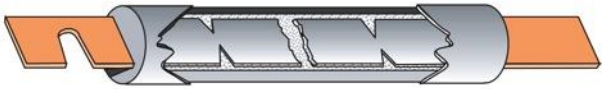


Cut-away view of single-element fuse.

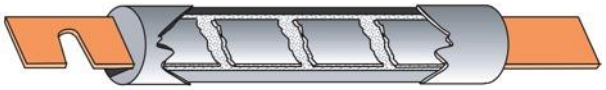


Under sustained overload, a section of the link melts and an arc is established.



The open single-element fuse after opening a circuit overload.

When subjected to a short circuit, several sections of the fuse link melt almost instantly.



The appearance of an open single-element fuse after opening a short circuit.

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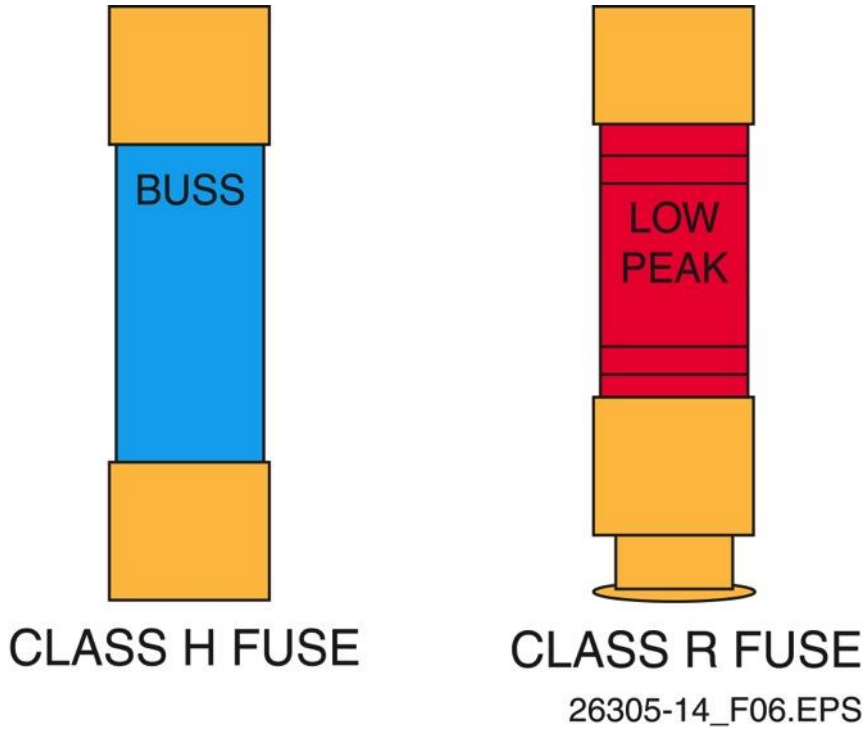
Next Session…

UL Fuse Classes

UL Fuse Classes

- UL Class R (rejection) fuses are mounted in special fuse clips to prevent accidental replacement with Type H fuses.
- Class H fuses are not current-limiting and could result in serious damage if used in a system designed for current-limiting devices.



Fuse Rejection Clips

- Fuse classes include Class CC, Class G, Class H, Class J, Class K, Class L, Class R, and Class T. Each fuse type is designed for a specific application.
- Special rejection clips or size restrictions are used with some fuses to prevent the installation of lower voltage or interrupting capacity devices. Class R rejection clips are shown here.

Current-Limiting Fuses

Circuit	Load	Ampere Rating	Fuse Type	Symbol	Voltage Rating (ac)	UL Class	Interrupting Rating (K)	Remarks
Main, Feeder, and Branch (Conventional dimensions)	All load types (optimum overcurrent protection)	0 to 600A	LOW PEAK® (dual-element time-delay)	LPN-RK	250V	RK1	200	All-purpose fuses. Unequaled for combined short circuit and overload protection.
				LPS-RK	600V			
		601 to 6,000A	LOW PEAK® time-delay	KRP-C	600V	L	200	
	Motors, welders, transformers, capacitor banks (circuits with heavy inrush currents)	0 to 600A	FUSETRON® (dual-element time-delay)	FRN-R	250V	RK5	200	Moderate degree of current limitation. Time-delay passes surge currents.
				FRS-R	600V			
		601 to 4,000A	LIMITRON® (time-delay)	KLU	600V	L	200	All-purpose fuse. Time-delay passes surge currents.
	Non-motor loads (circuits with no heavy inrush currents)	0 to 600A	LIMITRON® (fast-acting)	KTN-R	250V	RK1	200	Same short circuit protection as LOW PEAK® fuses but must be sized larger for circuits with surge currents: i.e., up to 300%.
				KTS-R	600V			
	LIMITRON® fuses particularly suited for circuit breaker protection	601 to 6,000A	LIMITRON® (fast-acting)	KTU	600V	L	200	A fast-acting, high-performance fuse.
	All load types (optimum overcurrent protection)	0 to 600A	LOW PEAK® (dual-element, time-delay)	LPJ	600V	J	200	All-purpose fuses. Unequaled for combined short circuit and overload protection.
	Non-motor loads (circuits with no heavy inrush currents)	0 to 600A	LIMITRON® (quick-acting)	JKS	600V	J	200	Very similar to KTS-R LIMITRON®, but smaller.
		0 to 1,200A	T-TRON™	JJN	300V	T	200	The space saver (⅓ the size of KTN-R/KTS-R).
				JJS	600V			

