Wire Sizes and Maximum Length Determination

(7/5/2007)

Wire sizes become important at low voltages. At 12 volts DC a loss of more than 10% in voltage across the length of the wire can mean the difference between the inverter running or not running. The currents can get high and any voltage drop becomes significant. In general at 12 Volts DC one should run the inverter close to the battery and then pipe the 120 Volts AC to the point of use on smaller wire.

The general rule is at low voltages pay attention to voltage drop and at high voltages pay attention to maximum current caring capacity for the size of wire.

Properly sized wire can make the difference between inadequate and full charging of a battery system, between dim and bright lights, and between feeble and full performance of tools and appliances. Designers of low voltage power circuits are often unaware of the implications of voltage drop and wire size. In conventional home electrical systems (120/240 volts ac), wire is sized primarily for safe amperage carrying capacity (ampacity). The overriding concern is fire safety.

In low voltage systems (12, 24, 48VDC) the overriding concern is power loss. Wire must not be sized merely for the ampacity, because there is less tolerance for voltage drop (except for very short runs). For example, a 1V drop from 12V causes 10 times the power loss of 1V drop from 120V.

Use the following charts as your primary tool in solving wire sizing problems.
Determining tolerable voltage drop for various electrical loads
A general rule is to size the wire for approximately 2 or 3% drop at typical load. When that turns out to be very expensive, consider some of the following advice. Different electrical circuits have different tolerances for voltage drop.

DC TO AC INVERTERS: Plan for 3 to 5% voltage drop. In a push to shove situation one can use up to a 10% voltage drop as a maximum.

LIGHTING CIRCUITS, INCANDESCENT AND QUARTZ HALOGEN (QH): Don't cheat on these! A 5% voltage drop causes an approximate 10% loss in light output. This is because the bulb not only receives less power, but the cooler filament drops from white-hot towards red-hot, emitting much less visible light.

LIGHTING CIRCUITS, FLUORESCENT: Voltage drop causes a nearly proportional drop in light output. A 10% drop in voltage is usually the max. Fluorescents use 1/2 to 1/3 the current of incandescent or QH bulbs for the same light output, so they can use smaller wire.

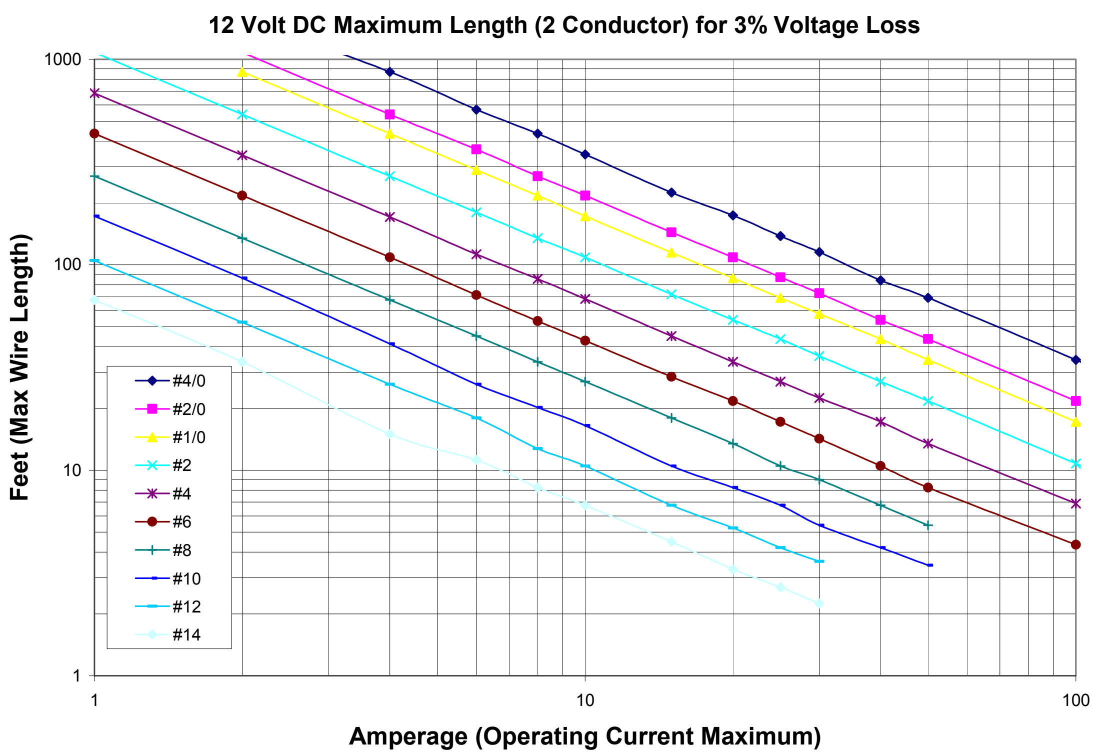
DC MOTORS operate at 10-50% higher efficiencies than AC motors, and eliminate the costs and losses associated with inverters. DC motors do NOT have excessive power surge demands when starting, unlike AC induction motors. Voltage drop during the starting surge simply results in a "soft start".

