12-National Electric Code

ECEGR 3500

Electrical Energy Systems

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Overview

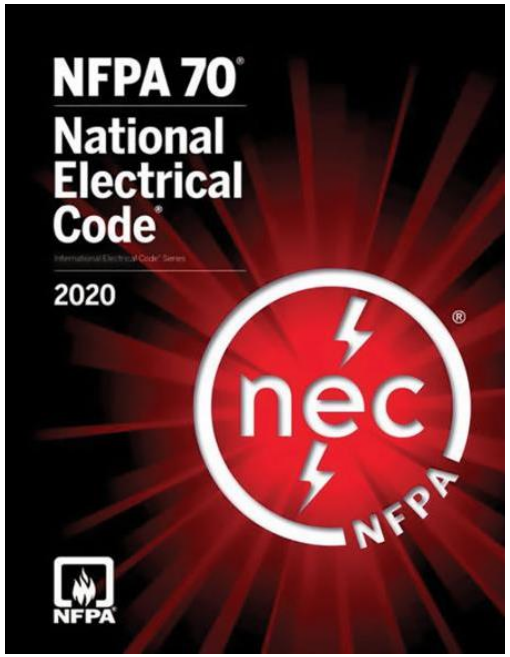
- National Electric Code
- Wire Rating
- Conductor Sizing
- Design Example

National Electrical Code

- Previous lecture focused on transmission/distribution system, next we examine end-use considerations in conductor and overcurrent protection design

National Electric Code (NEC)

- Commonly used standard (adopted throughout the U.S.) that considers the safe installation and electrical wiring of electrical equipment
- Also known as NFPA 70 (National Fire Prevention Association)
- First edition of NEC 1897, now on its 55th edition
- Many power engineering and building engineering design jobs require regular use of NEC to, among other uses, select conductors and circuit breakers

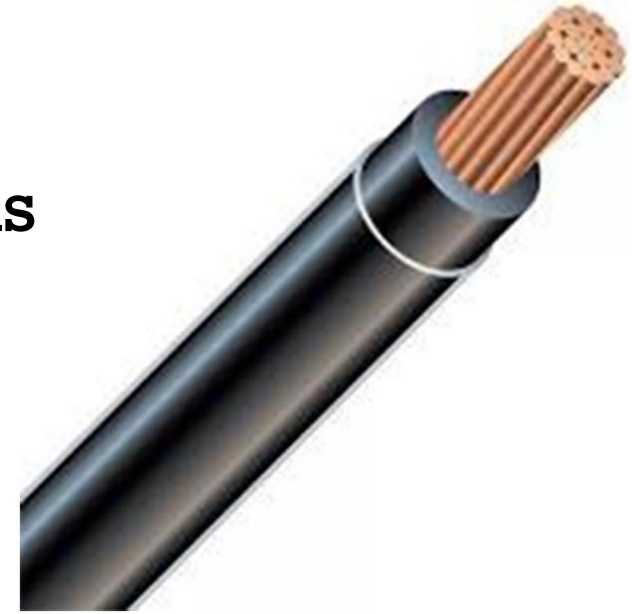


NEC Basic Conductor Sizing Approach

- Factors to consider when selecting conductors and overcurrent protection:
  - Continuous and non-continuous loads
  - Terminal temperature ratings (what the conductor is connected to)
  - Conductor environment
  - Conductor insulation type and temperature rating
  - Conductor ampacity
  - System voltage
- Also, if the wiring/equipment is a "special application"

