Motor Branch Circuit Over-Current Protection

For HVAC Project Engineers

Fachgesprach – 9

☹WTF Institute of Higher Learning☹

By Mat Ansari PE

- For HVAC Project Engineer's Reference Use Only
- Not for Electrical Design or Construction

A Tunnel Vision Look at NEC
No Code Articles Referenced

Disconnects

Circuit Breakers

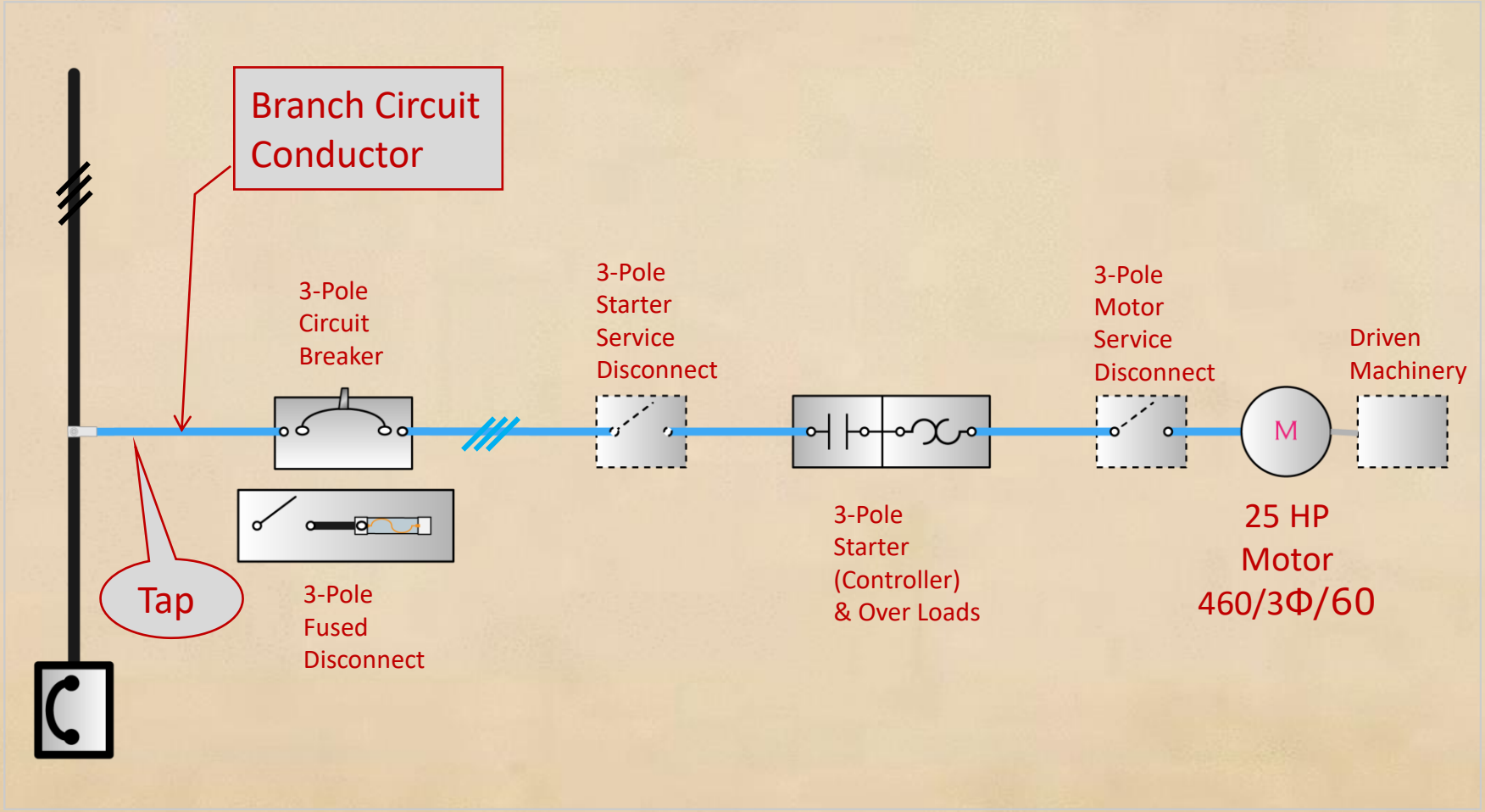
Motor Starters

Motor Overloads

Motor Branch Circuits

Let us use a 480 Volt 3-Phase System for our example.

(1-Phase motors will have only one pole like below. One hot and one Neutral/Grounded. You are not allowed to switch or fuse the Grounded conductor.)



Quick Review of our Last Fachgesprach – Wire Sizing

How much Current does the conductor need to carry?

1. HVAC Equipment (Packaged, Unitary, and Split etc.)

   The wire must safely carry the Manufacturer's MCA (Minimum Circuit Ampacity).

2. Stand Alone Motors (Fans and Pumps etc.)

   The wire must safely carry 125% of the motor FLC per NEC Table.

   Do NOT use Motor Nameplate FLA.

3. Multiple Motors Served by One Branch Circuit

   125% of the largest motor FLC Amps plus 100% of all others.

4. Non-Motor and Non-A/C loads (HVAC PE's viewpoint)

   Like Boilers, Heaters etc.

   125% of all continuous loads + 100% of all non-continuous loads

Standard Wire For Commercial HVAC

THHN/THWN-2 COPPER 90°C

Item (sold by the foot unless noted otherwise)	O.D. (inches)	Ampacity @ 90°C
14 AWG THHN, 500ft or 2500ft Spool »	0.109	15
12 AWG THHN, 500ft, 1000ft or 2500ft Spool »	0.128	20
12 AWG THHN 100ft or 200ft Coil »	0.128	20
10 AWG THHN, 500ft, 1000ft or 2500ft Spool »	0.161	30
10 AWG THHN, 100ft or 200ft Coil »	0.161	30
8 AWG THHN »	0.213	55
6 AWG THHN »	0.249	75
4 AWG THHN »	0.318	95
3 AWG THHN »	0.346	110
2 AWG THHN »	0.378	130
1 AWG THHN »	0.435	150
1/0 THHN »	0.474	170
2/0 THHN »	0.518	195
3/0 THHN »	0.568	225
4/0 THHN »	0.624	260

Wire Type THHN/THWN-2

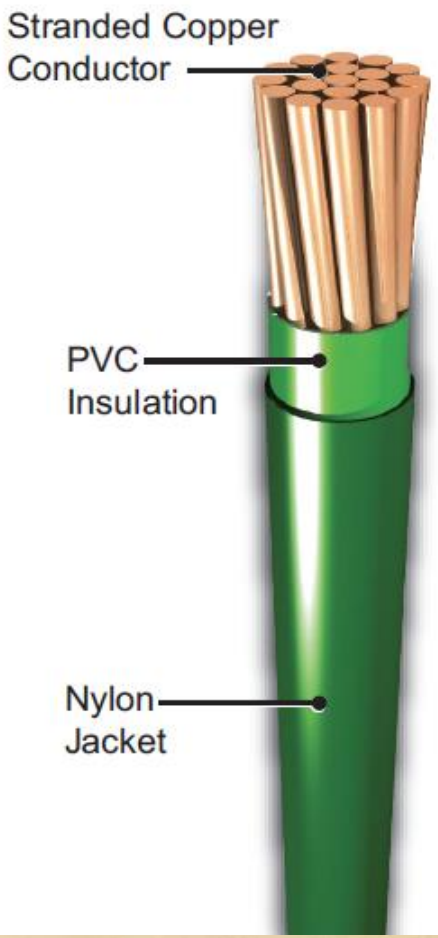


Table 310.15(B)(16) (formerly Table 310.16)
Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts
60°C Through 90°C (140°F Through 194°F)
Not More Than Three Current-Carrying Conductors in Raceway, Cable, Earth (Directly Buried)
Based on Ambient Temperature of 30°C (86°F)*

Temperature Rating of Conductor [See Table 310.104(A).]			
Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2
18	—	[7] —	14
16	—	[10] —	18
14**	15	[15]** 20	25
12**	20	[20]** 25	30
10**	30	[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

* Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).

** Refer to 240.4(D) for conductor overcurrent protection limitations.

WEIRD RULES – Table 310.15(B)16 Usage (Why it is misused so often.)

RULE #1

You can never use an ampacity higher than that in the 75°C Column.
If you have a 90°C conductor (like we usually do), you can use the 90°C rating before applying the "corrections" and "adjustments" but the final number cannot be any higher than the 75°C value.

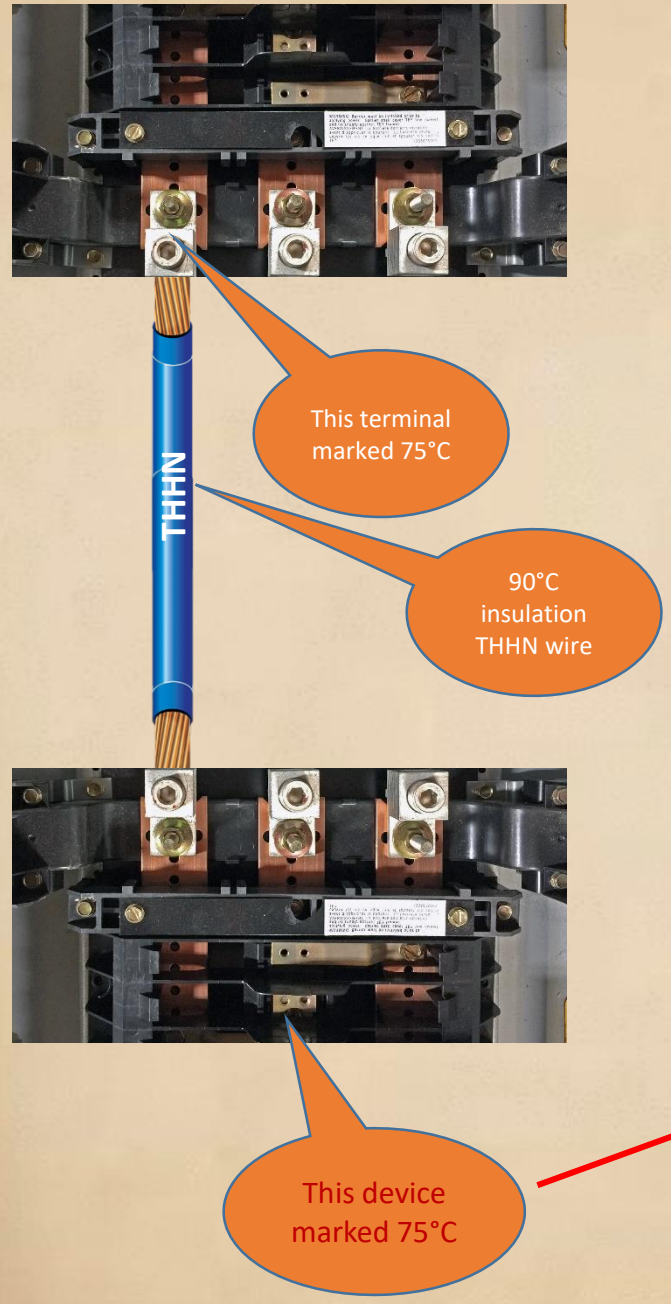
RULE #2

Loads < 100 Amps --- Use 60°C
Loads > 100 Amps --- Use 75°C
(Ignoring terminal markings.)

RULE #3

Non-Motor Loads --- Note small gage wire limits on Circuit Protection [xx]**

Terminal/Equipment Ratings



All electrical devices and terminals have temperature ratings under which they have been tested for continuous operation.

Most of the time (for larger equipment) the terminal rating is stamped on the device and is 75°C. There is no 90°C listed device under 600 Volts. (Disconnects, Circuit Breakers and Starters etc.).

Per NEC you cannot use wire ampacity from a column higher than the lowest wire/terminal/device rating (WEAKEST LINK CONCEPT).
So in this case we have to use 75°C Ampacity column even though the wire THHN is rated for 90°C. Remember you can start derating from 90°C THHN ampacity – but can never exceed the 75°C capacity.

Note that there is also a "heat rejection" factor. The testing and certification of a device might have used lower temp., larger dia. wire (more mass) to qualify.