AC INDUCTION MOTORS are commonly found in large power tools, appliances and well pumps. They exhibit very high surge demands when starting. Significant voltage drop in these circuits may cause failure to start and possible motor damage. Follow the National Electrical Code. In the case of a well pump, follow the manufacturer's instructions.

MOST CHARGING CIRCUITS are critical because voltage drop can cause a disproportionate loss of charge current. To charge a battery, a generating device must apply a higher voltage than already exists within the battery. A voltage drop greater than 5% will reduce this necessary voltage difference, and can reduce charge current to the battery by a much greater percentage.

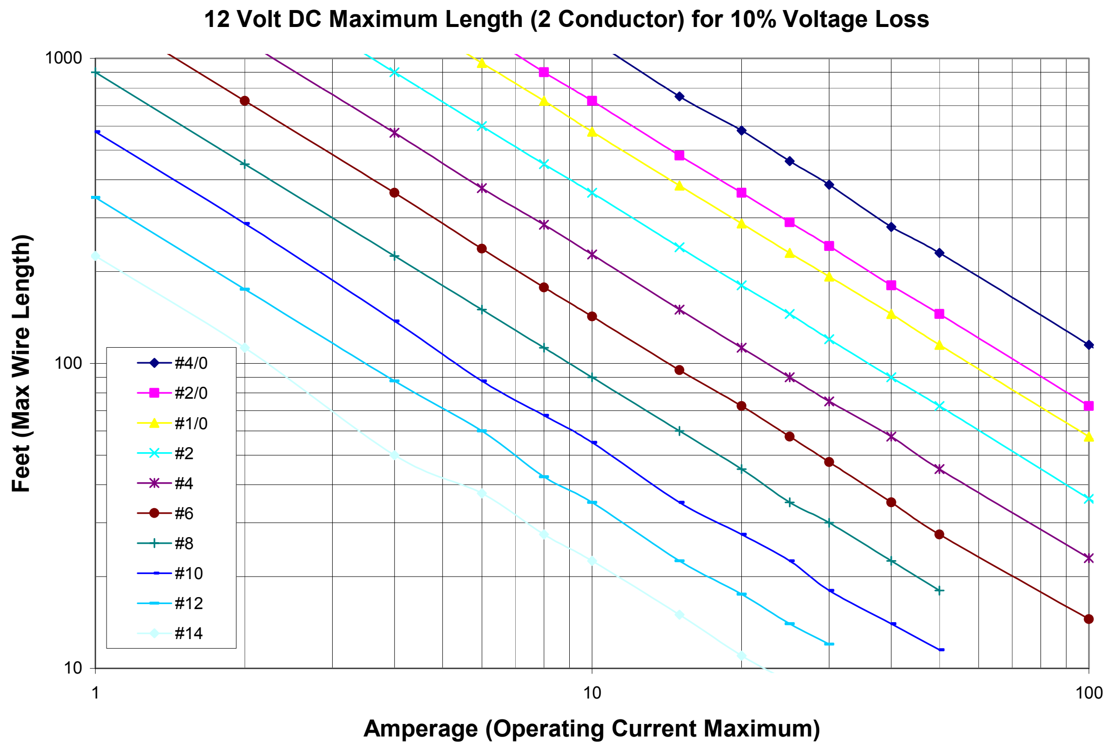
WIND GENERATOR CIRCUITS: At most locations, a wind generator produces its full rated current only during occasional windstorms or gusts. If wire sized for low loss is large and very expensive, you may consider sizing for a voltage drop as high as 10% at the rated current. That loss will only occur occasionally, when energy is most abundant. Consult the wind system's instruction manual.