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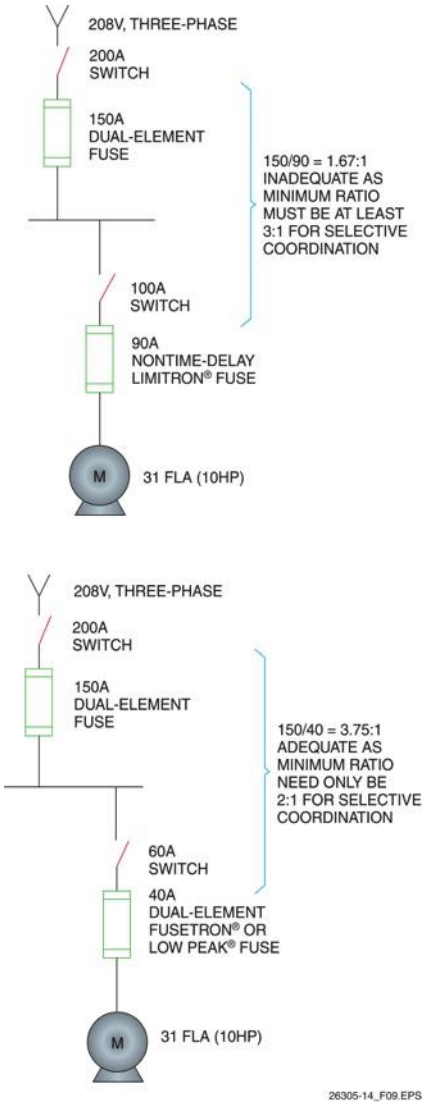
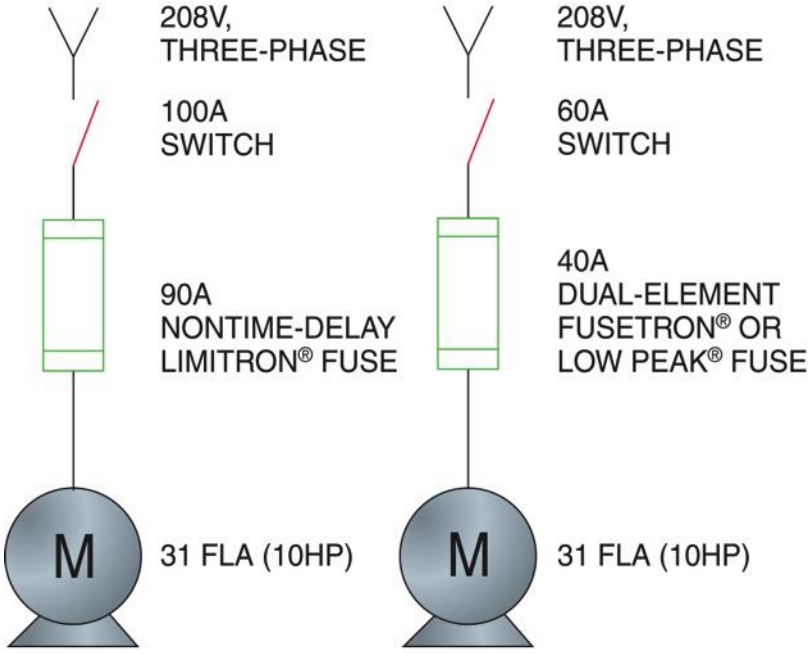
Fuses for Selective Coordination

- The larger the upstream device is relative to a downstream fuse, the less likely it is that an overcurrent in the downstream circuit will cause both devices to open.
- The minimum selective coordination ratio for a nontime-delay fuse to a larger time-delay upstream device is 3:1, while a dual-element fuse is only 2:1.



Comparison of Dual-Element Fuse and Single-Element, Nontime-Delay Fuse

A dual-element, time-delay fuse offers the advantage of using lower-rated devices to protect the same load.



