Motor Calculations (Refer to pg. 49) see one-line diagram.

NEC

The National Fire Protection Association (NFPA) is a national organization that provides guidance in assessing the hazards of the products of combustion. The NFPA publishes the National Electric Code (NEC).

What is the purpose of the NEC?

The NEC is the practical safeguarding of persons and property from the hazards arising from the use of electricity. The city, county, state, and federal agencies use the NEC to set requirements for electrical installations. Article 430 covers requirements for motors, motor circuits, and controllers.

Motor calculation steps:

The following steps adhere to article 430 of the NEC. The steps cover motor full load currents, branch circuit sizing, branch circuit overload protection, feeder sizing, and feeder over current protection sizing for single- and three-phase, Alternating Current Motors of more than 1 horsepower.

Step 1 Single Phase - Find the FLC (full load current) - Table 430-148 single phase

Step 1 Three Phase - Find the FLC (full load current) - Table 430-150 three phase

Step 2 Branch Circuit Conductor Sizing - 430-22 Single Motor: Calculate 125% of FLC = Ampacity - Turn to 310-16 to find the wire size.

Step 3 Branch Circuit Overcurrent Protection Sizing - 430-152 Select type of motor and type of over current protection device from the chart and multiply values given by the FLC of the motor. If the calculated value does not correspond to a standard fuse or breaker size listed in 240-6 then you are allowed to go up to the next higher size.

Step 4

Sizing Overload Protection - Minimum = 430-32, Maximum = 430-34
You will need the service factor and temperature rise information for this step.
Note: Use nameplate current rating when calculating overloads. If it is not given, you can use FLC from tables.

Conductor Insulation Abbreviations:

F - Fixture wire (solid or 7 strand)
FF - Flexible fixture wire (19 strands)
H - 75 deg Centigrade insulation rating
HH - 90 deg Centigrade insulation rating
N – Nylon outer cover
T – Thermoplastic insulation
W – Wet or damp

Example: TW can be described as: Thermoplastic insulation, suitable for wet or dry locations
Maximum operating temperature is *60°C
* Used table 310-13 (it is not in this handout)
Detailed explanation of steps:

**Step 1** - Find the 'Full Load Current' of the motor. The FLC is the current level required to produce full load torque on the motor shaft at the rated speed.

Find the phase of the motor, (this will dictate which table you will go to for the FLC. If the motor is single phase, use 430-148. If the motor is three phase, use 430-150. Once you are at the appropriate table. Find the voltage and horsepower of the motor and use the chart to find the FLC. Write the FLC down, you will need it throughout each step except step 2. If the nameplate FLC rating is given, you will use it in Step 2.

Example: What is the FLC of a single phase, 2 HP, 115 volt motor? Answer: T 430-148  FLC = 24 amps

Example: What is the FLC of a three phase, 5 HP, 230 volt motor? Answer: T 430-150 FLC = 15.2 amps

**Table 430-148. Full-Load Currents in Amperes**

<table>
<thead>
<tr>
<th>HP</th>
<th>115 Volts</th>
<th>200 Volts</th>
<th>208 Volts</th>
<th>230 Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/6</td>
<td>4.4</td>
<td>2.5</td>
<td>2.4</td>
<td>2.2</td>
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<td>3.3</td>
<td>3.2</td>
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<td>3/2</td>
<td>7.2</td>
<td>4.1</td>
<td>4.0</td>
<td>3.6</td>
</tr>
<tr>
<td>3</td>
<td>9.8</td>
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<td>5.4</td>
<td>4.9</td>
</tr>
<tr>
<td>2</td>
<td>13.8</td>
<td>7.9</td>
<td>7.6</td>
<td>6.9</td>
</tr>
</tbody>
</table>

**Table 430-150. Full-Load Current Three-Phase Alternating-Current Motors**

<table>
<thead>
<tr>
<th>HP</th>
<th>115 Volts</th>
<th>200 Volts</th>
<th>208 Volts</th>
<th>230 Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>4.4</td>
<td>2.5</td>
<td>2.4</td>
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</tr>
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<td>3/4</td>
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<td>3.5</td>
<td>3.2</td>
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<td>5.6</td>
<td>5.4</td>
</tr>
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<td>1 1/2</td>
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<td>6.6</td>
<td>6.0</td>
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<tr>
<td>2</td>
<td>13.6</td>
<td>7.8</td>
<td>7.5</td>
<td>6.8</td>
</tr>
<tr>
<td>3</td>
<td>15.0</td>
<td>8.8</td>
<td>8.5</td>
<td>7.8</td>
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<tr>
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<td>8.8</td>
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<tr>
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**Induction Type**