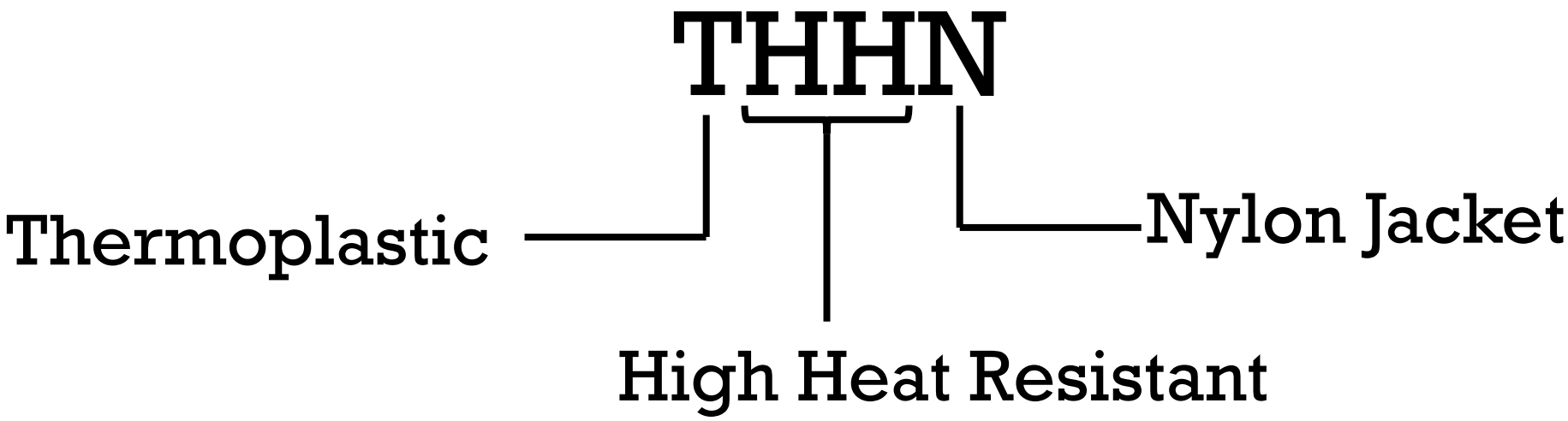
Electrical Cables

- Cables used at end-used facilities (homes, industrial facilities, etc.) consist of:
  - Conductor
  - Insulator
- Higher voltage cables may also include shields
- Need to protect insulation from overheating



source: zw-cable.com

Decoding Wire Types



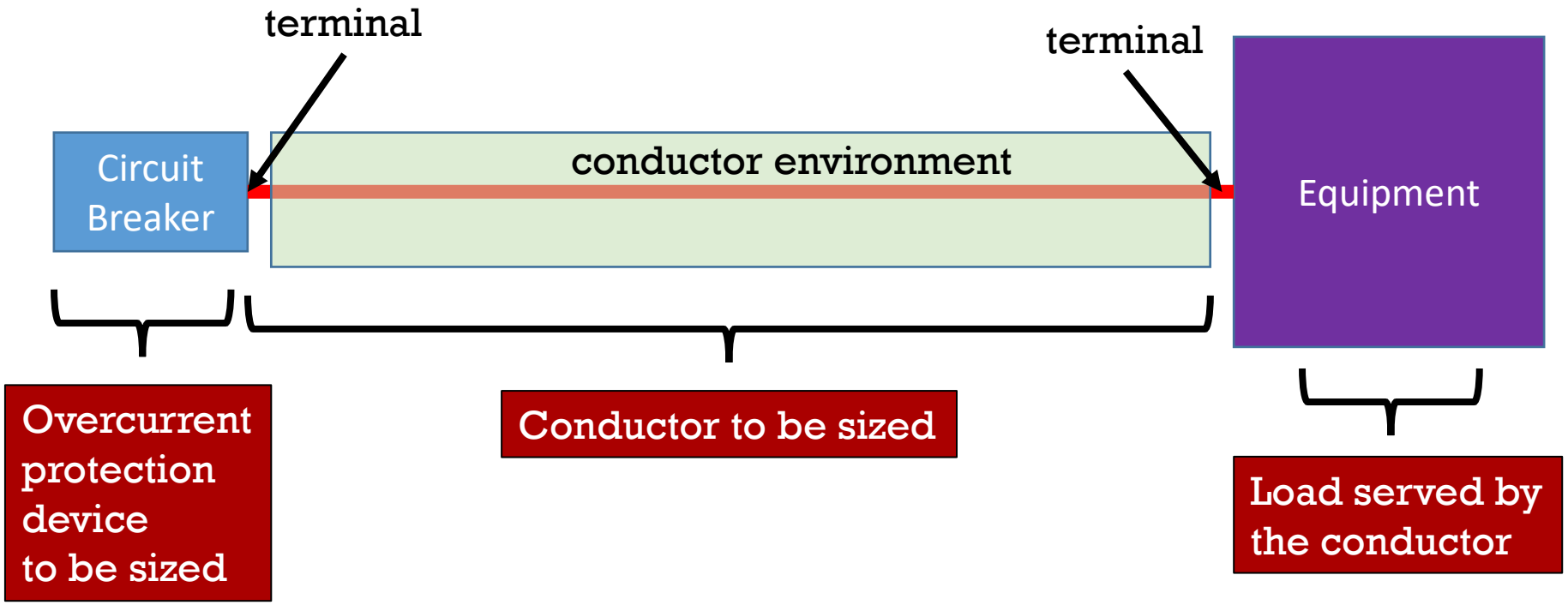
Decoding Wire Types

Temperature Rating

- Insulated conductors have a maximum operating temperature which should not be exceeded
  - Conductors can be operated at temperatures lower than their ratings
- Typical ratings: 60 °C, 75 °C, 90 °C
  - Some conductor types have multiple ratings, for example THHW which is rated at 90 °C in dry environments, but only 75 °C in wet environments