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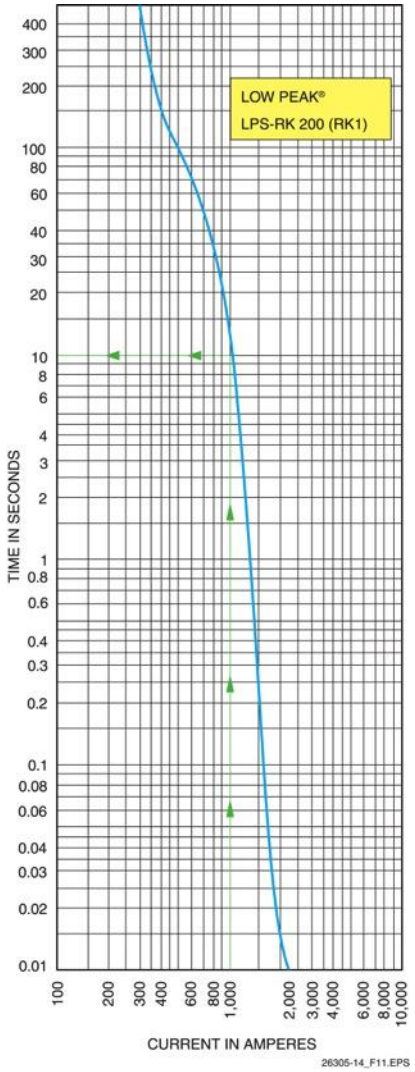
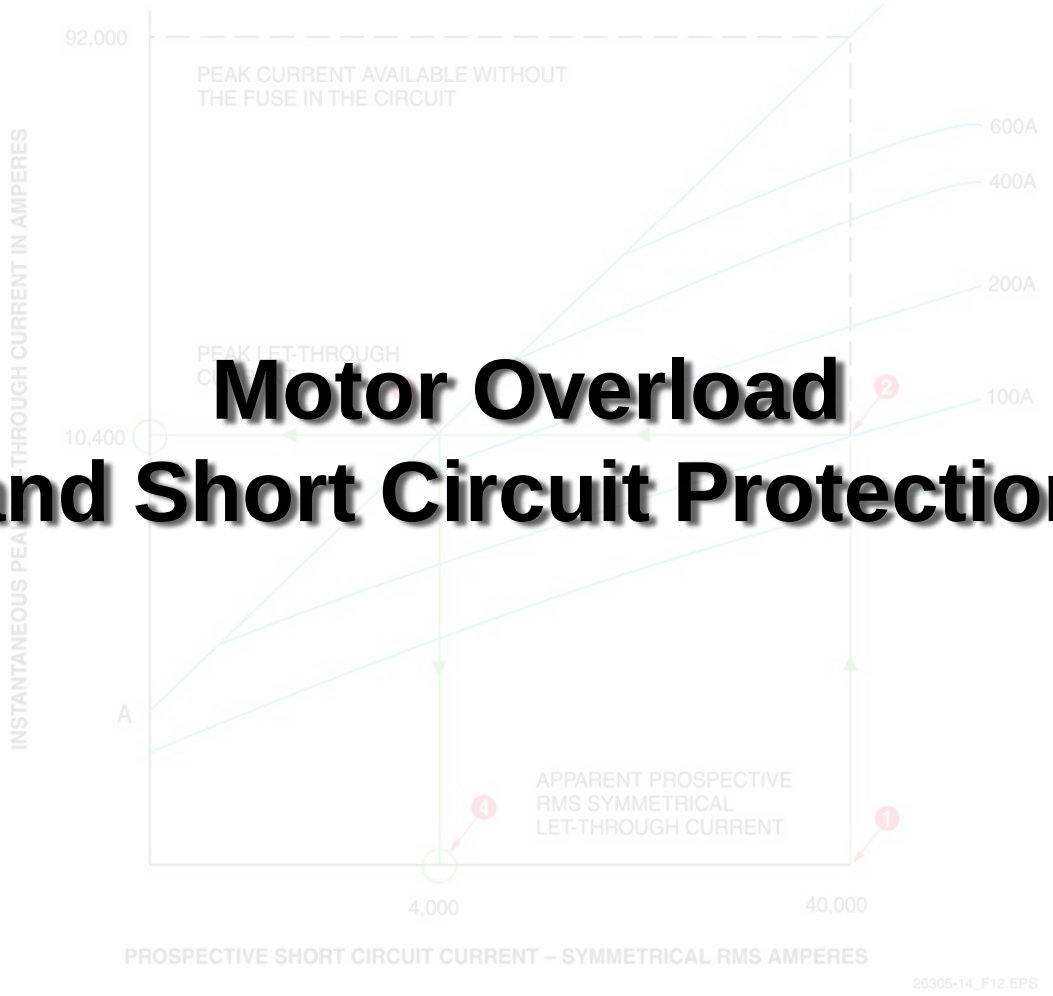
Fuse Time-Current Curves

- The fuse opening time is directly related to the magnitude of current.
- A low-level overcurrent will take longer to open the fuse and clear the fault, while a large overcurrent will open the circuit very quickly.



Next Session…



Motor Overload and Short Circuit Protection

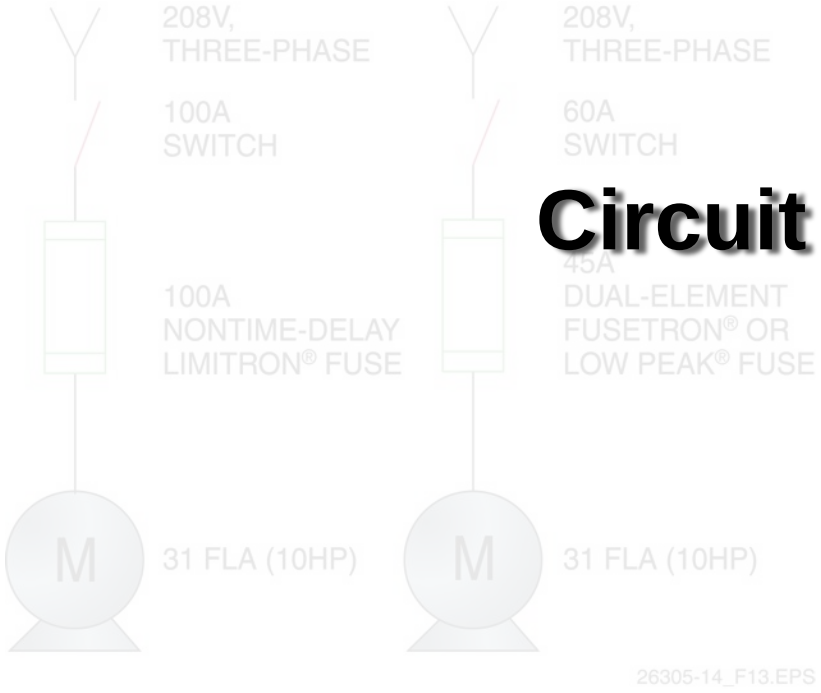
Motor Overload and Short Circuit Protection