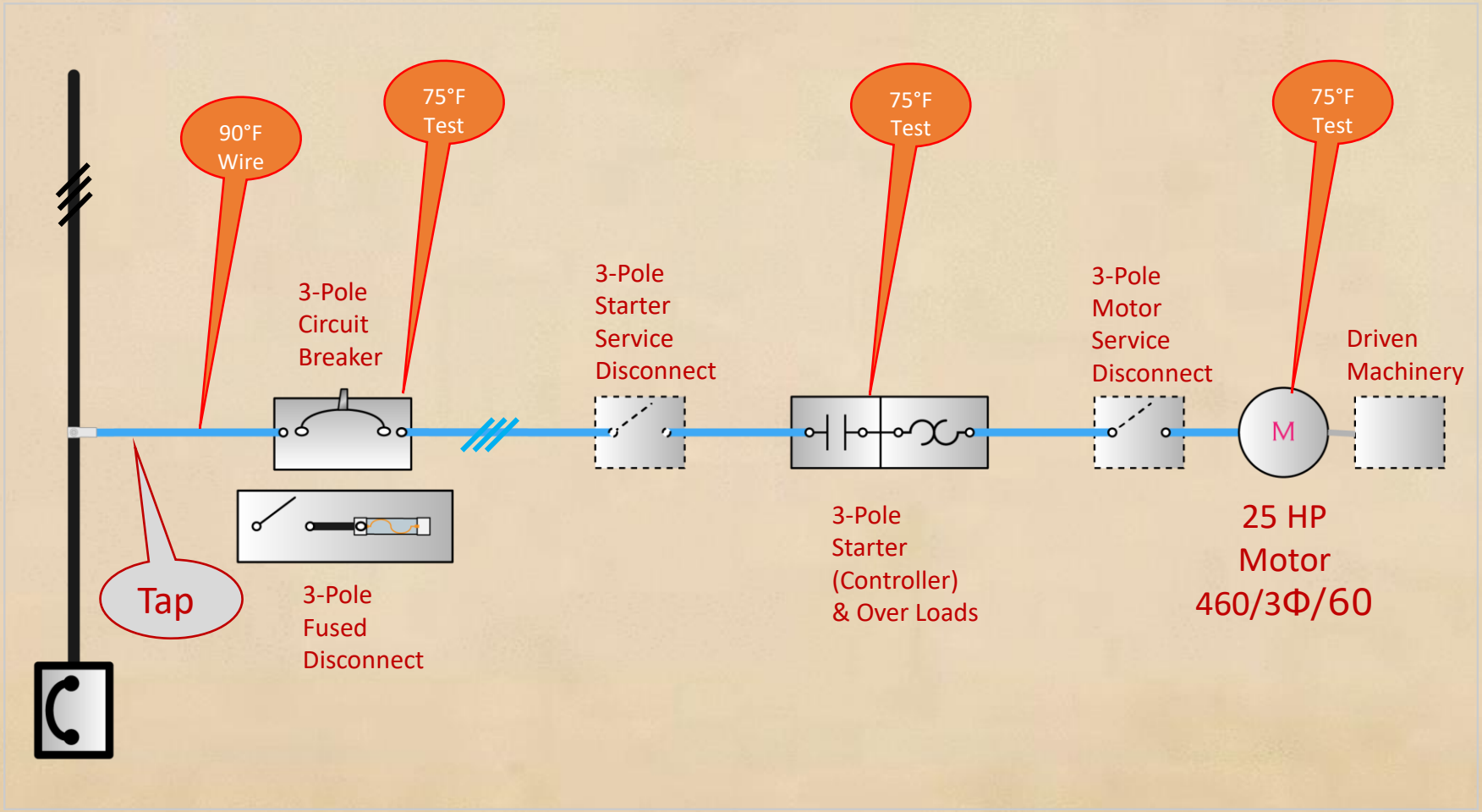
If no rating is marked on the equipment, (or unknown at time of design) then it is assumed to be rated at 60°C. (For < 100 amps. 75°C always OK for > 100 amps). Motor Branch circuits are an exception and 75°C can always be used.


AL100FA
FH 50 A
Circuit Breaker
Interruptor Automático
Disjoncteur
FHL3605014DC
Interrupting Rating
Valor de Interrupción
Valeur d'interruption
UL
CSA
NEMA
(V)
(kA)
500 Nom. 600Max.
20
Circuit breaker is suitable only for use with UPS and ungrounded systems.
Este interruptor automático es adecuado para usarse solo con suministro ininterrumpido de energía y sistemas no aterrizados.
Le disjoncteur convient a l'utilisation seulement avec des systemes d'alimentation sans coupure (ASC) et non mis a la terre.
LISTED C.B.
ISSUE NO. 186
E10027
SQUARE D
75°C only/sólo/seule.
AWG
lb-in/pul
#14 - #10 Cu 80
#14 - #1/0 Cu 80
#12 - #10 Al 40
#12 - #1/0 Al 80
mm²
N · m
2.5 - 6 Cu 9
2.5 - 50 Cu 9
2.5 - 6 Al 5
2.5 - 50 Al 9
CAUTION/PRECAUCION/ATTENTION
Connect only as shown/Conectar solo así/
Francher seulement comme suit:
300 V MAX.
300 V MAX.
or
o
ou
600 V MAX.
Load/Carga/Charge
Load/Carga/Charge
I
50
O
S2
64
40°C
06242
Type/Tipo FAL

Motor Branch Circuits

The "WEAKEST LINK" is 75°F

Per NEC the Conductor Ampacity cannot be more than that in 75°F Column



Name Plate of A Typical 25 HP Motor

H.P.:	25.0	VOLTS:	230/460	FREQUENCY:	60 Hz	S.RPM:	1800
FRAME:	284T	ENCLOSURE:	ODP	FLAMPS:	62/31	FLRPM:	1775
FORM:	VBK1	S.F.:	1.15	NEMA DESIGN:	B	INSUL CLASS:	F
TYPE:	TIKK	AMB.:	40 C	CODE:	G	DUTY:	CONT.
MODEL NO.:	0254DPSA31A-P			kW.:		SERIAL NO.:	
NOM. EFF.:	93.6	MIN. EFF.:		P.F.:	81		

EFFICIENCY (%)	POWER FACTOR (%)
FULL LOAD: 93.6	FULL LOAD: 81
3/4 LOAD: 93.7	3/4 LOAD: 93.7
1/2 LOAD: 92.8	1/2 LOAD: 67.5

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* Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).

** Refer to 240.4(D) for conductor overcurrent protection limitations.

Wire Size

Max Amps

Use this value for Adjustments

Table 310.15(B)(16)
(formerly Table 310.16)
(Table Chopped up. AL and larger wire sizes not shown.)

Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried),
[note:80% 4 to 6]

Based on Ambient Temperature of 30°C (86°F)*

(From Code FLC Table)

25 HP FLC = 34 Amps

MCA = 34 x 1.25 = 42.5 Amps

Assume no corrections

From the 75°C Col. read 8 AWG Wire

End of Review Slides

Model	CVHE	Compressor size	500
Impeller size	230	Orifice size	500
Motor size	287		
Motor frequency	60 Hz	Motor voltage	460
Incoming line frequency	60 Hz	Incoming line voltage	460
Evap shell size	050S	Cond shell size	050S
Evap bundle size	390	Cond bundle size	450
Evap tube type	TECU	Cond tube type	TECU
Evap tube thickness	0.025"	Cond tube thickness	0.028"
Evap passes	Two pass evap water box	Cond passes	Two pass cond

A

BHP 385
400 HP Motor ??
FLA 477

Design Information

Cooling capacity	400.0 tons	HCFC-123 refrigerant charge	600 lb
Primary power	245.7 kW	Shipping weight	17822 lb
Primary efficiency	0.614 kW/ton	Operating weight	19593 lb
NPLV	0.388 kW/ton	Free cooling option	No
Low voltage AFD type	Unit mounted low voltage AFD	Green Seal certification	No
Unit heat rejected to ambient	4.19 MBh	Application type	Standard cooli
AFD heat rejected to ambient	8.62 MBh		

BHP 329

B

T-24?

Evaporator Information

Evap leaving temp	42.00 F	Evap pressure drop	14.58 ft H2O
Evap flow rate	682.6 gpm	Evap fluid type	water
Evap entering temp	56.00 F	Evap fluid concentration	N/A
Evap flow/capacity	1.71 gpm/ton	Evap water box type	non-marine
Evap fouling factor	0.00010 hr-sq ft-deg F/Btu	Evap water box pressure	150 psig

Condenser Information

Cond entering temp	85.00 F	Cond pressure drop	20.20 ft H2O
Cond flow rate	1080.0 gpm	Cond fluid type	water
Cond leaving temp	95.53 F	Cond fluid concentration	N/A
Cond flow/capacity	2.70 gpm/ton	Cond water box type	non-marine
Cond fouling factor	0.00025 hr-sq ft-deg F/Btu	Cond water box pressure	150 psig

Electrical Information

LRA = Locked Rotor Amps

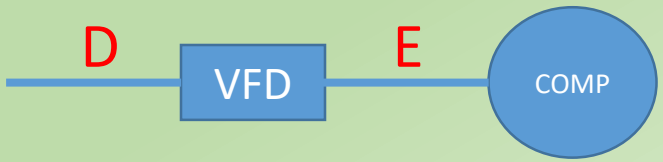
Motor LRA	2234 A	Compressor motor RLA	346.30 A
Primary RLA (Incoming line)	321.7 A	Min circuit ampacity	411 A
Un-corrected power factor	0.89	Max overcurrent protection	700 A

C D E F G

RLA = Rated Load Amps

CHILLER SUBMITTAL Discussion Points:

1. Let us start at TAG B. This is the kW draw at the ARI full load Temperature and Pressure Conditions.
    1. Divide by 0.746 to get 329 BHP.
    2. Divide by 400 Tons to get kW/Ton (T-24 Legal?)
2. TAG D: RLA is Rated Load Amps. (Not "Running" ☺)
    1. Dictated by UL bench testing at design Temp/Press.
    2. All safeties are keyed to this number.
    3. Wire sizing MCA is based on this number.
3. TAG F: MCA = 125% of Largest RLA + 100% of other
    1. $MCA = RLA \times 1.25 + VA_{Xformer}/Motor_{Volts}$
    2. $MCA = 321.7 \times 1.25 + 4000/460 = 411$ Amps
4. TAG A: This is the max. kW power OUTPUT of the motor actually used.
    1. Divide by 0.746 to get 385 BHP (or Shaft HP)
    2. Obviously this is a 400 HP Motor.
    3. Now there is a Full Load Amps (and NEC FLC) value associated with this 400 HP motor and it is ≈ 477 Amps. WE DON'T USE THIS VALUE. We use the MCA value which in turn is based on the RLA given below.
    4. This clearly shows the difference between FLA and RLA.
    5. The safeties are all set to trip in relation to the RLA and way before the FLA is ever reached.
5. TAG C: LRA is Locked Rotor Amps. Used in conjunction with Starter Type in determining MOCP. Gen Set Sizing.
6. TAG G: MOCP Important for (Electrical) Cost and VE opportunity. Often over-sized on electrical drawings.
7. TAG E: What is going on? Why is it different?
    1. VFD has a different (better) PF than the Compressor Motor. If you just forward the submittal to the Elec Sub, he will always use the higher number and cost you money.



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Evap tube thickness	0.025"	Cond tube thickness	0.028"
Evap passes	Two pass evap water box	Cond passes	Two pass cond water box

Verify "tube pull" Clearance

Verify connection side

Verify connection side

Design Information

1.5 - 2 lbs/ton ? R134a similar

Cooling capacity	400.0 tons	HCFC-123 refrigerant charge	600 lb
Primary power	245.7 kW	Shipping weight	17822 lb
Primary efficiency	0.614 kW/ton	Operating weight	19593 lb
NPLV	0.388 kW/ton	Free cooling option	No
Low voltage AFD type	Unit mounted low voltage AFD	Green Seal certification	No
Unit heat rejected to ambient	4.19 MBh	Application type	Standard cooling
AFD heat rejected to ambient	8.62 MBh		

Rigging Wt.
Operating Wt.

Chiller room load

Evaporator Information

Evap leaving temp	42.00 F	Evap pressure drop	14.58 ft H2O
Evap flow rate	682.6 gpm	Evap fluid type	water
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CHW PP Sizing

Min. Flow ?

14°F ΔT Coil?

Hi-Rise Static Check

Condenser Information

Cond entering temp	85.00 F	Cond pressure drop	20.20 ft H2O
Cond flow rate	1080.0 gpm	Cond fluid type	water
Cond leaving tem	95.53 F	Cond fluid concentration	N/A
Cond flow/capacit	2.70 gpm/ton	Cond water box type	non-marine
Cond fouling factor	0.00025 hr-sq ft-deg F/Btu	Cond water box pressure	150 psig

Note this is 10.5°F ΔT but much lower than 3 gpm per ton on dwgs.

CDW PP Sizing

Tower Performance Spec.

Compare

Hi-Rise Static Check

Electrical Information

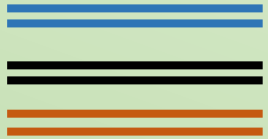
Motor LRA	2234 A	Compressor motor RLA	346.30 A
Primary RLA (Incoming line)	321.7 A	Min circuit ampacity	411 A
Un-corrected power factor	0.89	Max overcurrent protection	700 A

Mechanical Discussion Points:

1. Water boxes can be switched in the field but better to order them correctly. Example "facing the control panel" RHS or LHS connections
2. Number of Passes – Even on the same end. Odd opposite ends.
3. Verify "tube pull" clearance
4. Chiller Room ventilation load
5. Refrigerant Charge – You may need to buy separate.
6. Rigging Weight / Operating Weight. Make sure the rigger gets the right one and the Structural Engineer gets the right one.
7. Evaporator Flow Ask about min. Flow or Velocity
8. Chilled water ΔT. Check against Coil ΔT. Allow 1°F(?) temperature rise between chiller and air-handler.
9. Evaporator Water Pressure Drop – Pump Sizing. Flow follows square curve.
10. Evaporator Working Pressure – Hi-Rise design
11. Condenser Flows
12. Condenser Water Pressure Drop – Pump Sizing
13. Condenser Working Pressure – Hi-Rise design
14. Condenser fouling factor way to optimistic – careful when comparing 2 chiller performances.