Examples of Cable Specifications

Trade Name	Type Letter	Max. Temp.	Application Provisions
Heat-resistant thermoplastic	THHN	90° C	Dry and damp locations
Underground feeder and branch circuit	UF	60°C	Underground, including direct burial


terminal
terminal
Circuit Breaker
conductor environment
Equipment
Overcurrent protection device to be sized
Conductor to be sized
Load served by the conductor

General Approach

Given the type of conductor (e.g. THHN), the terminal and conductor environmental conditions, and the load, the steps to sizing the overcurrent protection and conductor rating are:

1. Determine the load, in Amperes, supplied by the conductor
2. Select overcurrent protection device rating
3. Determine smallest allowable conductor size that satisfies terminal conditions
4. Determine smallest allowable conductor size that satisfies conductor environmental conditions
5. Choose the larger of the sizes from step 3 and 4
6. Verify that selected conductor is protected by the selected overcurrent protection device (increase conductor size until conductor is protected)

1. Determining the Load

- What load will the circuit serve?
  - Generally, the conductor is selected to be able to supply no less than: 100% of non-continuous load + 125% of continuous load
  - Continuous load: loads where the maximum current is expected to continue for 3 hours or more (like lighting in certain applications, water heaters, etc.)
- Example: if non-continuous load = 12 A, continuous load = 40A, then the load is 12 + (40 x 1.25)= 62A
  - The actual load is 52A

Often, the load is specified in terms of VA, which can be readily converted to amperes if the voltage and configuration (three-phase, etc.) are known

2. Select Overcurrent Protection

- Rating of overcurrent protection device (e.g. fuse, circuit breaker) defines the circuit, so it is sized before the conductor
- Consult Table 240.6(A) and select the rating according "next-size-up" rule (the rating should be the closest size that is greater than the load)
    - Example: the load from the las slide (62 A) would require a 70A overcurrent protection device

Table 240.6(A) Standard Ampere Ratings for Fuses and Inverse Time Circuit Breakers

Standard Ampere Ratings				
15	20	25	30	35
40	45	50	60	70
80	90	100	110	125
150	175	200	225	250
300	350	400	450	500
600	700	800	1000	1200
1600	2000	2500	3000	4000
5000	6000	—	—	—

Conductor Ratings

- Ampacity: the maximum current that a conductor can carry continuously without exceeding its temperature rating
- The conductor must be sized to independently meet the requirements for the terminations AND the conditions in the environment the conductors are placed (e.g. raceway, open air, EMT, etc.)
- The conductor should not be less than the rating of the overcurrent protection device (or no more than one standard size smaller) and should not be less than the maximum load to be served

Ampacity Tables

- NEC table 310.16(A) shows unadjusted and uncorrected ampacity of conductors
- Default assumption is the conductor is copper, so we will focus on that side of the table

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]					
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM		
18*	—	—	14	—	—	—
16*	—	—	18	—	—	—
14*	15	20	25	—	—	—
12*	20	25	30	15	20	25
10*	30	35	40	25	30	35
8	40	50	55	35	40	45
6	55	65	75	40	50	55
4	70	85	95	55	65	75
3	85	100	115	65	75	85
2	95	115	130	75	90	100
1	110	130	145	85	100	115
1/0	125	150	170	100	120	135
2/0	145	175	195	115	135	150
3/0	165	200	225	130	155	175
4/0	195	230	260	150	180	205
250	215	255	290	170	205	230
300	240	285	320	195	230	260
350	260	310	350	210	250	280
400	280	335	380	225	270	305
500	320	380	430	260	310	350
600	350	420	475	285	340	385
700	385	460	520	315	375	425
750	400	475	535	320	385	435
800	410	490	555	330	395	445
900	435	520	585	355	425	480
1000	455	545	615	375	445	500
1250	495	590	665	405	485	545
1500	525	625	705	435	520	585
1750	545	650	735	455	545	615
2000	555	665	750	470	560	630