- Dual-element, time-delay fuses can be sized close to full-load amperes to provide maximum circuit protection.
- In contrast, if a sustained overload of 300% occurs with a single-element fuse, the fuse will not open and the motor could be damaged. This requires separate motor overload protection per the *NEC®.*

Fuse Type	Maximum Fuse Size (Amps)	Required Switch Size (Amps)
Dual-element, time-delay	45A	60A
Single-element, nontime-delay	100A	100A

Next Session…

Dual-Element Fuses Permit the Use of Smaller and Less Costly Switches

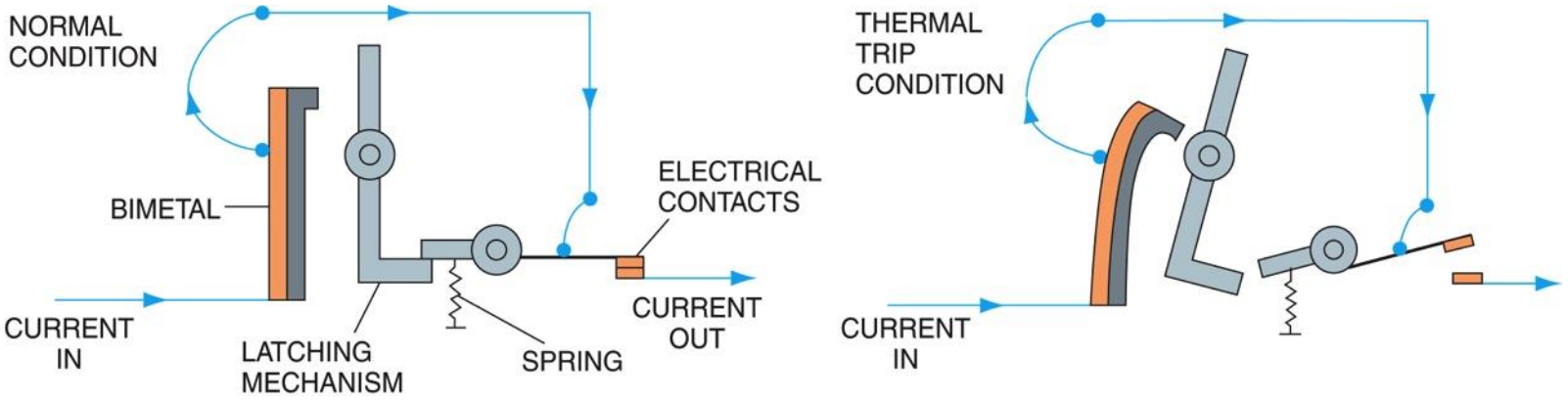


- Single-element fuses also require the use of larger switches since the switch rating must be equal to or larger than the ampere rating of the fuse.
- Dual-element fuses use smaller switches that may cost two or three times less than those required for use with single-element types.

Circuit Breakers

Circuit Breakers

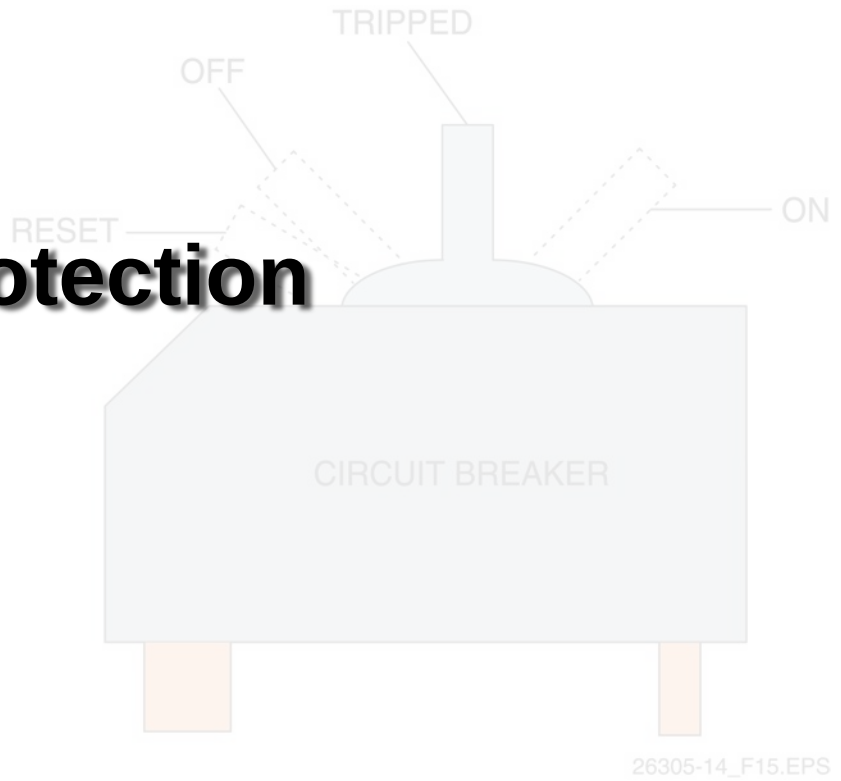
- Circuit breakers are used to interrupt a circuit under normal operating conditions (for service or maintenance) and abnormal conditions (during overloads or ground faults).
- As long as a breaker is applied within its rating, it will automatically interrupt any fault and is considered an intrinsically safe overcurrent protective device.



Next Session…

Circuit Protection

- When resetting a breaker, push it beyond the Off position to the Reset position and then back to On.
- Always determine why a breaker has tripped before resetting it.