<table>
<thead>
<tr>
<th>HP</th>
<th>115 Volts</th>
<th>200 Volts</th>
<th>208 Volts</th>
<th>230 Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>48.3</td>
<td>46.2</td>
<td>42.2</td>
<td>38.2</td>
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<td>20</td>
<td>62.1</td>
<td>49.4</td>
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<td>78.2</td>
<td>74.8</td>
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**Synchronous Type**

<table>
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<tr>
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<td>211</td>
<td>192</td>
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<td>150</td>
<td>414</td>
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<td>200</td>
<td>532</td>
<td>523</td>
<td>480</td>
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<td>500</td>
<td>572</td>
<td>562</td>
<td>523</td>
<td>494</td>
</tr>
</tbody>
</table>

*For 90 and 80 percent power factor, the above figures shall be multiplied by 1.1 and 1.25 respectively.
Step 3 - 430-22 Calculating the minimum size branch circuit for a single motor is as simple as multiplying the FLC by 125%. Conductors supplying a single motor shall have an ampacity of not less than 125%. Use the FLC rating from step 1.

Example: What is the minimum branch circuit ampacity for a 5hp, three phase, 230 volt motor using THW conductors?

Answer: FLC (T430-150) = 15.2 amps x 125% = 19 amps T310-16 = 14 AWG THW

Note: Smallest conductor size per NEC for branch circuits, feeders, or services is No. 14. Some local codes require a minimum No.12 for commercial and industrial installations. Conductors smaller than No. 14 are permitted for –Motor Control Circuits.

### Table 310-16

<table>
<thead>
<tr>
<th>AWG (kcmil)</th>
<th>60°C (140°F)</th>
<th>75°C (167°F)</th>
<th>90°C (194°F)</th>
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<td>TYPES</td>
<td>TYPES</td>
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<tr>
<td>18</td>
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<td>495</td>
<td>590</td>
<td>665</td>
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<tr>
<td>2000</td>
<td>560</td>
<td>665</td>
<td>750</td>
</tr>
</tbody>
</table>

† Unless otherwise specifically permitted in this Code, the overcurrent protection for conductor types marked with an ebelisk (†) shall not exceed 15 amperes for No.14, 20 amperes for No.12, and 30 amperes for No.10 copper, after any correction factors for ambient temperature and number of conductors have been applied.

Temperature Correction Factors

For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.

<table>
<thead>
<tr>
<th>Ambient Temp. °C</th>
<th>60°C</th>
<th>75°C</th>
<th>90°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<td>.82</td>
</tr>
<tr>
<td>60</td>
<td>....</td>
<td>.58</td>
<td>.71</td>
</tr>
<tr>
<td>70</td>
<td>....</td>
<td>.33</td>
<td>.58</td>
</tr>
<tr>
<td>80</td>
<td>....</td>
<td>....</td>
<td>.41</td>
</tr>
</tbody>
</table>
Step 3 - Table 430-152 - Motors shall have a rating or setting of motor branch-circuit short-circuit and ground-fault protective devices capable of carrying the motors inrush currents at startup. 430-152 is the maximum allowable ratings of these devices. You will need to know the type of protective device and the type of the motor. The protective devices are listed in a row at the top of the chart.

If it is a single phase motor, you only have one column on the chart to find the percentages of the FLC. If it is 3 phase (polyphase = more than one) you have several choices. You will need to know whether it is a Wound Rotor, other than a wound rotor, Squirrel Cage (Design E, or other than Design E,) or a Synchronous type motor. This will dictate which column you use to find the percentages of the FLC to calculate maximum overcurrent protection.

Example: What is the maximum size inverse time breaker for a 5hp, three phase, 230 volt, wound rotor motor?
Answer: FLC = 15.2 amps x 150 % (T430-152) = 22.8 go to 240-6. 22.8 is not a standard size. You are allowed to go up to the next higher size for branch circuits. Maximum size inverse time breaker = 25

Exercise:
Find the overload protection, wire size, and over current circuit protection for the following motor:
General Electric squirrel cage induction motor
Rated at:
5 HP 3-phase motor with SF 1.15
230/460 V
12.4/6.2 Amp nameplate current.

Use wire type THHW
Find dual element fuse and instantaneous circuit breaker size.