ALUMINUM WIRE may be more economical than copper for some main lines. Power companies use it because it is cheaper than copper and lighter in weight, even though a larger size must be used. It is safe when installed to code with AL-rated terminals. You may wish to consider it for long, expensive runs of #2 or larger. The cost difference fluctuates with the metals market. It is stiff and hard to bend, and not rated for submersible pumps.



Wire Sizes and Maximum Length Determination

(7/5/2007)



12 Volt 2% Wire Loss Chart

Maximum distance one-way in feet of various gauge two conductor copper wire from power source to load for 2% voltage drop in a 12 volt system. You can go twice the distance where a 4% loss is acceptable. A 4 to 5% loss is acceptable between batteries and lighting circuits in most cases. Multiply distances by 2 for 24 volts and by 4 for 48 volts.

2% Voltage Drop Chart										
Amps	**#14**	**#12**	**#10**	**#8**	**#6**	**#4**	**#2**	**#1/0**	**#2/0**	**#4/0**
1	45	70	115	180	290	456	720	.	.	.
2	22.5	35	57.5	90	145	228	360	580	720	1060
4	10	17.5	27.5	45	72.5	114	180	290	360	580
6	7.5	12	17.5	30	47.5	75	120	193	243	380
8	5.5	8.5	13.5	22.5	35.5	57	90	145	180	290
10	4.5	7	11	18	28.5	45.5	72.5	115	145	230
15	3	4.5	7	12	19	30	48	76.5	96	150
20	2	3.5	5.5	9	14.5	22.5	36	57.5	72.5	116
25	1.8	2.8	4.5	7	11.5	18	29	46	58	92
30	1.5	2.4	3.5	6	9.5	15	24	38.5	48.5	77
40	.	.	2.8	4.5	7	11.5	18	29	36	56
50	.	.	2.3	3.6	5.5	9	14.5	23	29	46
100	.	.	.	.	2.9	4.6	7.2	11.5	14.5	23
150	.	.	.	.	.	.	4.8	7.7	9.7	15

Maximum Ampacities (Amperage Capacity) for Wire

Allowable ampacities of conductors (wires) in conduit, raceway, cable or directly buried, based on ambient temperature of 86° F (30° C). NEC allows rounding up cable ampacity to the next size standard fuse or breaker. Use this table for high voltages of 120 volts or higher.

Maximum Ampacity for Copper and Aluminum Wire				
Wire Size	Copper		Aluminum	
	167° F (75° C)	194° F (90° C)	167° F (75° C)	194° F (90° C)
*14	20	25		.
*12	25	30	20	25
*10	35	40	30	35
8	50	55	40	45
6	65	75	50	60
4	85	95	65	75
2	115	130	90	100
1	130	150	100	115
1/0	150	170	120	135
2/0	175	195	135	150
3/0	200	225	155	175
4/0	230	260	180	205

* The national electric code (NEC) specifies that the over current protection device not exceed 30A for 10 AGW wire, 20A for 12 AGW wire and 15A for 14 AWG wire.
http://www.builditsolar.com/References/pvwiring.htm