We will discuss adjusted and corrected ampacities later

Ampacity Tables

- Conductor types listed in multiple columns have multiple ratings (e.g. THHW: 90 °C in dry conditions, 75 °C in wet)
- The "-2" means "second generation" and have a higher temperature rating

Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430
600	350	420	475
700	385	460	520
750	400	475	535
800	410	490	555
900	435	520	585
1000	455	545	615
1250	495	590	665
1500	525	625	705
1750	545	650	735
2000	555	665	750

Ampacity Tables

- Each row (conductor size) has three ampacities shown, one for each standard temperature rating
- Interpretation for size 6 AWG:
  - can supply 55A without its temperature exceeding 60 °C,
  - can 65A without its temperature exceeding 75 °C
  - can 75A without its temperature exceeding 90 °C
- Which column to choose depends on what temperature we allow conductor to get to (with some exceptions)

Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430
600	350	420	475
700	385	460	520
750	400	475	535
800	410	490	555
900	435	520	585
1000	455	545	615
1250	495	590	665
1500	525	625	705
1750	545	650	735
2000	555	665	750

Exercise

What is the maximum current a 1/0 USE-2 conductor can supply without its temperature exceeding 60 °C?

Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430
600	350	420	475
700	385	460	520
750	400	475	535
800	410	490	555
900	435	520	585
1000	455	545	615
1250	495	590	665
1500	525	625	705
1750	545	650	735
2000	555	665	750

Exercise

What is the maximum current a 1/0 USE-2 conductor can supply without its temperature exceeding 60 °C?

Answer: 125A

Even though USE-2 is shown in the 90 °C column, we use the 60 °C in this particular case (there are several reasons why we may not want the temperature to reach 90 °C, as discussed on the next slide)

Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430
600	350	420	475
700	385	460	520
750	400	475	535
800	410	490	555
900	435	520	585
1000	455	545	615
1250	495	590	665
1500	525	625	705
1750	545	650	735
2000	555	665	750

3. Conductor Size Based on Terminal Conditions

- The equipment connected to either end of a conductor have their own temperature ratings (which should not be exceeded)
- The equipment rating is usually 60 °C or 75 °C, which may be different than the chosen conductor type insulation rating (for example THHN 90 °C)
  - If the equipment at either end have different ratings, use the lower rating
  - In circuits rated less than or equal to 100A, always use 60 °C column
- Use the column in the ampacity table that corresponds to the lesser of the equipment rating or insulation rating
- Load: 100% non-continuous + 125% continuous

Exercise

What is the ampacity of 3 AWG copper type RHH conductor that is connected equipment rated at 60 °C?

Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430

Exercise

What is the ampacity of 3 AWG copper type RHH conductor that is connected equipment rated at 60 °C?

Answer: 85 A

If the equipment were rated at 90 °C, the answer would be 115A

Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430

3. Conductor Size Based on Terminal Conditions

- Example:
  - continuous load = 40A
  - non-continuous load = 12 A
  - Terminals rated at 60 °C
- Required ampacity is 40 x 1.25 + 12 = 62A
- Size 4 AWG is required

Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430

4. Conductor Size Based on Conductor Environment Conditions

Sizing based on:

- 100% of load (i.e. the actual load) after applying correction and adjustment factors
- Temperature rating of the conductor (not the terminal rating) (110.14.C)

Correction & Adjustment Factors

- Correction and adjustment factors are multipliers that affect (de-rate) the ampacity listed in the table
  - Correction factor: used to correct ampacity for deviations in ambient temperature from standard
  - Adjustment factor: used to adjust ampacity when multiple current-carrying conductors are near each other
- This calculation can use the temperature rating of the cable's insulator, even if the terminal temperature rating is lower

There is no real functional difference between "correction" and "adjustment"

Temperature Correction Factors

- Ambient temperature affects conductor ampacity (use peak temperature, not average)
- NEC table 310.15(B)(1) shows to adjust the rating based due to temperature
- Higher temperature = lower ampacity; lower temperature = higher ampacity
- Calculation:

corrected ampacity = ampacity rating x temperature correction factor

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Example

- Let non-continuous load = 12 A, continuous load = 40A, then the load is 12 + 40 = 52A
- If conductor with 90 °C insulation is used, what size is needed if the ambient temperature is 37 °C?

Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430

Example

- Let non-continuous load = 12 A, continuous load = 40A, then the actual load is 12 + 40 = 52A
- If conductor with 90 °C insulation is used, what size is needed if the ambient temperature is 37 °C?
- The correction factor for 37 °C for 90 °C rated insulation is 0.91

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Example

- The correction factor for 37 °C for 90 °C rated insulation is 0.91
- De-rate all ampacities in the 90 °C column by 0.91
- Examples
  - 10: 40 x 0.91 ⟹ 36.4A
  - 8: 55 x 0.91 ⟹ 50.1A
  - 6: 75 x 0.91 ⟹ 68.3A
- The load is 52A, so 6 AWG is needed

Size AWG or kcmil	60°C (140°F)	75°C (167°F)	90°C (194°F)
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430

Adjustment for Number of Current-Carrying Conductors

- Heat generated from nearby conductors should also be considered
- NEC table 310.15(C)(1) provides adjustment factors based on number of current-carrying conductors

adjusted ampacity= ampacity x number of current carrying conductor adjustment factor

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

Note: neutral conductor in a four-wire wye system can be considered to be current carrying if there is reason to believe the load isn't balanced or is non-linear (computers, etc.)

Example

- Let non-continuous load = 12 A, non-continuous load = 40A, then the load is 12 + 40 = 52A
- If conductor with 90 °C insulation is used, what size is needed if the ambient temperature is 37 °C and the conductor will be in a raceway with 6 current-carrying conductors

Example

- Let non-continuous load = 12 A, non-continuous load = 40A, then the load is 12 + 40 = 52A
- If conductor with 90 °C insulation is used, what size is needed if the ambient temperature is 37 °C and the conductor will be in a raceway with 6 current-carrying conductors
- Adjustment factor is 80% (0.80), but this needs to be combined with corrected for ambient temperature as well

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

Example

- If conductor with 90 °C insulation is used, what size is needed if the ambient temperature is 37 °C and the conductor will be in a raceway with 6 current-carrying conductors
- De-rate all ampacities in the 90 °C column by 0.91 and 0.80
- Examples
  - 10: 40 x 0.91 x 0.80 ⇒ 29.1A
  - 8: 55 x 0.91 x 0.80 ⇒ 40.0A
  - 6: 75 x 0.91 x 0.80 ⇒ 54.6A
  - 4: 95 x 0.91 x 0.80 ⇒ 69.2A
- The load is 52A, so 6 AWG is needed

Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430

5. Choose the larger conductor from step 3 and 4

- Terminal conditions:
  - 125% of continuous load + 100% of non-continuous load: 4 AWG
- Conductor environment:
  - 100% of load after applying correction and adjustment factors: 6 AWG

- The wire must be 4 AWG

Keep in mind, a lower AWG means a larger size conductor!

6: Verify that selected conductor is protected by the selected overcurrent protection device (increase conductor size until conductor is protected)

- Ensure the overcurrent protection will activate before the conductor overheats
- From the example:
  - Selected overcurrent protection rating: 70A
  - Conductor size: 4 AWG
    - 90 °C rating after adjustment and corrections: 95 x 0.91 x 0.8= 69.2A
- The 70A breaker protects the conductor

Example

Determine the overcurrent protection and conductor sizing (type XHHW-2) sizing for a 480Y/277 V feeder whose load is 38,900 VA (non-continuous) and 56,600 VA (continuous). The load contains non-linear elements (discharge lighting). The ambient temperature is 35 °C. The conductors are in a raceway that has four other current-carrying conductors. The equipment at the conductor's terminations are rated at 75 °C.

Example

Determine the overcurrent protection and conductor (type XHHW-2) sizing for a 480Y/277 V feeder whose load is 38,900 VA (non-continuous) and 56,600 VA (continuous). The load contains non-linear elements (discharge lighting). The ambient temperature is 35 °C. The conductors are in a raceway that has four other current-carrying conductors. The equipment at the conductor's terminations are rated at 75 °C.

First, compute the line current associated with the load

Total VA: 38,900 + 1.25 x (56,600) = 109,650 VA

$|S_a|$ = 109,650/3 = 36,550 VA

$|I_{line}|$ = $|S_a|$/277 = 132 A

Example

Determine the overcurrent protection and conductor (type XHHW-2) sizing for a 480Y/277 V feeder whose load is 38,900 VA (non-continuous) and 56,600 VA (continuous). The load contains non-linear elements (discharge lighting). The ambient temperature is 35 °C. The conductors are in a raceway that has four other current-carrying conductors. The equipment at the conductor's terminations are rated at 75 °C.