Quick Sizing Electrical Service: Chiller (Or Any Large HVAC Equipment)

- Example – 400 Ton Water Cooled Centrifugal Chiller
- To "Ball Park" water cooled centrifugal chiller electrical service:
- Title-24 mandates certain minimum efficiency levels. 0.6kw/ton is a good budget number. (T-24 See Handout)
- 400 tons x 0.6 kW/ton = 240 kW
- 3 phase kW = (V x Amps x 1.73 x PF) ÷ 1000
- Amps = (kW x 1000) ÷ (V x 1.73 x PF) = kW x 1.42 for 480v and 0.85PF
- Amps = 240 kW x 1.42 = 340 Amps RLA
- MCA = 340 x 1.25 = 425 Amps
- MCOP = 425 x 1.75 = 743 Amps. Next std. size down is 700 Amp Breaker (Compr. Rule)
- (Compare to previous slide (411 Amps). Difference due to kW/ton, PF and ignoring CT amps.)
- Need to get kW per ton from COP and EER. See next slide.



2 parallel conductors
for each phase
size 4/0 each conductor

EER • COP • kW/Ton

kW/Ton x EER = 12

Kw/Ton x COP = 3.517

Fuses & 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

Overcurrent Protection Sizing

1. HVAC Equipment (Packaged, Unitary, and Split etc.)

   At or below M(ax)OCP Listed on nameplate. Usually not more than 175% of RLA.

2. Stand Alone Motors (Fans and Pumps etc.)

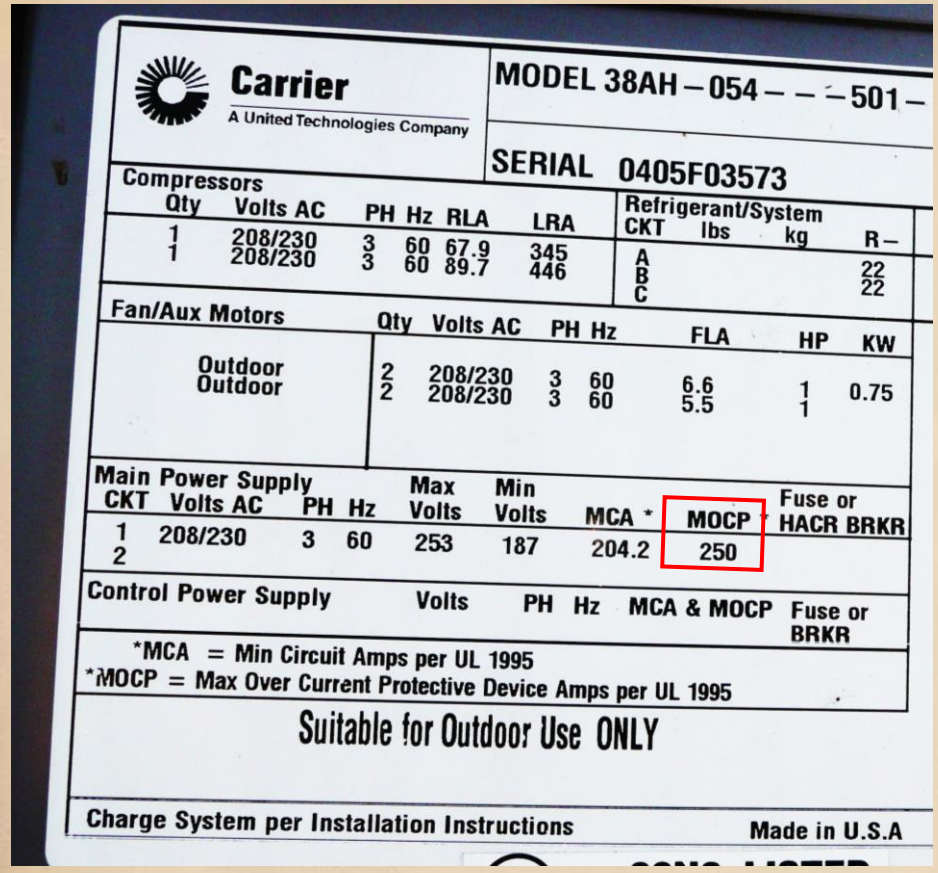
   Inverse Time Breaker 250%. Time Delay Fuse 175%. (Max. Values, but next Std. size OK.)

3. Feeder Serving Multiple Motors

   Will explain by example.

There are many kinds of Circuit Breakers and Fuses – but for our discussion we will only consider Inverse Time Breakers (HACR included) and Time Delay Fuses.

MCOP - Maximum Overcurrent Protection



Carrier
A United Technologies Company

MODEL 38AH – 054 – – – 501 –

SERIAL 0405F03573

Compressors Qty	Volts AC	PH	Hz	RLA	LRA
1	208/230	3	60	67.9	345
1	208/230	3	60	89.7	446

Refrigerant/System CKT	lbs	kg	R–
A			22
B			22
C			

Fan/Aux Motors	Qty	Volts AC	PH	Hz	FLA	HP	KW
Outdoor	2	208/230	3	60	6.6	1	0.75
Outdoor	2	208/230	3	60	5.5	1	

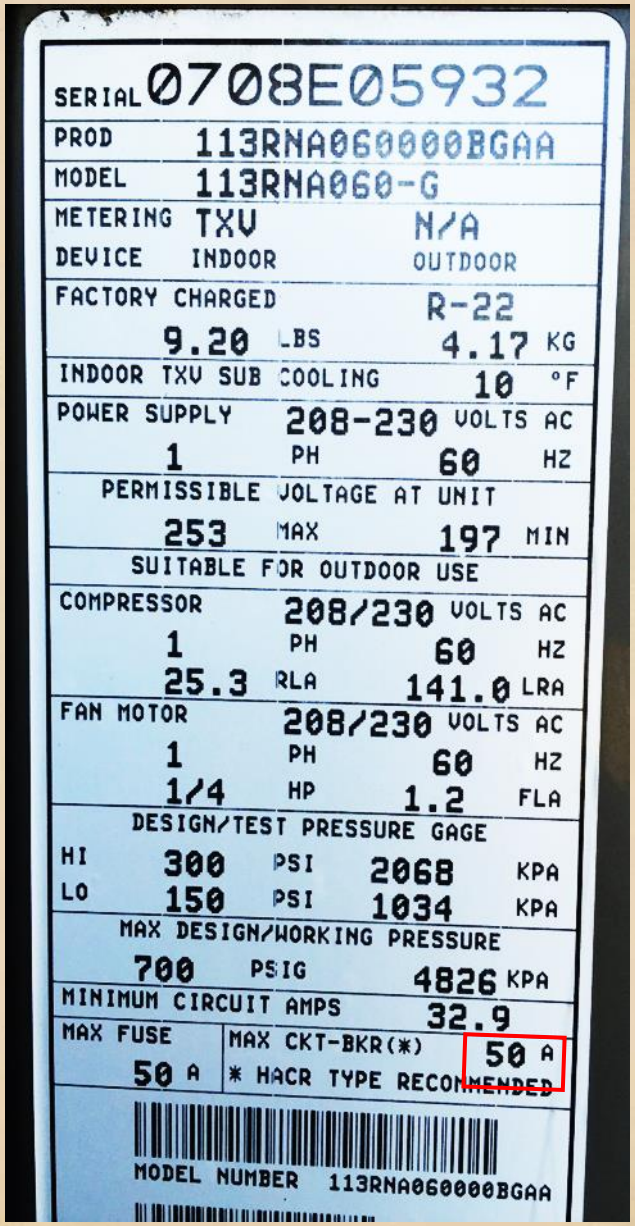
Main Power Supply CKT	Volts AC	PH	Hz	Max Volts	Min Volts	MCA *	MOCP *	Fuse or HACR BRKR
1 2	208/230	3	60	253	187	204.2	250	

Control Power Supply	Volts	PH	Hz	MCA & MOCP	Fuse or BRKR

*MCA = Min Circuit Amps per UL 1995
*MOCP = Max Over Current Protective Device Amps per UL 1995

Suitable for Outdoor Use ONLY

Charge System per Installation Instructions — Made in U.S.A



SERIAL 0708E05932
PROD 113RNA060000BGAA
MODEL 113RNA060-G
METERING DEVICE TXV INDOOR / N/A OUTDOOR
FACTORY CHARGED 9.20 LBS 4.17 KG R-22
INDOOR TXV SUB COOLING 10 °F
POWER SUPPLY 208-230 VOLTS AC 1 PH 60 HZ
PERMISSIBLE VOLTAGE AT UNIT 253 MAX 197 MIN
SUITABLE FOR OUTDOOR USE
COMPRESSOR 208/230 VOLTS AC 1 PH 60 HZ 25.3 RLA 141.0 LRA
FAN MOTOR 208/230 VOLTS AC 1 PH 60 HZ 1/4 HP 1.2 FLA
DESIGN/TEST PRESSURE GAGE
HI 300 PSI 2068 KPA
LO 150 PSI 1034 KPA
MAX DESIGN/WORKING PRESSURE 700 PSIG 4826 KPA
MINIMUM CIRCUIT AMPS 32.9
MAX FUSE 50 A
MAX CKT-BKR(*) 50 A
* HACR TYPE RECOMMENDED
MODEL NUMBER 113RNA060000BGAA

ACTUAL NAME PLATE EXAMPLES.

For Hermetic Compressors & Across the Line Starter: 175% of MCA (Next size lower if not std. size.)

BUT - Bottom Line: Forget all the formulas – just use MOCP on Nameplate for CB sizing!

Note:
The M in MCA stands for Minimum
The M in MOCP stands for Maximum

Overcurrent Protection Sizing

1. HVAC Equipment (Packaged, Unitary, and Split etc.)

   At or below M(ax)OCP Listed on nameplate. Usually not more than 175% of RLA.

2. Stand Alone Motors (Fans and Pumps etc.)

   Inverse Time Breaker 250%. Time Delay Fuse 175%.

3. Feeder Serving Multiple Motors

   Will explain by example.

Before we select the CB for Stand Alone Motors, let us understand CBs a little better.

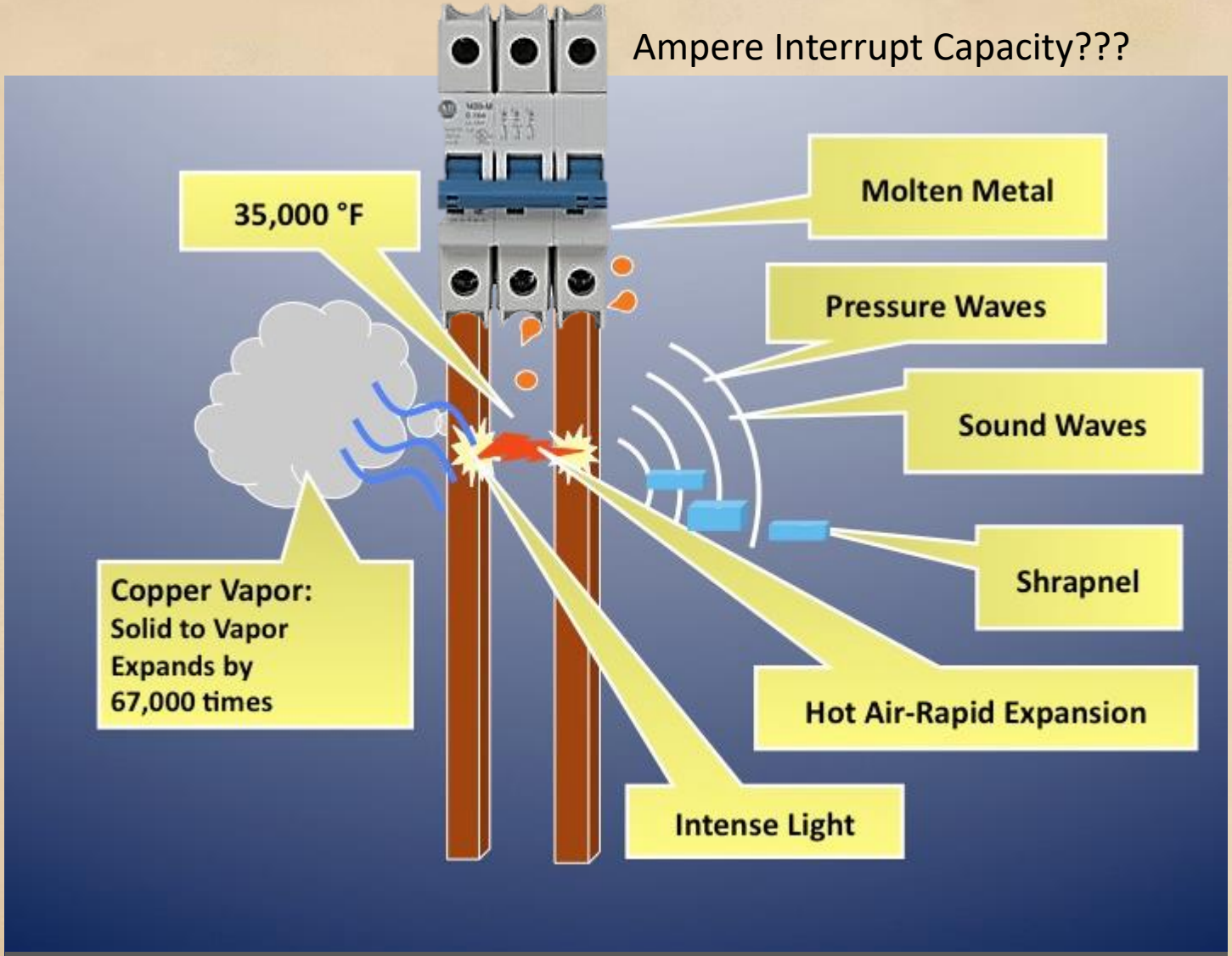
Branch Circuit OverCurrent Protection

OverCurrent Can Be of 3 Types:

1. Short Circuit (2 hot wires or 1 hot & 1 grounded.)
2. Ground Fault
3. Overload

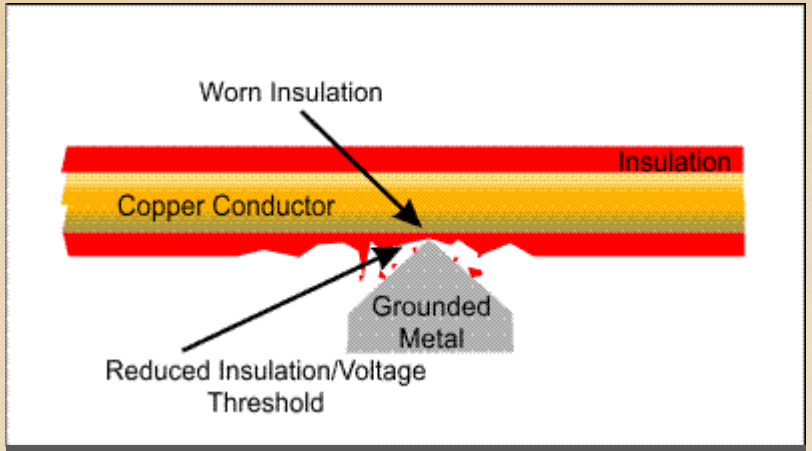
Bolted Fault – Short Circuit

Ampere Interrupt Capacity???



Order of Magnitude 20,000 Amps ???

Ground Fault



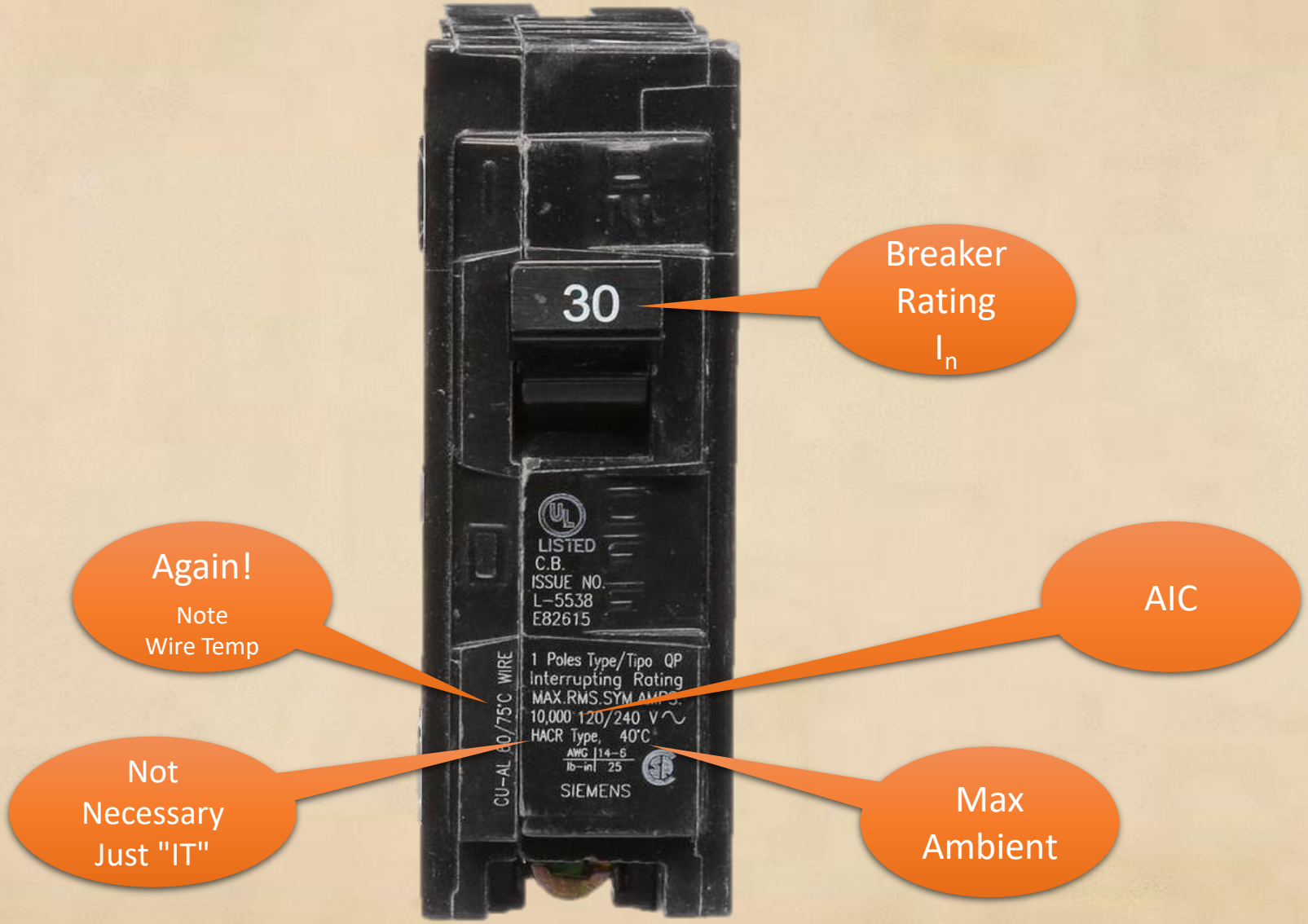
Current 1000 Amps ???

Steady Overload

Example:

Motor FLC	34 Amps
Actual Draw	44 Amps

Ampere Interrupting Capacity [AIC]



If the available short circuit amps are 50,000 at this breaker …
This breaker will explode!

OverCurrent Protection
The Basic Intent of Code

Table 310.15(B)(16) (formerly Table 310.16)
Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts
60°C Through 90°C (140°F Through 194°F)
Not More Than Three Current-Carrying Conductors in Raceway, Cable, Earth (Directly Buried)
Based on Ambient Temperature of 30°C (86°F)*

Temperature Rating of Conductor [See Table 310.104(A).]			
Size AWG or kcmil	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2
18	—	[7] —	14
16	—	[10] —	18
14**	15	[15]** 20	25
12**	20	[20]** 25	30
10**	30	[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

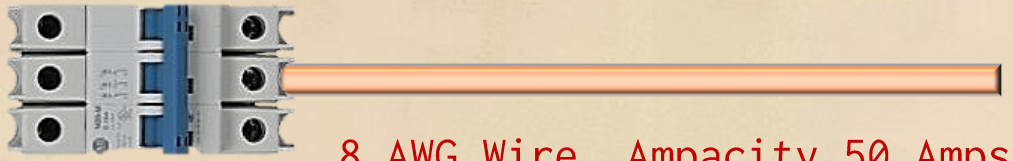
* Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).

** Refer to 240.4(D) for conductor overcurrent protection limitations.

Wire Size

Max Amps

50 Amp Breaker



8 AWG Wire Ampacity 50 Amps
Must be protected by a
50 Amp Breaker

20 Amp Breaker

12 AWG Wire Ampacity 25 Amps
Must be protected by a
20 Amp Breaker.
(Small AWG Exception.)

Motors are an Exception

NEC FLC 34 Amps
FLA 31 Amps
Inrush = 31 x 6 = 186 Amps
Transient = FLA x (13 to 20)??

50 Amp Inverse Time Breaker

8 AWG Wire Ampacity 50 Amps

25 HP
Motor
460/3Φ/60

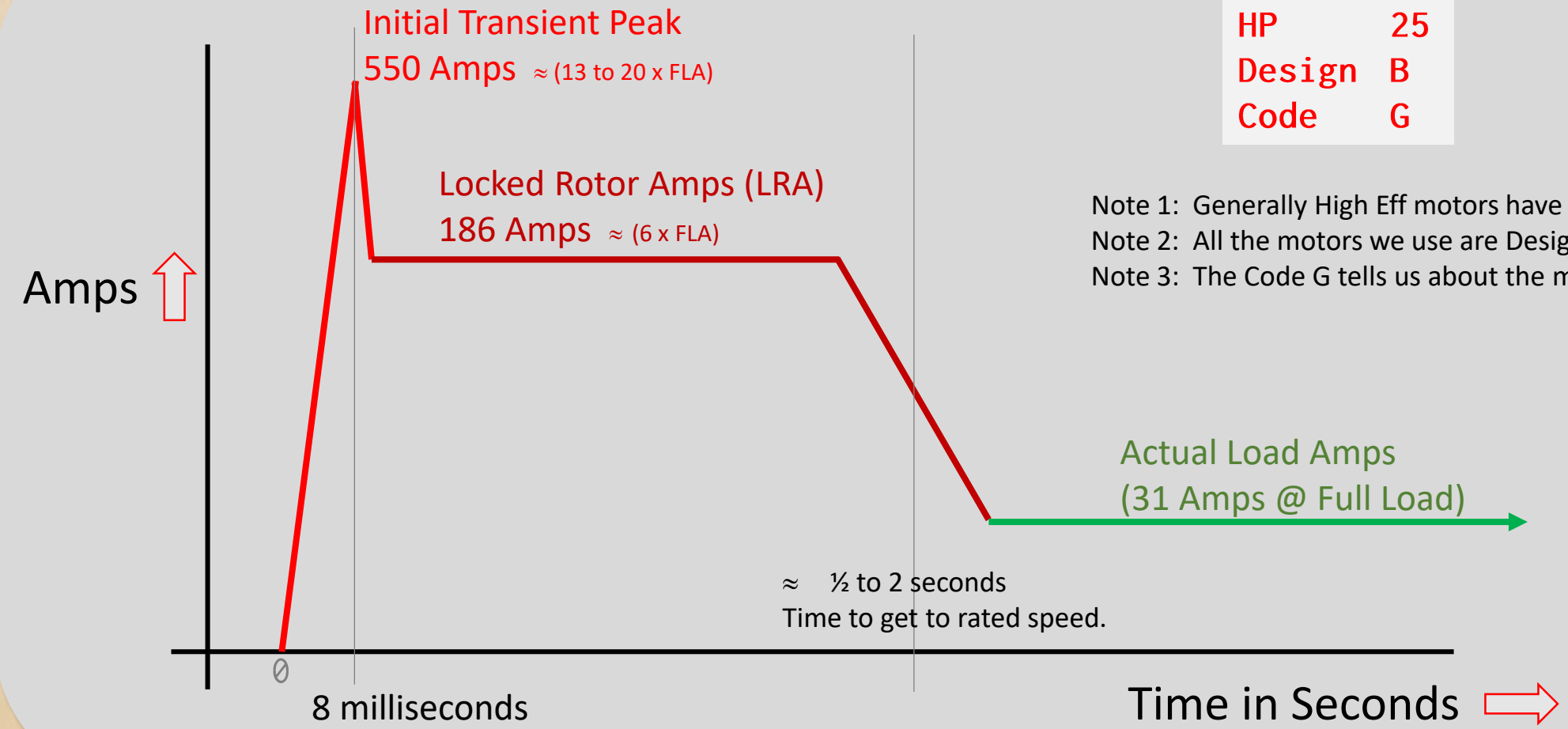
This motor may not be able to start!