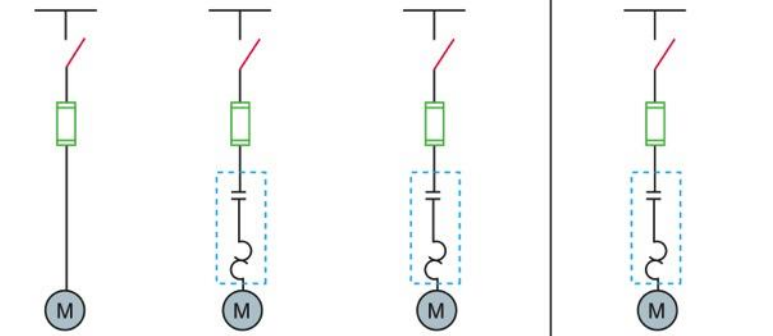


Circuit Protection

Application	Rule	*NEC*® Reference
Scope	Overcurrent protection for conductors and equipment is provided to open the circuit if the current reaches a value that will cause an excessive or dangerous temperature in conductors or conductor insulation. See also *NEC Sections 110.9 and 110.10* for requirements for interrupting capacity and protection against fault currents.	*NEC Section 240.1 Informational Note*
Protection required	Each ungrounded service-entrance conductor must have overcurrent protection in series with each ungrounded conductor.	*NEC Section 230.90(A)*
Number of devices	Up to six circuit breakers or sets of fuses may be considered as the overcurrent device.	*NEC Section 230.90(A), Exception No. 3*
Location in building	The overcurrent device must be an integral part of the service disconnecting means or be located immediately adjacent to it.	*NEC Section 230.91*
Accessibility	In a property comprising more than one building under single management, the ungrounded conductors supplying each building served shall be protected by overcurrent devices, which may be located in the building served or in another building on the same property, provided they are accessible to the occupants of the building served. In a multiple-occupancy building, each occupant shall have access to the overcurrent protective devices.	*NEC Sections 230.92 and 230.72(C), Exception*
Location in circuit	The overcurrent device must protect all circuits and devices, except equipment which may be connected on the supply side, including: (1) Service switch; (2) Special equipment, such as surge arrestors; (3) Circuits for emergency supply and load management (where separately protected); (4) Circuits for fire alarms or fire pump equipment (where separately protected); (5) Meters with all metal housing grounded (600V or less); (6) Control circuits for automatic service equipment, if suitable overcurrent protection and disconnecting means are provided.	*NEC Section 230.94 plus Exceptions*
Installation and use	Listed or labeled equipment shall be used and installed in accordance with any instructions included in the listing or labeling.	*NEC Section 110.3(B)*
Interrupting rating	Equipment intended to interrupt current at fault levels shall have an interrupting rating at nominal circuit voltage sufficient for the current which is available at the line terminals of the equipment.	*NEC Section 110.9*
Circuit impedance, short circuit ratings, and other characteristics	The overcurrent protective devices, total impedance, equipment short circuit current ratings, and other characteristics of the circuit to be protected shall be so selected and coordinated as to permit the circuit protective devices used to clear a fault without the occurrence of extensive damage to the electrical equipment of the circuit.	*NEC Section 110.10*
General	Normally noncurrent-carrying electrically conductive materials that are likely to become energized shall be connected together and to the electrical supply source in a manner that establishes an effective grounding fault current path.	*NEC Section 250.4(A)(4)*
Bonding other enclosures	Metal raceways, cable trays, cable armor, cable sheath, enclosures, frames, fittings, and other metal noncurrent-carrying parts that are to serve as equipment grounding conductors, with or without the use of supplementary equipment grounding conductors, shall be bonded where necessary to ensure electrical continuity and the capacity to safely conduct any fault current likely to be imposed on them. Any nonconductive paint, enamel, or similar coating shall be removed at threads, contact points, and contact surfaces or be connected by means of fittings so designed as to make such removal unnecessary.	*NEC Section 250.96(A)*

Fuse Application Guidelines for Motor Branch Circuits

Type of Motor	Dual-Element, Time-Delay Fuses			Nontime-Delay Fuses
	Desired Level of Protection			
	Motor Overload and Short Circuit	Backup Overload and Short Circuit	Short Circuit Only (Based on *NEC Tables 430.247 through 430.250* current ratings)	Short Circuit Only (Based on *NEC Tables 430.247 through 430.250* current ratings)
Service Factor 1.15 or Greater or 40°C Temp. Rise or Less	125% or less of motor nameplate current	125% or next standard size (not to exceed 140%)	150% to 175%	150% to 300%
Service Factor Less Than 1.15 or Greater Than 40°C Temp. Rise	115% or less of motor nameplate current	115% or next standard size (not to exceed 130%)	150% to 175%	150% to 300%



Fuses give overload and short circuit protection.

Overload relay gives overload protection and fuses provide backup overload protection.

Overload relay provides overload protection and fuses provide only short circuit protection.

Overload relay provides overload protection and fuses provide only short circuit protection.