Quick Overview

As electric current flows through wire, there is a loss in voltage. This loss is referred to as IR voltage drop. Voltage (Drop) = Wire Resistance Times Amps of current (E=IR)

Calculating the voltage loss for a pair of wires gets a little complicated, so we have constructed a quick look up table for what size wire you will need for your application. The table below is for 12-volt ac or dc devices only. You just need to know the power in Watts (VA), or Amps and the table will show how far you can go in feet for any size wire pair listed. The table is based on a 10% loss of voltage on a pair of wires. This should work for most 12-volt devices. Checking the manufacturer's specifications, use the maximum watts or current and be sure the minimum operational voltage is 10v or below. The footage in the table is linear, a 20% loss would double the distance, or 5% would cut it in half.

The table calculations are based on the ohms of the wire at 70oF. If the wire temperature is raised to 130oF the voltage drop would increase by about 3%. The voltage drop calculations are also based on a conventional load.

The recommended maximum distances in feet for AC or DC are listed in the cell below the wire size.

12V TABLE

POWER W(VA)/Amps	8awg	10awg	12awg	14awg	16awg	18awg	20awg	22awg	24awg	26awg
3W/.25A	3,733	2,396	1,508	947	595	376	234	146	93	59
4W/.33A	2,828	1,815	1,142	717	451	285	177	111	70	44
5W/.42A	2,222	1,426	898	564	354	224	139	87	55	35
10W/.83A	1,124	722	454	285	179	113	71	44	28	18
20W/1.67A	559	359	226	142	89	56	35	22	14	9
30W/2.50A	373	240	151	95	60	38	23	15	N/A	N/A
40W/3.33A	280	180	113	71	45	28	18	11	N/A	N/A
50W/4.17A	224	144	90	57	36	23	14	N/A	N/A	N/A
60W/5.00A	187	120	75	47	30	19	12	N/A	N/A	N/A
70W/5.83A	160	103	65	41	26	16	10	N/A	N/A	N/A
80W/6.67A	140	90	57	35	22	14	N/A	N/A	N/A	N/A
90W/7.50A	124	80	50	32	20	13	N/A	N/A	N/A	N/A
100W/8.33A	112	72	45	28	18	11	N/A	N/A	N/A	N/A
110W/9.17A	102	65	41	26	16	10	N/A	N/A	N/A	N/A
120W/10.00A	93	60	38	24	15	N/A	N/A	N/A	N/A	N/A

WIRE GAUGE

http://www.securitypower.com/AN2Wire.html

12 Volts – Wire Sizes (Gauge) 3 % Drop for Radios

Total Wire Length in Feet

		10	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Amp	**5**	18	16	14	12	12	10	10	10	8	8	8	6
	10	14	12	10	10	10	8	6	6	6	6	4	4
	15	12	10	10	8	8	6	6	6	4	4	2	2
	20	10	10	8	6	6	6	4	4	2	2	2	2
	25	10	8	6	6	6	4	4	2	2	2	1	1
	30	10	8	6	6	4	4	2	2	1	1	0	0
	40	8	6	6	4	4	2	2	1	0	0	2/0	2/0
	50	6	6	4	4	2	2	1	0	2/0	2/0	3/0	3/0
	60	6	4	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0
	70	6	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0	
	80	6	4	2	2	1	0	3/0	3/0	4/0	4/0		
	90	4	2	2	1	0	2/0	3/0	4/0	4/0			
	100	4	2	2	1	0	2/0	3/0	4/0				

Wire Sizes and Maximum Length Determination

(7/5/2007)