Motor Inrush Current Table

NEMA LRA CODE	APPROXIMATE Inrush Amperes Per HP				
	Single Phase (1 Φ)		Three Phase (3 Φ)		
	115 Volts	230 Volts	200 Volts	230 Volts	460 Volts
D	39	19	12.5	10.8	5.4
E	43	20	13.6	11.8	5.9
F	48	23	15.4	13.3	6.6
G	54	26	17.1	14.8	7.4
H	61	29	19.4	16.8	8.4
J	68	33	21.8	18.8	9.4
k	77	37	24.7	21.3	10.6
L	86	41	27.6	23.8	11.9
M	96	46	30.7	26.5	13.3
N	107	51	34.2	29.5	14.8

Current Draw Versus Time – Typical 25 HP Motor

Why The 50 Amp Breaker Will Trip

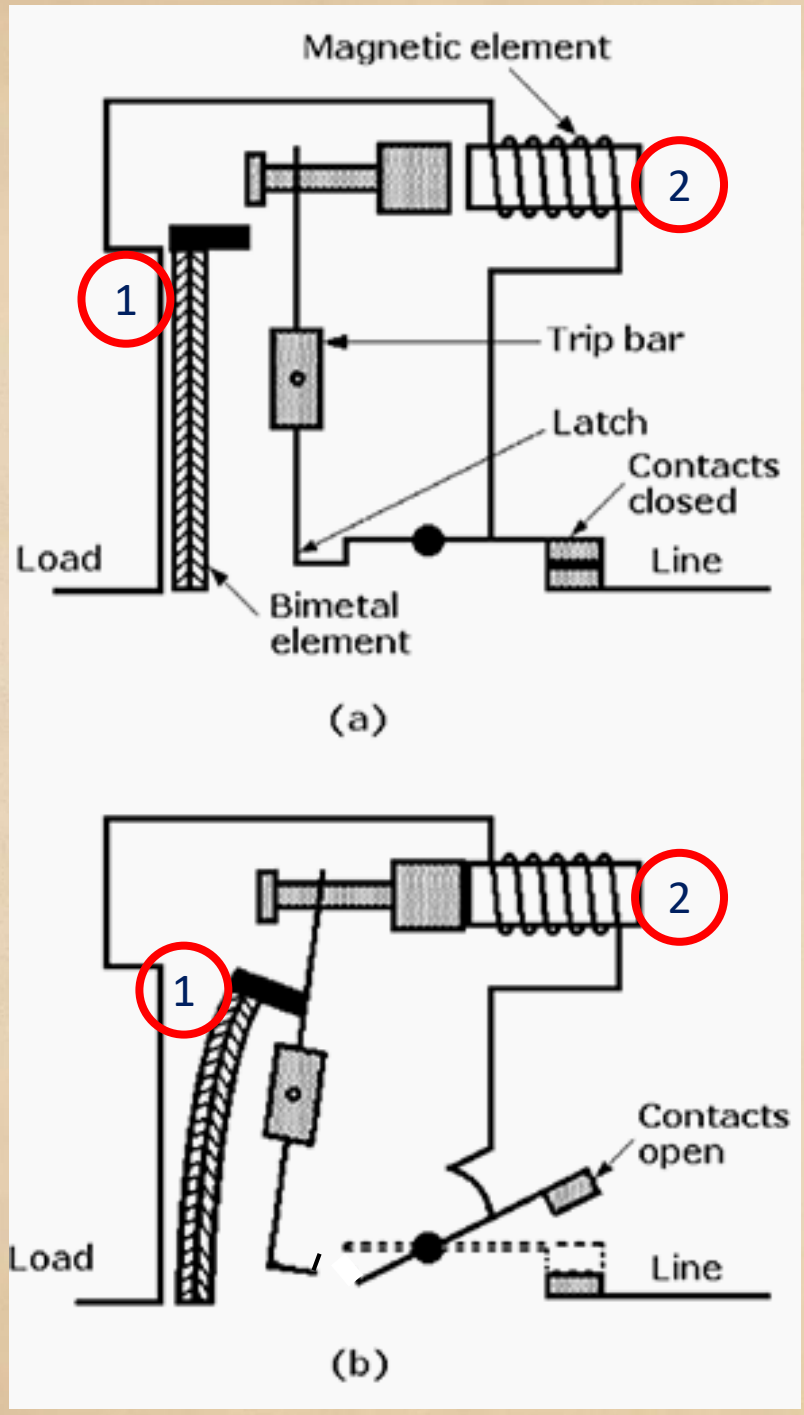


HP	25
Design	B
Code	G

Note 1: Generally High Eff motors have a higher spike
Note 2: All the motors we use are Design-B
Note 3: The Code G tells us about the motor LRA

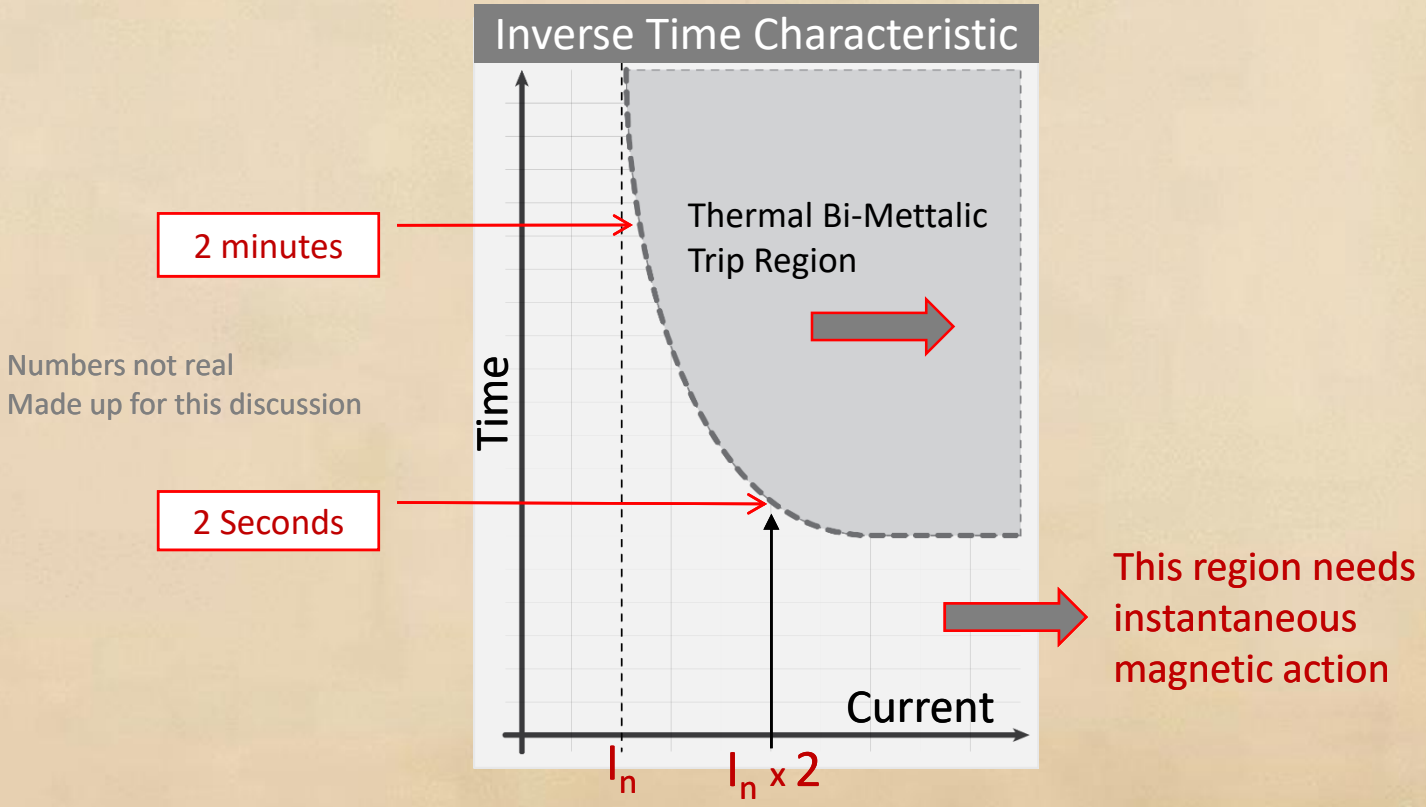
Not to any SCALE

How Thermal Magnetic CBs Work

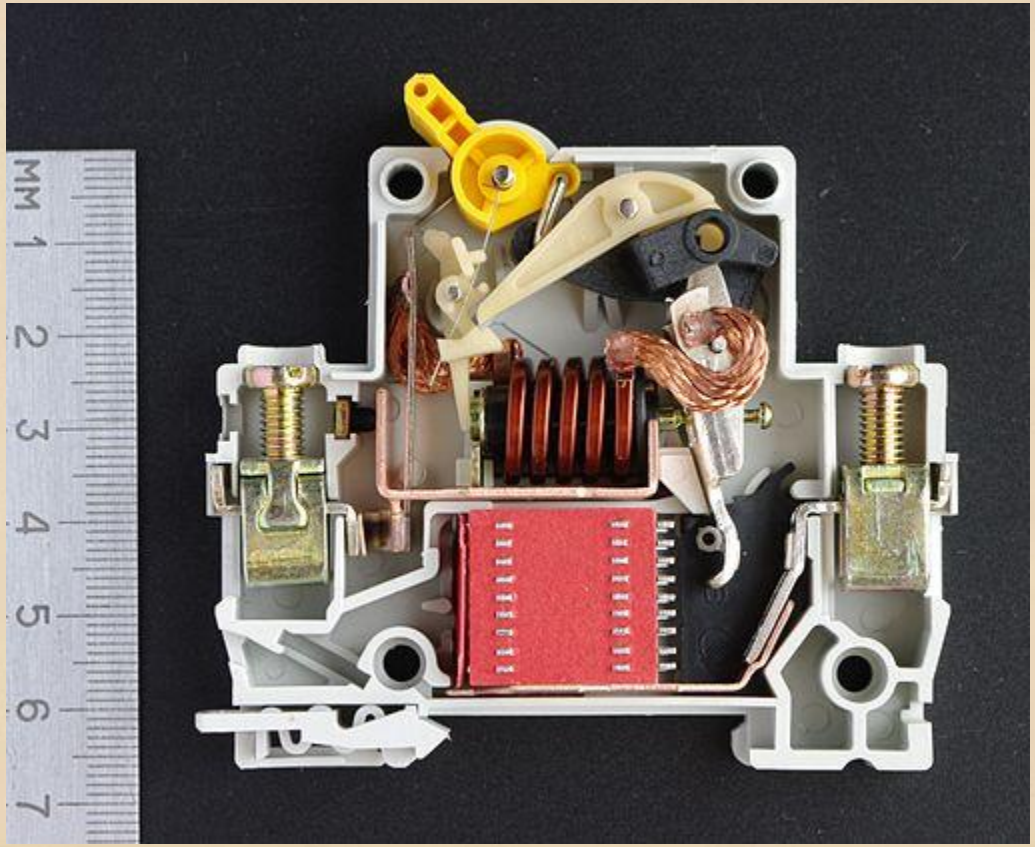


1. The Thermal Bi-Metallic Strip (just like in old thermostats) takes care of the OVERLOAD portion

2. The Magnetic Coil action (quick-acting) takes care of SHORT CIRCUITS and GROUND FAULTS



Inside a Small Amp Circuit Breaker



Sizing the Motor Branch Circuit Breaker

NEC FLC 34 Amps
FLA 31 Amps
Inrush = 31 x 6 = 186 Amps

90 Amp Inverse Time Breaker

8 AWG Wire - Ampacity 50 Amps

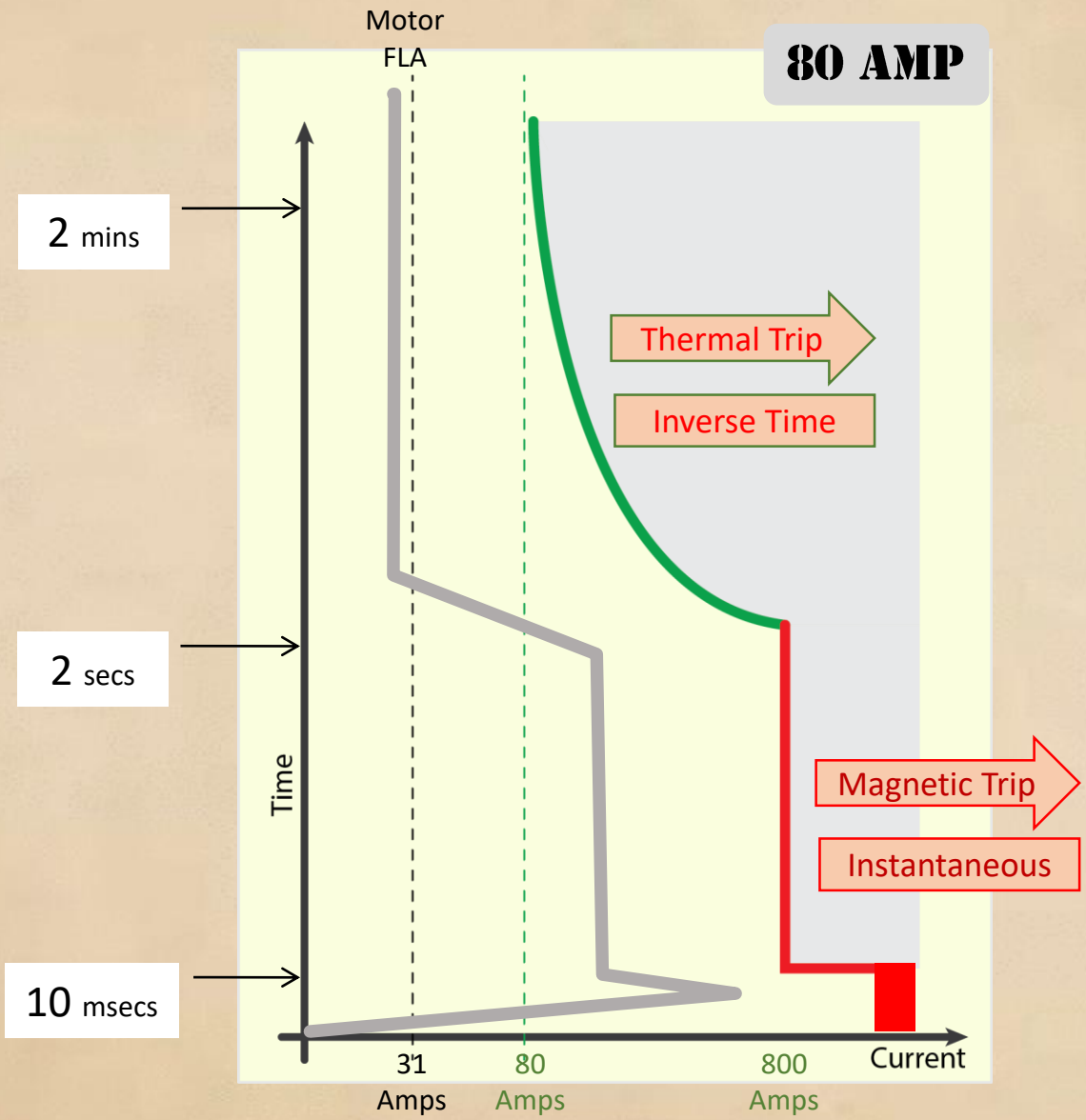
25 HP
Motor
460/3Φ/60

Code Allowed (Max.) CB = FLC x 250% Inverse Time Breaker
ITB Size = 34 x 2.5 = 85 Amps

Note 1: There is no 85 Amp Standard Breaker Rating.
The Code allows next larger (90 Amp) Standard Breaker.
If you understand ITB curves, you may find that 80 Amp will work OK.