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Selection of Fuses for Motor Protection

Dual-Element Fuse Size	Motor Protection (Used without properly sized relays) Motor Full-Load Amps		Backup Motor Protection (Used with properly sized overload relays) Motor Full-Load Amps	
	Motor service factor of 1.15 or greater or with temperature rise not over 40°C	Motor service factor less than 1.15 or with temperature rise not over 40°C	Motor service factor of 1.15 or greater or with temperature rise not over 40°C	Motor service factor of less than 1.15 or with temperature rise not over 40°C
1/10	0.08–0.09	0.09–0.10	0–0.08	0–0.09
1/8	0.10–0.11	0.11–0.15	0.09–0.10	0.10–0.11
5/100	0.12–0.15	0.14–0.15	0.11–0.12	0.12–0.13
2/10	0.16–0.19	0.18–0.20	0.13–0.16	0.14–0.17
1/4	0.20–0.23	0.22–0.25	0.17–0.20	0.18–0.22
3/10	0.24–0.30	0.27–0.30	0.21–0.24	0.23–0.26
4/10	0.32–0.39	0.35–0.40	0.25–0.32	0.27–0.35
1/2	0.40–0.47	0.44–0.50	0.33–0.40	0.36–0.43
6/10	0.48–0.60	0.53–0.60	0.41–0.48	0.44–0.52
8/10	0.64–0.79	0.70–0.80	0.49–0.64	0.53–0.70
1	0.80–0.89	0.87–0.97	0.65–0.80	0.71–0.87
1 1/8	0.90–0.99	0.98–1.08	0.81–0.90	0.88–0.98
1 1/4	1.00–1.11	1.09–1.21	0.91–1.00	0.99–1.09
1 4/10	1.12–1.19	1.22–1.30	1.01–1.12	1.10–1.22
1 1/2	1.20–1.27	1.31–1.39	1.13–1.20	1.23–1.30
1 6/10	1.28–1.43	1.40–1.56	1.21–1.28	1.31–1.39
1 8/10	1.44–1.59	1.57–1.73	1.29–1.44	1.40–1.57
2	1.60–1.79	1.74–1.95	1.45–1.60	1.58–1.74
2 1/4	1.80–1.99	1.96–2.17	1.61–1.80	1.75–1.96
2 1/2	2.00–2.23	2.18–2.43	1.81–2.00	1.97–2.17

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Selection of Fuses for Motor Protection

Dual-Element Fuse Size	Motor Protection (Used without properly sized relays) Motor Full-Load Amps		Backup Motor Protection (Used with properly sized overload relays) Motor Full-Load Amps	
	Motor service factor of 1.15 or greater or with temperature rise not over 40°C	Motor service factor less than 1.15 or with temperature rise not over 40°C	Motor service factor of 1.15 or greater or with temperature rise not over 40°C	Motor service factor of less than 1.15 or with temperature rise not over 40°C
2 6/10	2.24–2.39	2.44–2.60	2.01–2.24	2.18–2.43
3	2.40–2.55	2.61–2.78	2.25–2.40	2.44–2.60
3 2/10	2.56–2.79	2.79–3.04	2.41–2.56	2.61–2.78
3 1/2	2.80–3.19	3.05–3.47	2.57–2.80	2.79–3.04
4	3.20–3.59	3.48–3.91	2.81–3.20	3.05–3.48
4 1/2	3.60–3.99	3.92–4.34	3.21–3.60	3.49–3.91
5	4.00–4.47	4.35–4.86	3.61–4.00	3.92–4.35
5 6/10	4.48–4.79	4.87–5.21	4.01–4.48	4.36–4.87
6	4.80–4.99	5.22–5.43	4.49–4.80	4.88–5.22
6 1/4	5.00–5.59	5.44–6.08	4.81–5.00	5.23–5.43
7	5.60–5.99	6.09–6.52	5.01–5.60	5.44–6.09
7 1/2	6.00–6.39	6.53–6.95	5.61–6.00	6.10–6.52
8	6.40–7.19	6.96–7.82	6.01–6.40	6.53–6.96
9	7.20–7.99	7.83–8.69	6.41–7.20	6.97–7.83
10	8.00–9.59	8.70–10.00	7.21–8.00	7.84–8.70
12	9.60–11.99	10.44–12.00	8.01–9.60	8.71–10.43
15	12.00–13.99	13.05–15.00	9.61–12.00	10.44–13.04
17 1/2	14.00–15.99	15.22–17.39	12.01–14.00	13.05–15.21
20	16.00–19.99	17.40–20.00	14.01–16.00	15.22–17.39
25	20.00–23.99	21.74–25.00	16.01–20.00	17.40–21.74
30	24.00–27.99	26.09–30.00	20.01–24.00	21.75–26.09
35	28.00–31.99	30.44–34.78	24.01–28.00	26.10–30.43

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Next Session…

Fuses for Motor Protection

Dual-Element Fuse Size	Motor Protection (Used without properly sized relays) Motor Full-Load Amps		Backup Motor Protection (Used with properly sized overload relays) Motor Full-Load Amps	
	Motor service factor of 1.15 or greater or with temperature rise not over 40°C	Motor service factor less than 1.15 or with temperature rise not over 40°C	Motor service factor of 1.15 or greater or with temperature rise not over 40°C	Motor service factor of less than 1.15 or with temperature rise not over 40°C
40	32.00–35.99	34.79–39.12	28.01–32.00	30.44–37.78
45	36.00–39.00	39.13–43.47	32.01–36.00	37.79–39.13
50	40.00–47.99	43.48–50.00	36.01–40.00	39.14–43.48
60	48.00–55.99	52.17–60.00	40.01–48.00	43.49–52.17
70	56.00–59.99	60.87–65.21	48.01–56.00	52.18–60.87
75	60.00–63.99	65.22–69.56	56.01–60.00	60.88–65.22
90	72.00–79.99	78.26–86.95	64.01–72.00	69.58–78.26
100	80.00–87.99	86.96–95.64	72.01–80.00	78.27–86.96
110	88.00–99.00	95.65–108.69	80.01–88.00	86.97–95.65
125	100.00–119.00	108.70–125.00	88.01–100.00	95.66–108.70
150	120.00–139.99	131.30–150.00	100.01–120.00	108.71–130.43
175	140.00–159.99	152.17–173.90	120.01–140.00	130.44–152.17
200	160.00–179.99	173.91–195.64	140.01–160.00	152.18–173.91
225	180.00–199.99	195.65–217.38	160.01–180.00	173.92–195.62
250	200.00–239.99	217.39–250.00	180.01–200.00	195.63–217.39
300	240.00–279.99	260.87–300.00	200.01–240.00	217.40–260.87
350	280.00–319.99	304.35–347.82	240.01–280.00	260.88–304.35
400	320.00–359.99	347.83–391.29	280.01–320.00	304.36–347.83
450	360.00–399.99	391.30–434.77	320.01–360.00	347.84–391.30
500	400.00–479.99	434.78–500.00	360.01–400.00	391.31–434.78
600	480.00–600.00	521.74–600.00	400.01–480.00	434.79–521.74