12 Volts – Wire Sizes (Gauge) 10 % Drop for Lights

Total Wire Length in Feet

		10	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Amp	**5**	18	18	18	18	18	16	16	14	14	14	12	12
	10	18	18	16	16	14	14	12	12	10	10	10	10
	15	18	16	14	14	12	12	10	10	8	8	8	8
	20	16	14	14	12	12	10	10	8	8	8	6	6
	25	16	14	12	12	10	10	8	8	6	6	6	6
	30	14	12	12	10	10	8	8	6	6	6	6	4
	40	14	12	10	10	8	8	6	6	6	4	4	4
	50	12	10	10	8	8	6	6	4	4	4	2	2
	60	12	10	8	8	6	6	4	4	2	2	2	2
	70	10	8	8	6	6	6	4	2	2	2	2	1
	80	10	8	8	6	6	4	4	2	2	2	1	1
	90	10	8	6	6	6	4	2	2	2	1	1	0
	100	10	8	6	6	4	4	2	2	1	1	0	0
	150	8	8	4	4	2	2	1	0	0	2/0	2/0	2/0
	200	6	6	4	4	2	1	2/0	2/0	2/0	4/0	4/0	4/0

24 Volts – Wire Sizes (Gauge) 10 % Drop for Lights

Total Wire Length in Feet

		10	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Amp	**5**	18	18	18	18	18	18	18	18	16	16	16	16
	10	18	18	18	18	18	16	16	14	14	14	12	12
	15	18	18	18	16	16	14	14	12	12	12	10	10
	20	18	18	16	16	14	14	12	12	10	10	10	10
	25	18	16	16	14	14	12	12	10	10	10	8	8
	30	18	16	14	14	12	12	10	10	8	8	8	8
	40	16	14	14	12	12	10	10	8	8	8	6	6
	50	16	14	12	12	10	10	8	8	6	6	6	6
	60	14	12	12	10	10	8	8	6	6	6	6	4
	70	14	12	10	10	8	8	6	6	6	6	4	4
	80	14	12	10	10	8	8	6	6	6	4	4	4
	90	12	10	10	8	8	6	6	6	4	4	4	2
	100	12	10	10	8	8	6	6	4	4	4	2	2

Universal Wire Sizing Chart
A 2-Step Process

This chart works for any voltage or voltage drop, American (AWG) or metric (mm2) sizing. It applies to typical DC circuits and to some simple AC circuits (single-phase AC with resistive loads, not motor loads, power factor = 1.0, line reactance negligible).

Wire Size	Area mm2	COPPER		ALUMINUM	
AWG		VDI	Ampacity	VDI	Ampacity
16	1.31	1	10	Not Recommended	
14	2.08	2	15		
12	3.31	3	20		
10	5.26	5	30		
8	8.37	8	55		
6	13.3	12	75		
4	21.1	20	95		
2	33.6	31	130	20	100
0	53.5	49	170	31	132
00	67.4	62	195	39	150
000	85.0	78	225	49	175
0000	107	99	260	62	205

STEP 1: Calculate the Following:

VDI = (AMPS x FEET)/(%VOLT DROP x VOLTAGE)
VDI = Voltage Drop Index (a reference number based on resistance of wire) FEET = ONE-WAY wiring distance (1 meter = 3.28 feet) %VOLT DROP = Your choice of acceptable voltage drop (example: use 3 for 3%)

STEP 2: Determine Appropriate Wire Size from Chart

Compare your calculated VDI with the VDI in the chart to determine the closest wire size. Amps must not exceed the AMPACITY indicated for the wire size.

Metric Size by cross-sectional area	COPPER (VDI x 1.1 = mm2)	ALUMINUM (VDI x 1.7 = mm2)
Available Sizes: 1 1.5 2.5 4 6 10 16 25 35 50 70 95 120 mm2		

EXAMPLE:
20 Amp load at 24V over a distance of 100 feet with 3% max. voltage drop

Wire Sizes and Maximum Length Determination

(7/5/2007)

VDI = (20x100)/(3x24) = 27.78	For copper wire, the nearest VDI=31. *This indicates #2 AWG wire or 35mm2*