Note 2: If the motor will not start with the 90 Amp max. the code allows further bumping up the size. Refer to NEC for details.

Generic Inverse Time Breaker Curves



Note: The Bi-Metallic trip element of the CB is set way too high to help in the case of motor Overload. For e.g. if we select a 80 Amp breaker for the 25 hp motor, then the CB thermal mechanism will not consider anything less than 80 Amps as Overload. (There are certain very special circumstances where that will work. See NEC.)

The Curve Brings Out a KEY CONCEPT

- The Circuit Breaker Is Not There To Protect The Motor (Or The Branch Circuit) Against OVERLOAD.
- It Is There To Protect The Branch Circuit In Case Of A Short Circuit Or Ground Fault.
- That Is Why The CB Can Be So Generously Sized To Accommodate the LRA
- And That Is Why You Must Have Motor Overload Protection

Equipment Grounding Conductor

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350

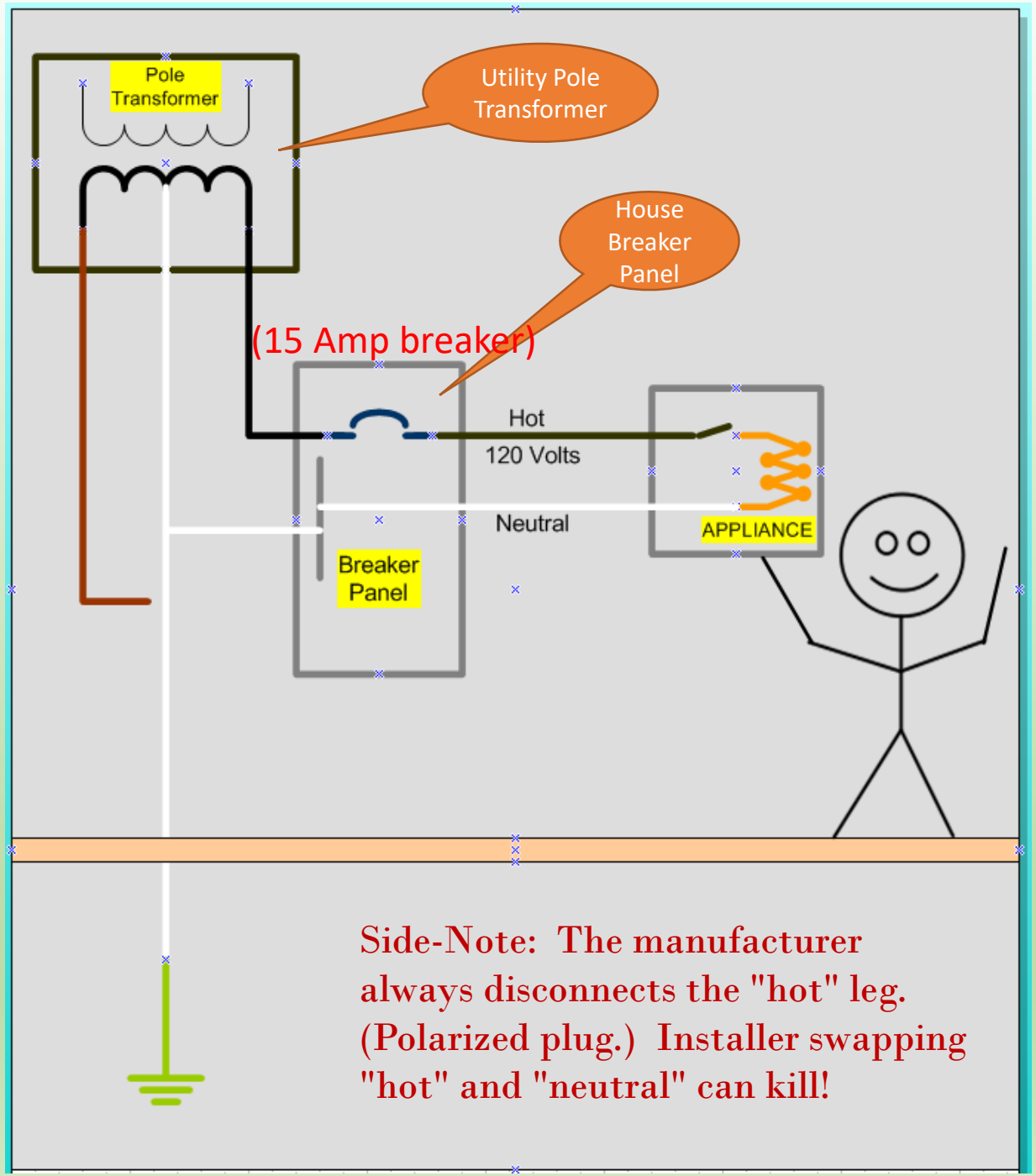
(The Green or Bare Wire)

Use NEC Table 250.122.

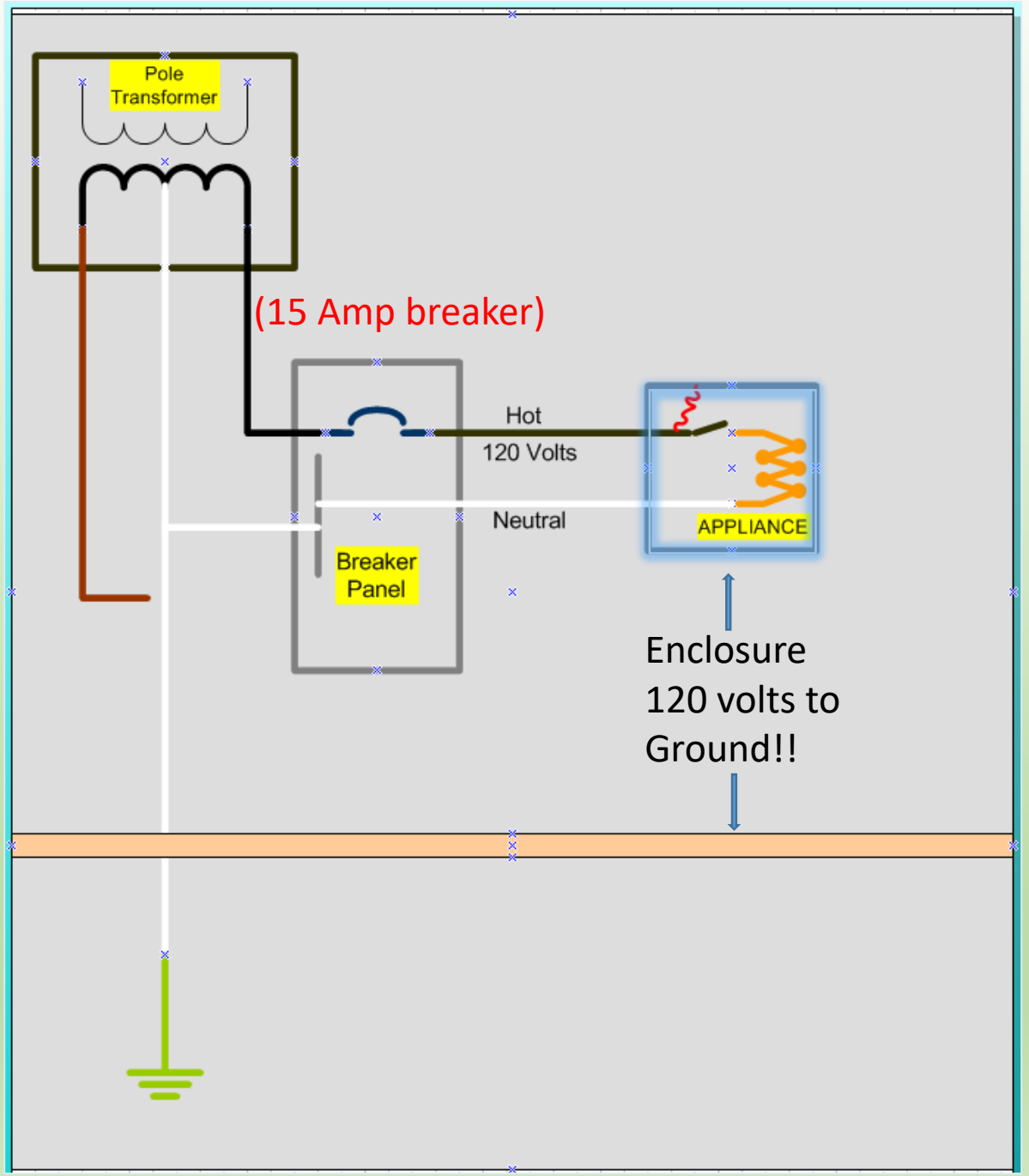
Check rule about increasing size if the current carrying conductors are increased in size due to voltage drop calculations.

Never larger than the current carrying conductors. Quite possible with motors.

EGC - 1


Pole Transformer
Utility Pole Transformer
House Breaker Panel
(15 Amp breaker)
Hot
120 Volts
Neutral
Breaker Panel
APPLIANCE
Side-Note: The manufacturer always disconnects the "hot" leg. (Polarized plug.) Installer swapping "hot" and "neutral" can kill!

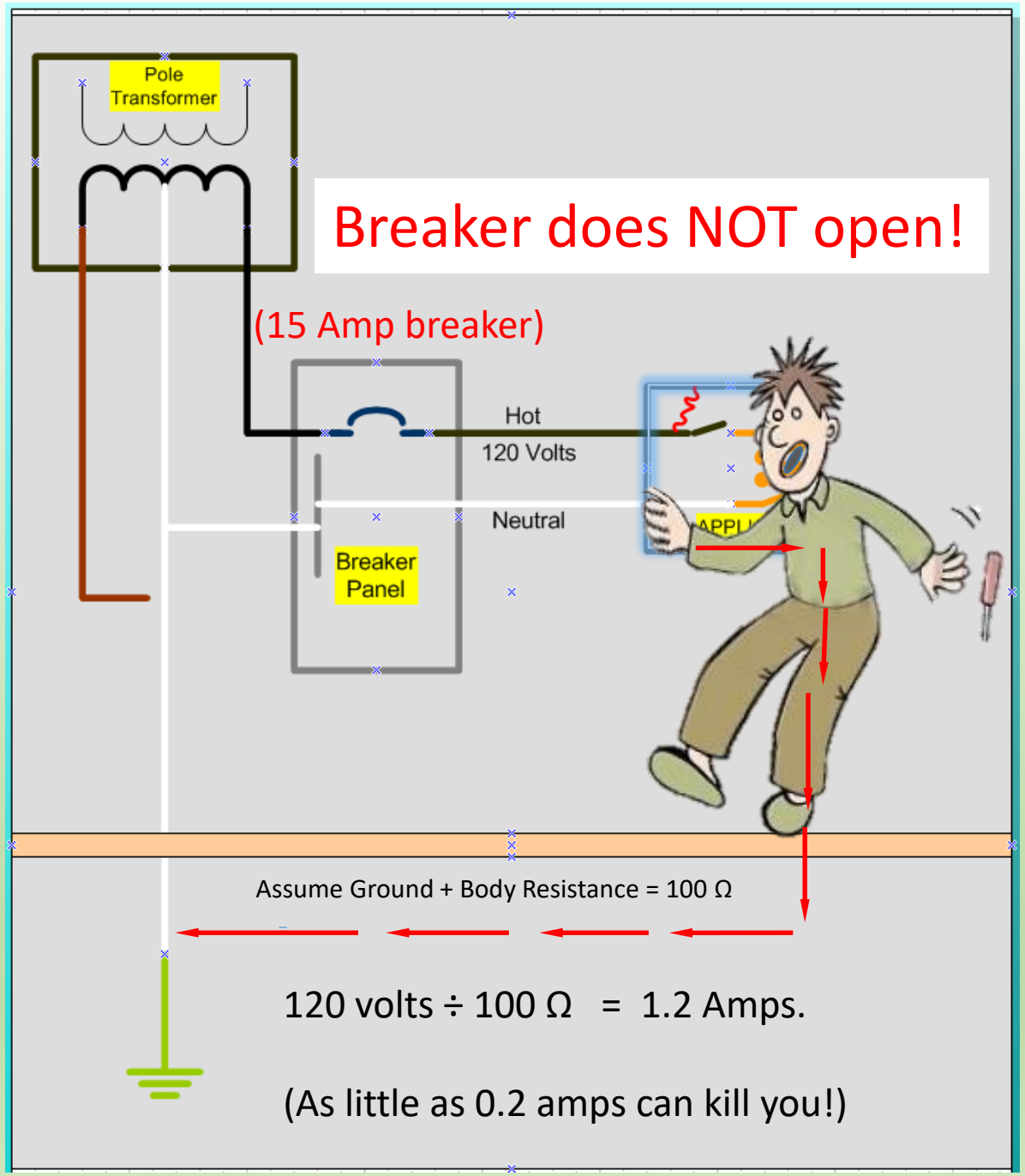
EGC - 2


Pole
Transformer
(15 Amp breaker)
Hot
120 Volts
Neutral
Breaker
Panel
APPLIANCE
Enclosure
120 volts to
Ground!!