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Short Circuit Calculations

Short Circuit Calculations

Voltage (Line-to-Line)	Transformer kVA Rating								
	150	167	225	300	500	750	1,000	1,500	2,000
208	417	464	625	834	1,388	2,080	2,776	4,164	5,552
220	394	439	592	788	1,315	1,970	2,630	3,940	5,260
240	362	402	542	722	1,203	1,804	2,406	3,609	4,812
440	197	219	296	394	657	985	1,315	1,970	2,630
460	189	209	284	378	630	945	1,260	1,890	2,520
480	181	201	271	361	601	902	1,203	1,804	2,406

- The first step in selecting devices with the proper interrupting rating to provide sufficient component protection is to determine the available short circuit currents.
- The point-to-point method is commonly used to determine the available short circuit currents at various points for either single-phase or three-phase electrical distribution systems.

Short Circuit Currents Available from Various Size Transformers

Voltage and Phase	kVA	Full-Load Amps	% Impedance	Short Circuit Amps
	25	104	1.6	10,300
	37½	156	1.6	15,280
120/240V Single phase	50	209	1.7	19,050
	75	313	1.6	29,540
	100	417	1.6	38,540
	167	695	1.8	54,900
	150	417	2.0	20,850
	225	625	2.0	31,250
	300	834	2.0	41,700
120/208V Three phase	500	1,388	2.0	69,444
	750	2,080	3.5	59,426
	1,000	2,776	3.5	79,310
	1,500	4,164	3.5	118,965
	2,000	5,552	5.0	111,040
	2,500	6,950	5.0	139,000
	112½	135	1.0	13,500
	150	181	1.2	15,083
	225	271	1.2	22,583
277/480V Three phase	300	361	1.2	30,083
	500	601	1.3	46,230
	750	902	3.5	25,770
	1,000	1,203	3.5	34,370
	1,500	1,804	3.5	51,540
	2,000	2,406	5.0	48,120
	2,500	3,077	5.0	60,140

C Values for Conductors and Busways

AWG or kcmil	Copper, Three Single Conductors				Copper, Three-Conductor Cable			
	Steel Conduit		Nonmagnetic Conduit		Steel Conduit		Nonmagnetic Conduit	
	600V	5kV	600V	5kV	600V	5kV	600V	5kV
14	389	389	389	389	389	389	389	389
12	617	617	617	617	617	617	617	617
10	981	981	981	981	981	981	981	981
8	1,557	1,551	1,558	1,555	1,559	1,557	1,559	1,558
6	2,425	2,406	2,430	2,417	2,431	2,424	2,433	2,428
4	3,806	3,750	3,825	3,789	3,830	3,811	3,837	3,823
3	4,760	4,760	4,802	4,802	4,760	4,790	4,802	4,802
2	5,906	5,736	6,044	5,926	5,989	5,929	6,087	6,022
1	7,292	7,029	7,493	7,306	7,454	7,364	7,579	7,507
1/0	8,924	8,543	9,317	9,033	9,209	9,086	9,472	9,372
2/0	10,755	10,061	11,423	10,877	11,244	11,045	11,703	11,528
3/0	12,843	11,804	13,923	13,048	13,656	13,333	14,410	14,118
4/0	15,082	13,605	16,673	15,351	16,391	15,890	17,482	17,019
250	16,483	14,924	18,593	17,120	18,310	17,850	19,779	19,352
300	18,176	16,292	20,867	18,975	20,617	20,051	22,524	21,938
350	19,703	17,385	22,736	20,526	22,646	21,914	24,904	24,126
400	20,565	18,235	24,296	21,786	24,253	23,371	26,915	26,044
500	22,185	19,172	26,706	23,277	26,980	25,449	30,028	28,712
600	22,965	20,567	28,033	25,203	28,752	27,974	32,236	31,258
750	24,136	21,386	28,303	25,430	31,050	30,024	32,404	31,338
1,000	25,278	22,539	31,490	28,083	33,864	32,688	37,197	35,748