<table>
<thead>
<tr>
<th>Table 430-152. Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percent of Full-Load Current</strong></td>
</tr>
<tr>
<td><strong>Type of Motor</strong></td>
</tr>
<tr>
<td>Single-phase motors</td>
</tr>
<tr>
<td>AC polyphase motors other than wound-rotor</td>
</tr>
<tr>
<td>Squirrel Cage:</td>
</tr>
<tr>
<td>Other than Design E</td>
</tr>
<tr>
<td>Design E</td>
</tr>
<tr>
<td>Synchronous†</td>
</tr>
<tr>
<td>Wound rotor</td>
</tr>
<tr>
<td>Direct-current (constant voltage)</td>
</tr>
</tbody>
</table>

*For certain exceptions to the values specified, see Sections 430-52 through 430-54.
**The values in the Non-time Delay Fuse Column apply to Time-Delay Class CC fuses.
†Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as are used to drive reciprocating compressors, pumps, etc., that start unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 percent of full-load current.

(a) Fuses and Fixed Trip Circuit Breakers. The standard ampere ratings for fuses and inverse time circuit breakers shall be considered 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, and 6000 amperes.

Exception: Additional standard ratings for fuses shall be considered 1, 3, 6, 10, and 601.
Step 4 - 430-32 Calculate to find the **minimum** overload protection. You must know the **service factor** and the **temperature rise** ratings of the motor.

The **service factor** rating is the amount of output the motor can develop without causing harm to the motor. If a 5 HP motor has a service factor of 1.15 the motor can produce an output of 5.75 HP without harming the motor. The service factor could be seen as a safety measure which would allow the motor to produce extra power if it was needed.

The **temperature rise** is the difference of the motor winding temperature when running at its full potential and the ambient temperature. If the temperature rise does not exceed 40 C when running at its full potential, the motor will not be harmed. This is also a safety margin.

Overloads protect the motor. This is why the service factor and the temperature rise are important. Look at 430-32. If the service factor is not less than 1.15 or the temperature is not more than 40 C then you are allowed to size the overload at 125% of the FLC. If the motor has less than a 1.15 service factor or the temperature rise is greater than 40 C then it falls into the "all other motors" category and you must size the overload at 115%.

**Maximum** overload 430-34 - If the minimum overload is not of sufficient size to start the motor or carry the load, the next higher size overload can be used, but you cannot exceed the percentages listed in 430-34. You are allowed 140% of the nameplate for motors with service factors of not less than 1.15 or a temperature rise of not over 40 C. All other motors shall have a maximum overload protection of 130% of the nameplate FLC.

!!!!!! Always use the nameplate FLC if given when calculating OVERLOADS !!!!!!

Example: What is the minimum overload for a 3hp, single phase, and 115 volt motor with a nameplate FLC of 32 amps, with a temperature rise of 40 C?

Answer: Nameplate rating = 32 amps x 125% (from table 430-32) = 40 minimum overload

Example: What is maximum overload for the above motor?
Answer: Nameplate rating = 32 amps x 140% (from table 430-34) = 44.8 maximum overload

Example: What if it asked for the maximum overload and did not give the nameplate rating?
Answer: FLC from T430-148 = 34 amps x 140% = 47.6 maximum overload.

**Always use nameplate FLC if given!**

Example: What is the minimum overload for a 3hp, single phase, 115 volt motor with a nameplate of 32 amps and a service factor of 1.10?
Answer: Nameplate rating = 32 amps x 115% (all other motors because the service factor was less than 1.15) = 36.8 minimum overload

### 430-32. Continuous-Duty Motors.

(a) **More than 1 Horsepower.** Each continuous-duty motor rated more than 1 horsepower shall be protected against overload by one of the following means:

1. A separate overload device that is responsive to motor current. This device shall be selected to trip or shall be rated at no more than the following percent of the motor nameplate full-load current rating.

   - Motors with a marked service factor not less than 1.15 ………. 125%
   - Motors with a marked temperature rise not over 40°C ………. 125%
   - All other motors……………………………………….. 115%

   Modification of this value shall be permitted as provided in Section 430-34. For a multispeed motor, each winding connection shall be considered separately.

   Where a separate motor overload device is so connected that it does not carry the total current designated on the motor nameplate, such as for wye-delta starting, the proper percentage of load current shall be calculated and the overload shall be selected so as not to exceed the above limits.

### 430-34. Selection of Overload Relay.

Where the overload relay selected in accordance with Sections 430-32(a)(1) and (c)(1) is not sufficient to start the motor or to carry the load, the next higher size overload relay shall be permitted to be used, provided the trip current of the overload relay does not exceed the following percentage of motor nameplate full-load current rating.

- Motors with marked service factor not less than 1.15 ………. 140%
- Motors with a marked temperature rise not over 40°C ………. 140%
- All other motors……………………………………….. 130%

If not shunted during the starting period of the motor as provided in Section 430-35, the overload device shall have sufficient time delay to permit the motor to start and accelerate its load.