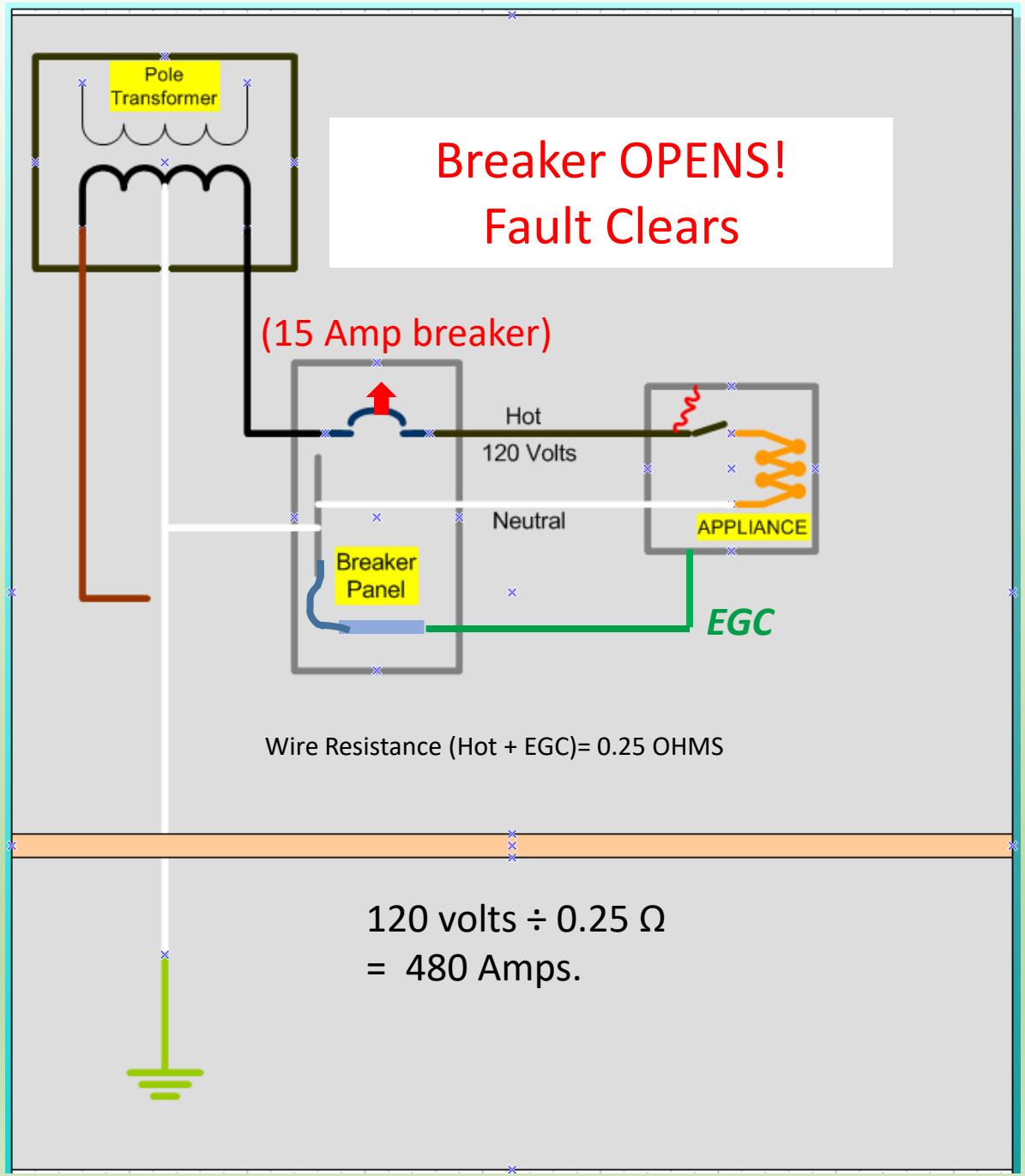
EGC - 3

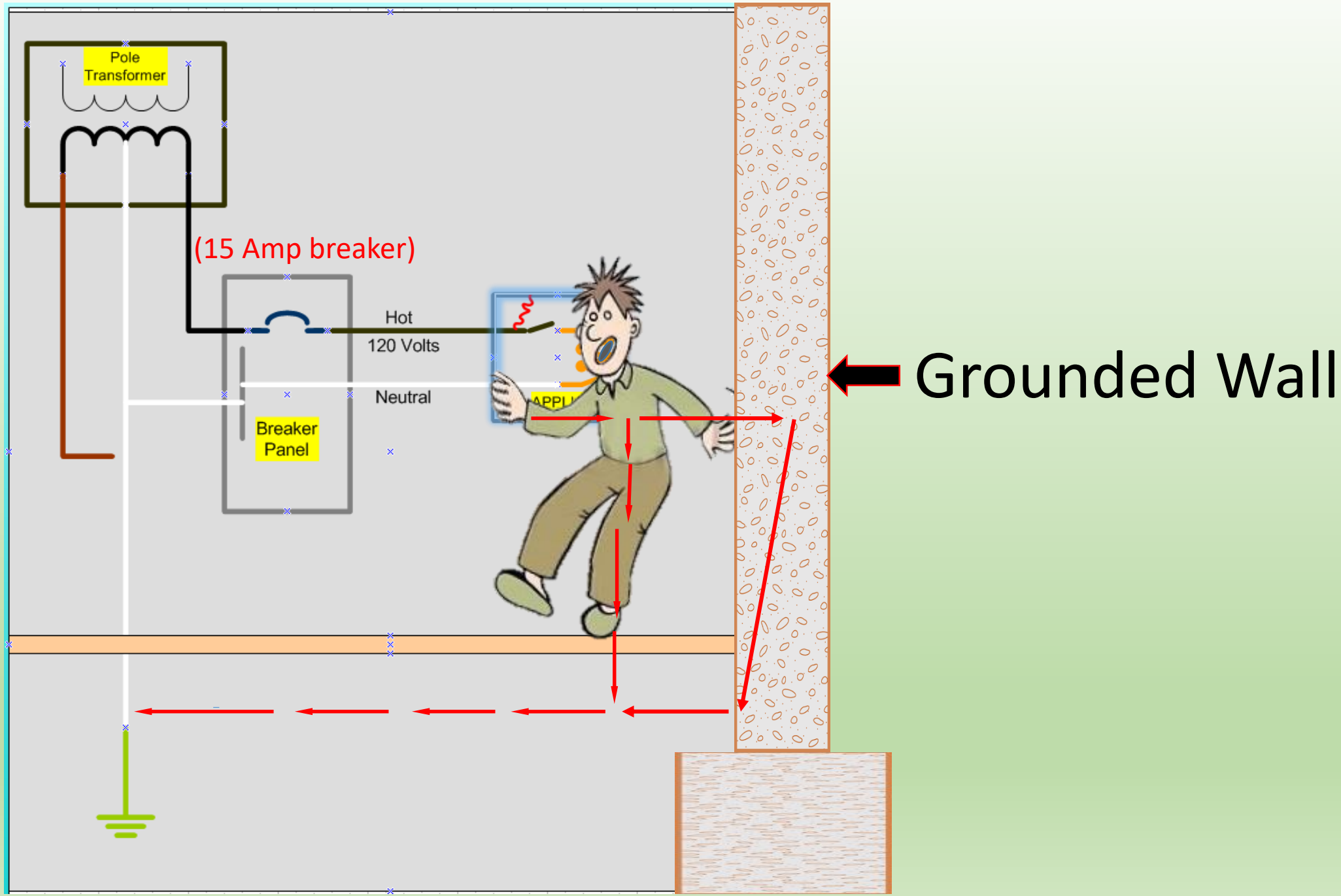
OHM's Law

$$\text{Amps} = \frac{\text{Volts}}{\text{Resistance}}$$

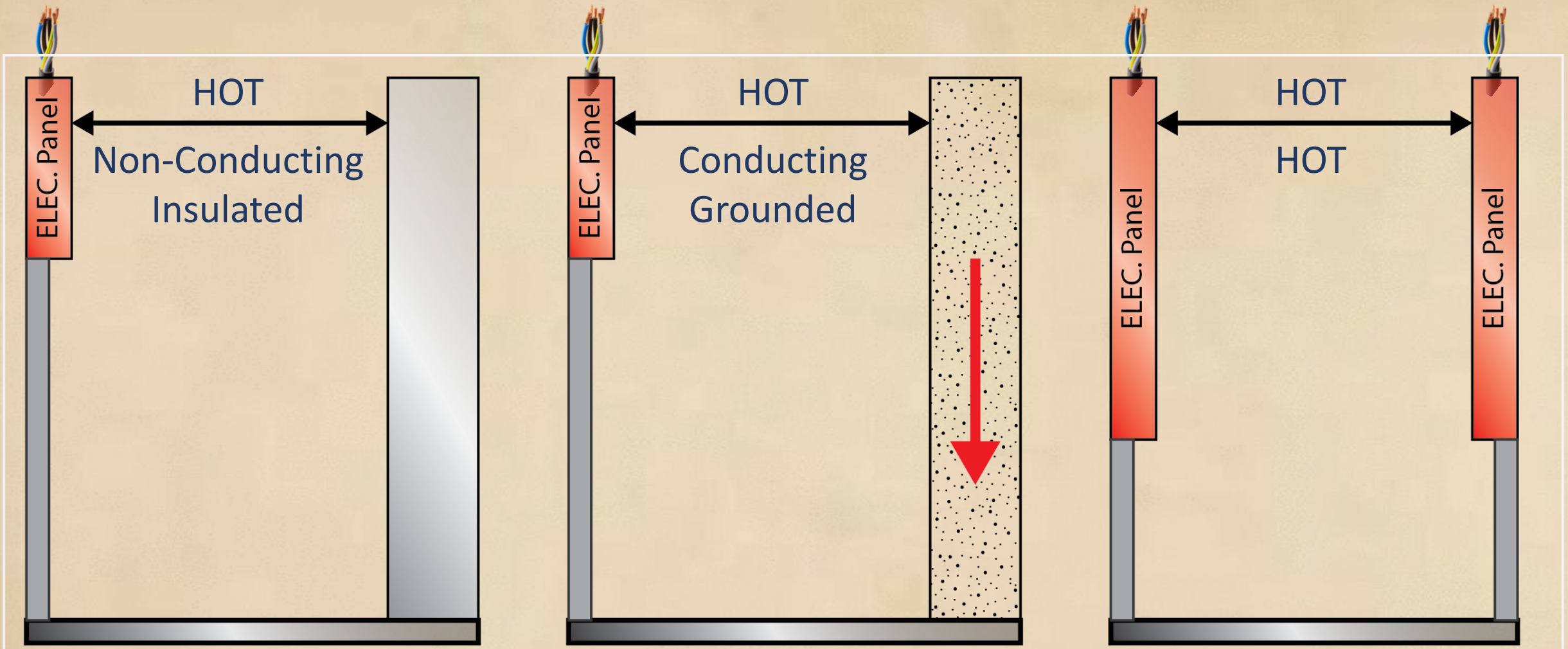


EGC - 4


Pole
Transformer
Breaker OPENS!
Fault Clears
(15 Amp breaker)
Hot
120 Volts
Neutral
APPLIANCE
Breaker
Panel
EGC
Wire Resistance (Hot + EGC)= 0.25 OHMS
120 volts ÷ 0.25 Ω
= 480 Amps.