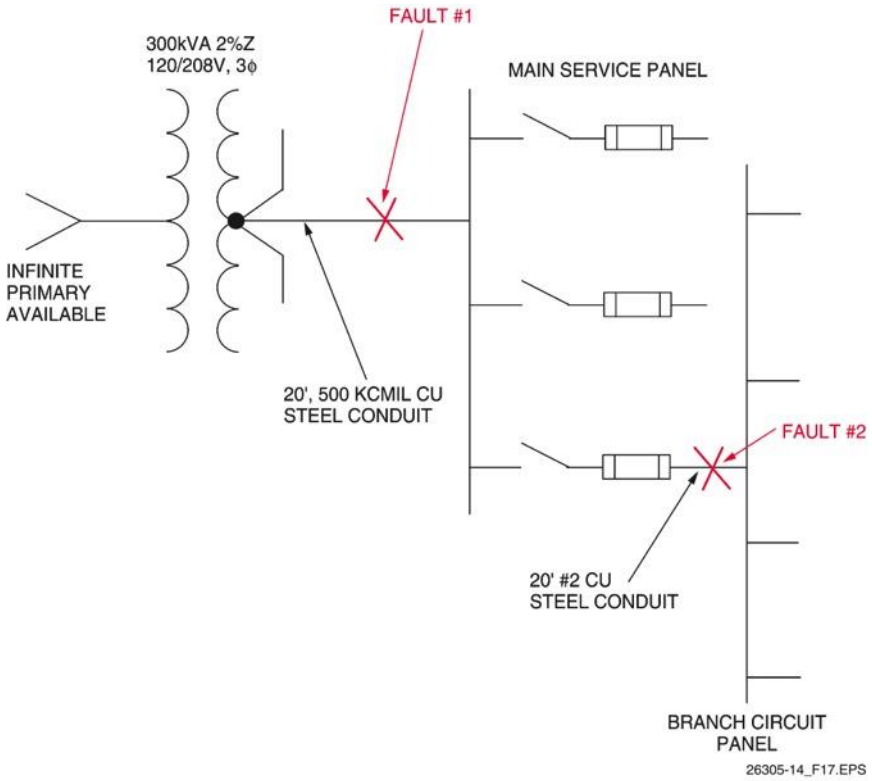
Note: The C values of other conductors/busways can be found in the manufacturer's literature for the device being sized.

Multipliers

f	M	f	M
0.01	0.99	1.50	0.40
0.02	0.98	1.75	0.36
0.03	0.97	2.00	0.33
0.04	0.96	2.50	0.29
0.06	0.94	3.50	0.22
0.07	0.93	4.00	0.20
0.08	0.93	5.00	0.17
0.09	0.92	6.00	0.14
0.10	0.91	7.00	0.13
0.15	0.87	8.00	0.11
0.20	0.83	9.00	0.10
0.25	0.80	10.00	0.09
0.30	0.77	15.00	0.06
0.35	0.74	20.00	0.05
0.40	0.71	30.00	0.03
0.50	0.67	40.00	0.02
0.60	0.63	50.00	0.02
0.70	0.59	60.00	0.02
0.80	0.55	70.00	0.01
0.90	0.53	80.00	0.01
1.00	0.50	90.00	0.01
1.20	0.45	100.00	0.01

Practical Application

Use the point-to-point method to determine the total short circuit amps at Faults #1 and #2.



Next Session…

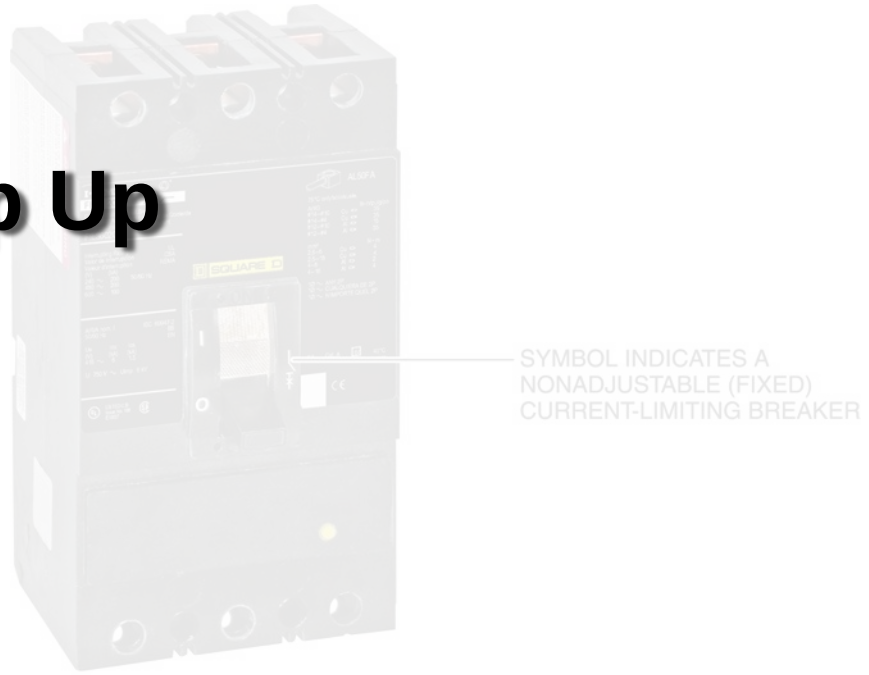
Troubleshooting and Testing Circuit Breakers and Fuses

Next Session…

Troubleshooting and Testing Circuit Breakers and Fuses

- Only current-limiting breakers have peak let-through charts.
- Always stand to one side and look away from a circuit breaker when it is being re-energized. Only qualified individuals may troubleshoot circuit breakers and fuses.

Wrap Up



Wrap Up

3-2-1

3 – Write 3 important things learned during class

2 – Write 2 questions you have about the material

1 – Write 1 thought you had about the material

Next Session…

MODULE EXAM

Review the complete module to prepare for the module exam. Complete the Module Review as a study aid.