Now select the overcurrent protection size

$|I_{line}| = 132$ A

We select the 150 A breaker (the 125A breaker may cause nuisance tripping)

Table 240.6(A) Standard Ampere Ratings for Fuses and Inverse Time Circuit Breakers

Standard Ampere Ratings				
15	20	25	30	35
40	45	50	60	70
80	90	100	110	125
150	175	200	225	250
300	350	400	450	500
600	700	800	1000	1200
1600	2000	2500	3000	4000
5000	6000	—	—	—

- Terminal conditions require use of 75 °C column, even though XHHW-2 is rated for 90 °C
- Required size is 1/0 (150 > 131)

Size AWG or kcmil	Temperature Rating of Cond		
	60°C (140°F)	75°C (167°F)	90°C (194°F)
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430
600	350	420	475
700	385	460	520
750	400	475	535
800	410	490	555
900	435	520	585
1000	455	545	615
1250	495	590	665
1500	525	625	705
1750	545	650	735
2000	555	665	750

Example

Determine the overcurrent protection and conductor (type XHHW-2) sizing for a 480Y/277 V feeder whose load is 38,900 VA (non-continuous) and 56,600 VA (continuous). The load contains non-linear elements (discharge lighting). The ambient temperature is 35 °C. The conductors are in a raceway that has four other current-carrying conductors. The equipment at the conductor's terminations are rated at 75 °C.

Now consider the conductor's environment

100% of load after applying correction and adjustment factors using the conductor's insulation rating

Example

Determine the overcurrent protection and conductor (type XHHW-2) sizing for a 480Y/277 V feeder whose load is 38,900 VA (non-continuous) and 56,600 VA (continuous). The load contains non-linear elements (discharge lighting). The ambient temperature is 35 °C. The conductors are in a raceway that has four other current-carrying conductors. The equipment at the conductor's terminations are rated at 75 °C.

100% of load after applying correction and adjustment factors using the conductor's insulation rating

Actual VA: 38,900 + 56,600 = 95,550 VA

$|S_a|$ = 95,550/3 = 36,550 VA

$|I_{line}|$ = $|S_a|$/277 = 115 A

Example

Now apply correction factors. We can use the 90 °C (not 75 °C) column because we are considering the conductor in the raceway, not at its terminals

115/0.96 = 120 A

Note: dividing the current by the correction factor is the same as multiplying the ampacity by the correction factor

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Example

Now apply the number of current-carrying conductors correction factor. Recall that the raceway is shared with another 4-wire system:

120/0.70 = 171 A

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

Example

- Find the closest size XHHW-2 (90°C) that exceeds the required ampacity of 171 A.
- Required size is 2/0 (195A > 171A)

Size AWG or kcmil	Temperature Rating of Co		
	60°C (140°F)	75°C (167°F)	90°C (194°F)
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2
	COPPER		
18*	—	—	14
16*	—	—	18
14*	15	20	25
12*	20	25	30
10*	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	115
2	95	115	130
1	110	130	145
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430
600	350	420	475
700	385	460	520
750	400	475	535
800	410	490	555
900	435	520	585
1000	455	545	615
1250	495	590	665
1500	525	625	705
1750	545	650	735
2000	555	665	750

Example

- Recap
  - Terminal requirement: 1/0
  - Conductor environment requirement: 2/0
- Select the larger of the two (2/0)
- Now ensure that the 2/0 conductor is protected by the selected overcurrent device (150A)

Example

- The uncorrected, unadjusted ampacity of 2/0 conductor sing the 90 °C rating is 195A
- De-rate according to temperature and number of current-carrying conductors: 195 x 0.96 x 0.70 = 131A
- Although the 150 A breaker is rated greater than 131 A, it is allowed because the NEC allows for the "next size up" to protect the feeder (NEC 204.4.B)
  - Otherwise, a larger conductor size would be needed

Disclaimers

- There are lots of exceptions, special cases, and nuance in the NEC
- NEC has special rules for rounding and significant digits, which are not necessarily followed in this lecture
- The process and calculations in this lecture are illustrative only

Key Points

- Electrical codes such as the NEC provide rules that govern the sizing of conductors and overcurrent protection devices
- Consideration of ampacity, environmental conditions, terminal equipment affect required size