(FPN): A Class 20 or 30 overload relay will provide a longer motor acceleration time than a Class 10 or 20, respectively. Use of a higher class overload relay may preclude the need for selection of a higher trip current.
Step 5 - 430-24 When you have more than one motor or you have one motor and an additional load the feeder conductors shall be equal to the sum of the FLC for all the motors and all additional loads plus 25% of the FLC of the largest motor. IMPORTANT: If you have an additional load which is not a motor, and the FLC of the additional load is greater than the largest motor, you do not add 25% to the additional load, you must add the 25% to the largest motor, regardless of the size of the additional load. Turn to 310-16 to find the wire size.

Example - You have a motor with a FLC of 10 amps and a heat load of 15 amps on a feeder.
Largest motor = 10 amps x 125% = 12.5 amps plus the additional heat load of 15 amps = 27.5 amps
Even though the heat load FLC was greater than that of the motor, we still added the 25% to the largest motor!

Example: What is the minimum size THHN feeder allowed for 1 - 3hp, three phase, 208 volt motor and 1 - 2hp, single phase 208 volt motor?
Answer: 3hp motor = 10.6 amps - 2hp motor = 13.2 amps
Largest FLC motor = 13.2 amps x 125% = 16.5 amps plus smaller FLC motor 10.6 amps = 27.1 Go to 310-16 - THHN for 27.1 amps = 12 AWG Feeder Conductor

Step 6 - 430-62 A feeder supplying a specific fixed motor load(s) and consisting of conductor sizes based on 430-24 shall be provided with a protective device having a rating or setting not greater than the largest rating of the largest protective device for any motor supplied by the feeder plus the sum of the FLC of the other motors in the group.

You simply find the motor with the largest overcurrent protective device from step 4 and add to the rating of that device the full load currents of all the other motors.

Example: What size feeder overcurrent protection using dual element fuses is required for 1 - 3hp, three phase, 208 volt motor and 1 - 2hp, single phase 208 volt motor?
Answer:
Branch circuit OCP 3hp, 3 phase motor = 10.6 amps x 175% (T430-152) = 18.55 next higher size 20 amp
Branch circuit OCP 2hp, 1 phase motor = 13.2 amps x 175% (T430-152) = 23.10 next higher size = 25 amp
For Feeder overcurrent protection you add the branch circuit OCP for the largest motor 13.2 amps = 25 amp plus the FLC of the other motor(s).
25 amps (largest FLC motor) plus 10.6 amps (FLC of the smaller motor) = 35.6 amps
Go to 240-6 to find standard fuse sizes. 35.6 is not a standard fuse size.
You are not allowed to go up to the next higher size for feeder overcurrent protection. You must go down.
Maximum feeder overcurrent protection = 35 amp

<table>
<thead>
<tr>
<th>Steps &amp; NEC Rules</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 Motor FLC</td>
<td>Table 430-148 &amp; 150</td>
<td>_______ FLC</td>
<td>_______ FLC</td>
</tr>
<tr>
<td>Step 2 Branch circuit</td>
<td>Conductor</td>
<td>______ X 1. 25 = ______</td>
<td>______ X 1. 25 = ______</td>
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<tr>
<td></td>
<td>Table 430-22, Table 310-16</td>
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<td></td>
</tr>
<tr>
<td>Step 3 Branch circuit</td>
<td>protection</td>
<td>______ X ______ = ______</td>
<td>______ X ______ = ______</td>
</tr>
<tr>
<td></td>
<td>Table 430-152, Table 240-6</td>
<td>Next size up</td>
<td>Next size up</td>
</tr>
<tr>
<td>Step 4 Overload heaters</td>
<td>based on motor nameplate</td>
<td>______ X 1. ______ = ______</td>
<td>______ X 1. ______ = ______</td>
</tr>
<tr>
<td></td>
<td>current</td>
<td>Standard 430-32</td>
<td></td>
</tr>
<tr>
<td>Step 4 Overload heaters</td>
<td>Maximum 430-34</td>
<td>______ X 1. ______ = ______</td>
<td>______ X 1. ______ = ______</td>
</tr>
<tr>
<td>Step 5 Feeder conductor</td>
<td>Table 430-24, Table 310-16</td>
<td>______ X 1. 25 + ______</td>
<td>______ + ______ + ______</td>
</tr>
<tr>
<td></td>
<td>and 240-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 6 Feeder Protection</td>
<td>Table 430-62, Table 310-152</td>
<td>______ + ______ + ______</td>
<td>______ + ______ + ______</td>
</tr>
<tr>
<td></td>
<td>and 240-6</td>
<td>Next size down</td>
<td></td>
</tr>
</tbody>
</table>