Pole
Transformer
(15 Amp breaker)
Hot
120 Volts
Neutral
Breaker
Panel
Grounded Wall

Electrical Clearances [Minimums]



≤ 150 Volts to ground = 3 Feet
> 150 Volts to ground = 3 Feet

≤ 150 Volts to ground = 3 Feet
> 150 Volts to ground = 3.5 Feet

≤ 150 Volts to ground = 3 Feet
> 150 Volts to ground = 4 Feet

Note: Clear Width > of 30" or Panel Width

Terminology Not Per NEC

Disconnects
Standard Ampere Ratings

30 60 100 200 400 600 800

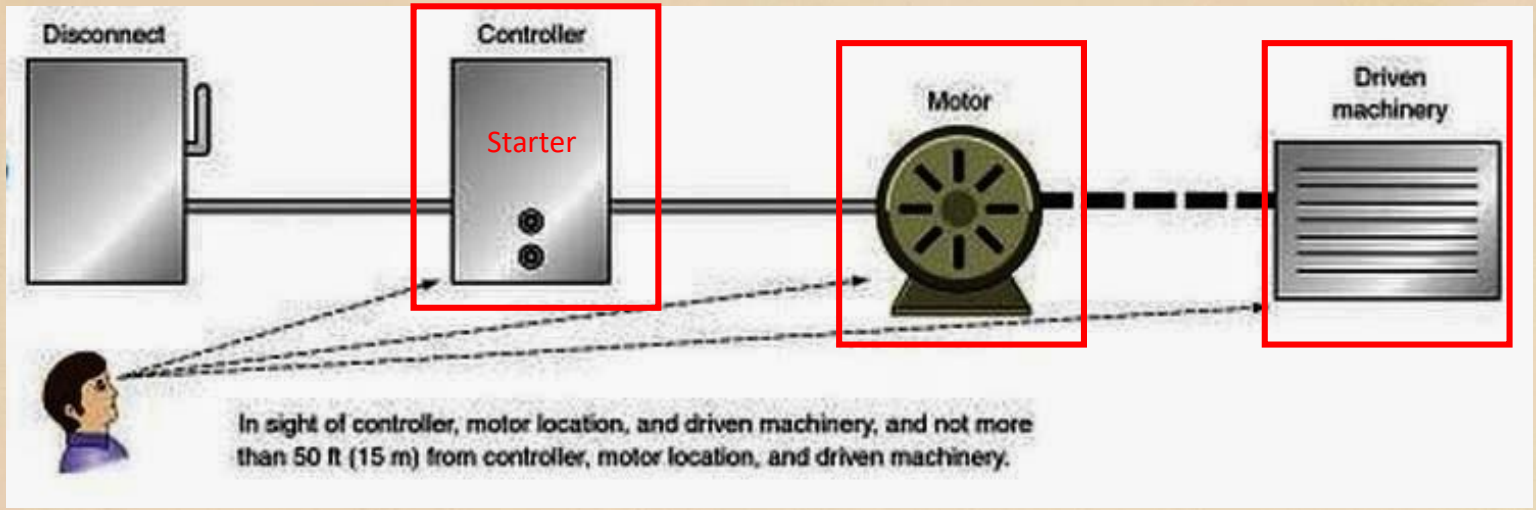
Size Disconnect > 115% of Motor FLC

25 Hp Motor – FLC = 34 Amps

Disconnect = 34 x 1.15 = 39.1 Amps

Next Larger Standard Size 60 Amps

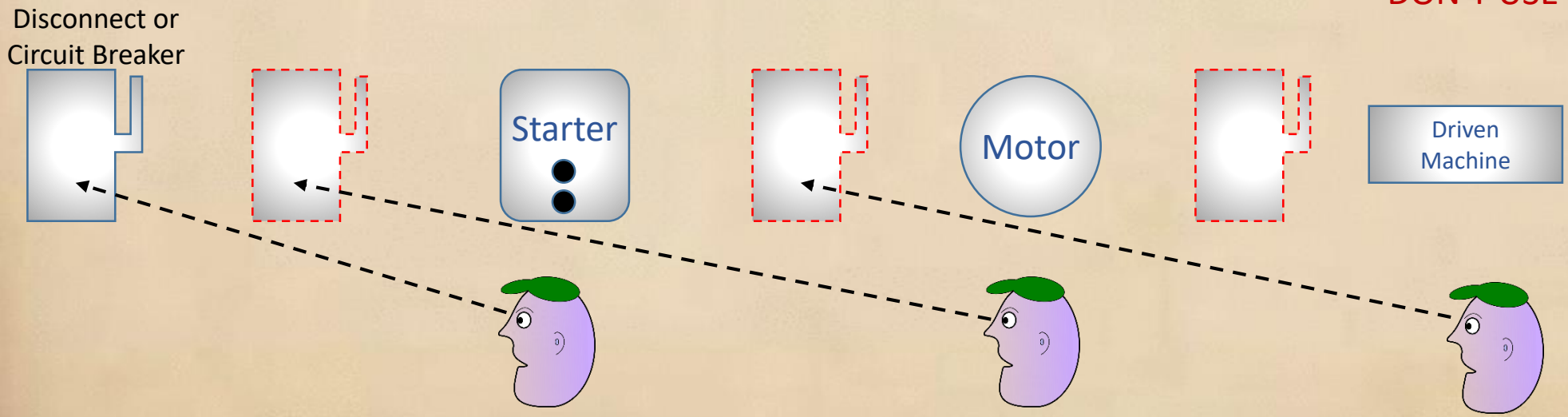
Disconnects Required & Sizing



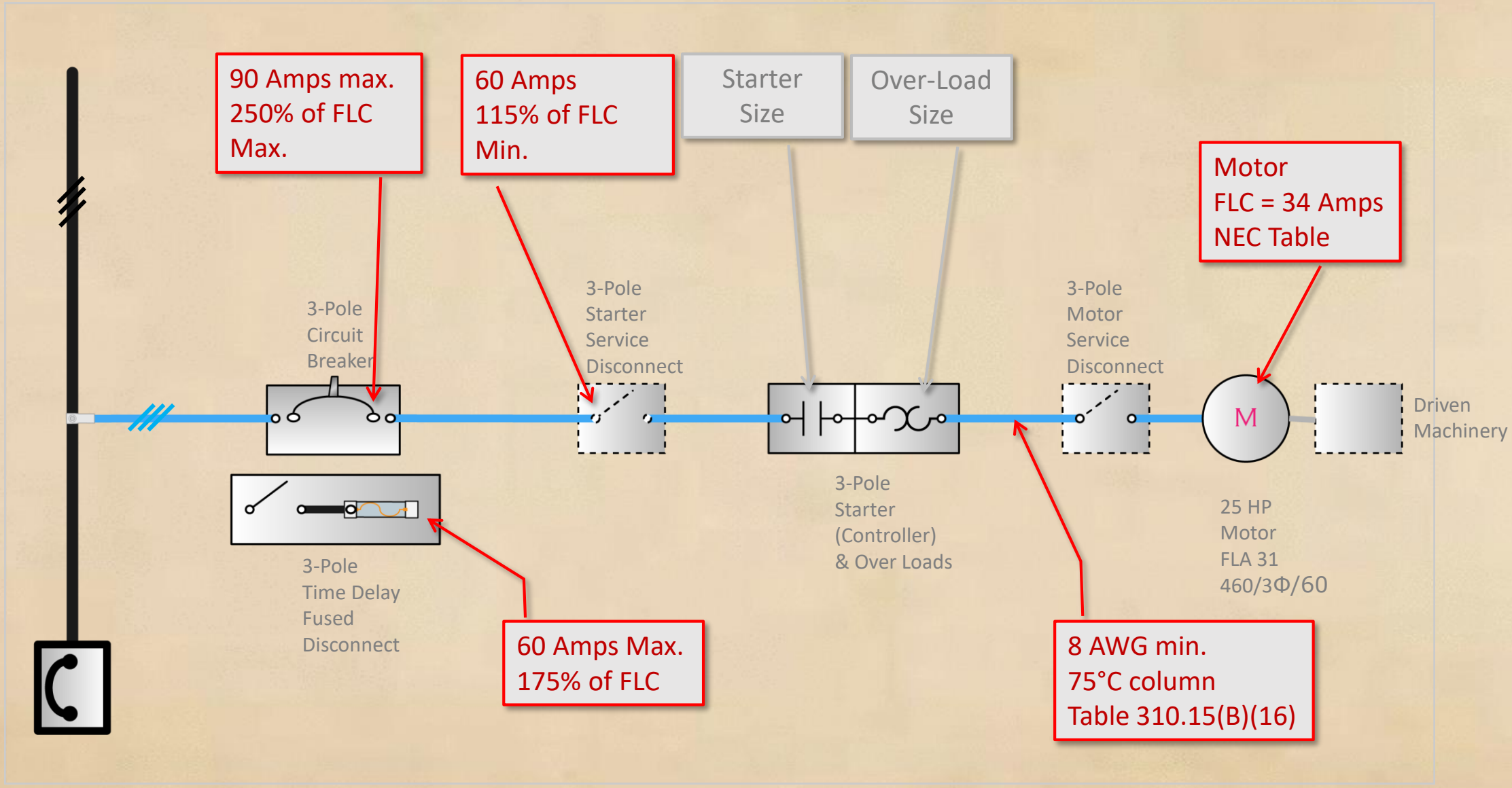
Code Requires "In Sight & < 50ft"
Disconnects for:
- Starters (Controllers)
- Motors
- Driven Machinery

Unless an upstream one is within 50' AND in sight.

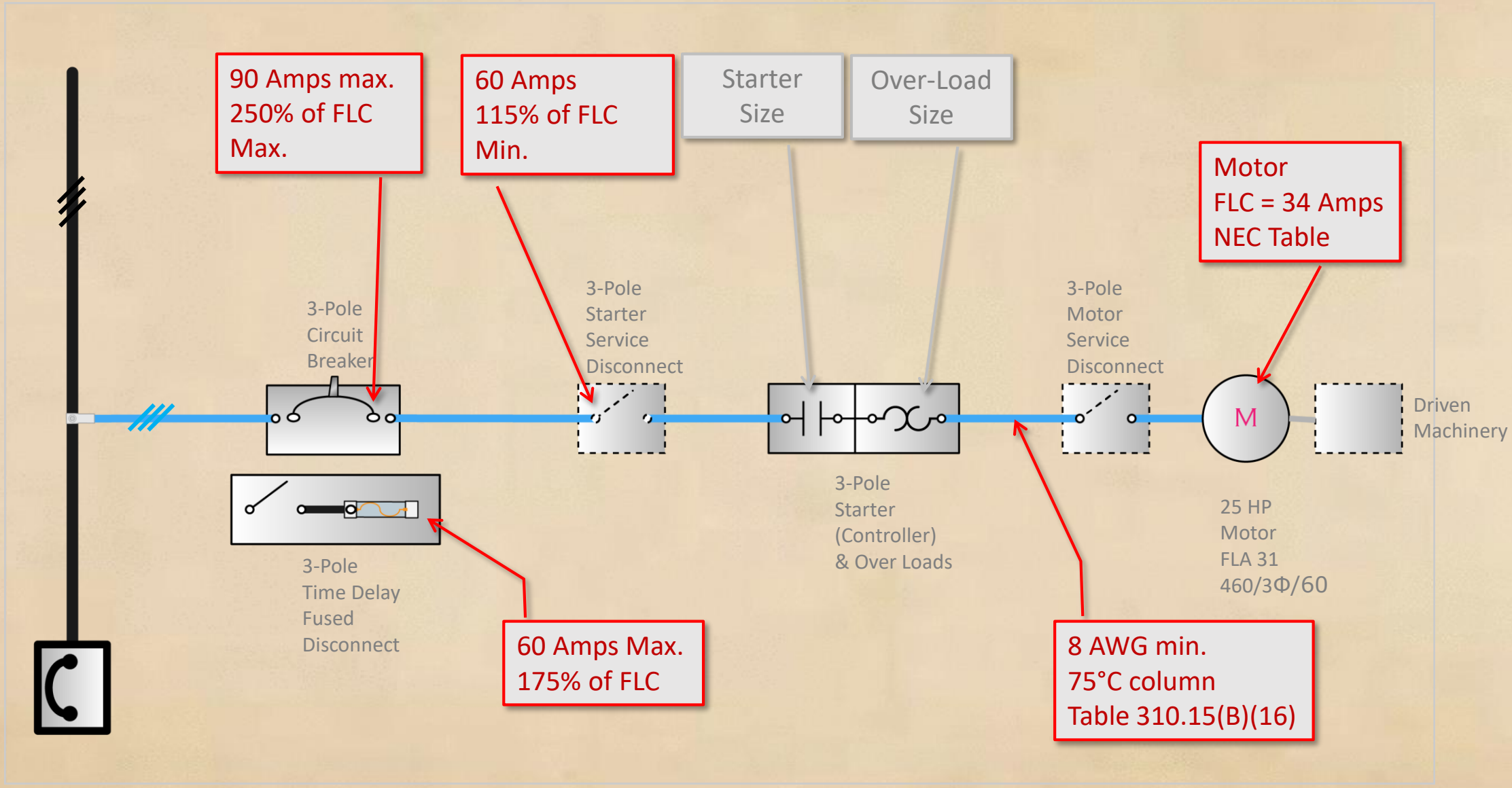
There are exceptions.
DON'T USE THEM.



Motor Branch Circuits Over-Current Protection



Motor Branch Circuits Over-Current Protection



Sizing Motor Overloads

- Motors rated more than 1 hp, used in a continuous-duty application without integral thermal protection, must have an overload device sized to open at no more than 115% of the motor nameplate FLC rating [430.32(A)(1)].
- But size the overload device no more than 125% of the nameplate FLC if:
  - The nameplate service factor (SF) is 1.15 or more.
  - The nameplate temperature rise is 40°C or less.
- NOTE: Ignore Above. Always use 115% unless the motor is really loaded close to the FLA.