NOTES: AWG=Amercan Wire Gauge. Ampacity is based on the National Electrical Code (USA) for 30 degrees C (85 degrees F) ambient air temperature, for no more than three insulated conductors in raceway in freee air of cable types AC, NM, NMC and SE; and conductor insulation types TA, TBS, SA, AVB, SIS, RHH, THHN and XHHW. For other conditions, refer to National Electric Code or an engineering handbook.

http://howto.altenergystore.com/Reference-Materials/How-to-Size-Wiring-and-Cabling-for-Your-System/a62/

The above formula results in:

Maximum feet for one wire running at Amp Capacity (ampacity)							
AWG	**Ampacity**	**12V-3%**	**12V-10%**	**48V-3%**	**48V-10%**	**120V-3%**	**120V-10%**
16	10	4	12	14	48	36	120
14	15	5	16	19	64	48	160
12	20	5	18	22	72	54	180
10	30	6	20	24	80	60	200
8	55	5	17	21	70	52	175
6	75	6	19	23	77	58	192
4	95	8	25	30	101	76	253
2	130	9	29	34	114	86	286
O	170	10	35	42	138	104	346
OO	195	11	38	46	153	114	382
OOO	225	12	42	50	166	125	416
OOOO	260	14	46	55	183	137	457

Power Streams Table

AWG gauge	Diameter Inches	Diameter mm	Ohms per 1000 ft	Ohms per km	Maximum amps for chassis wiring	Maximum amps for power transmission
OOOO	0.4600	11.6840	0.0490	0.16072	380	302
OOO	0.4096	10.4038	0.0618	0.20270	328	239
OO	0.3648	9.2659	0.0779	0.25551	283	190
0	0.3249	8.2525	0.0983	0.32242	245	150
1	0.2893	7.3482	0.1239	0.40639	211	119
2	0.2576	6.5430	0.1563	0.51266	181	94
3	0.2294	5.8268	0.1970	0.64616	158	75

4	0.2043	5.1892	0.2485	0.81508	135	60
5	0.1819	4.6203	0.3133	1.02762	118	47
6	0.1620	4.1148	0.3951	1.29593	101	37
7	0.1443	3.6652	0.4982	1.63410	89	30
8	0.1285	3.2639	0.6282	2.06050	73	24
9	0.1144	2.9058	0.7921	2.59809	64	19
10	0.1019	2.5883	0.9989	3.27639	55	15
11	0.0907	2.3038	1.2600	4.13280	47	12
12	0.0808	2.0523	1.5880	5.20864	41	9.3
13	0.0720	1.8288	2.0030	6.56984	35	7.4
14	0.0641	1.6281	2.5250	8.28200	32	5.9
15	0.0571	1.4503	3.1840	10.4435	28	4.7
16	0.0508	1.2903	4.0160	13.1725	22	3.7
17	0.0453	1.1506	5.0640	16.6099	19	2.9
18	0.0403	1.0236	6.3850	20.9428	16	2.3
19	0.0359	0.9119	8.0510	26.4073	14	1.8
20	0.0320	0.8128	10.1500	33.2920	11	1.5
21	0.0285	0.7239	12.8000	41.9840	9	1.2
22	0.0254	0.6452	16.1400	52.9392	7	0.92
23	0.0226	0.5740	20.3600	66.7808	4.7	0.729
24	0.0201	0.5105	25.6700	84.1976	3.5	0.577
25	0.0179	0.4547	32.3700	106.174	2.7	0.457
26	0.0159	0.4039	40.8100	133.857	2.2	0.361
27	0.0142	0.3607	51.4700	168.822	1.70	0.288
28	0.0126	0.3200	64.9000	212.872	1.40	0.226
29	0.0113	0.2870	81.8300	268.402	1.20	0.182
30	0.0100	0.2540	103.2000	338.496	0.86	0.142
31	0.0089	0.2261	130.1000	426.728	0.70	0.113
32	0.0080	0.2032	164.1000	538.248	0.53	0.091
Metric 2.0	0.0079	0.2000	169.3900	555.610	0.51	0.088
33	0.0071	0.1803	206.9000	678.632	0.43	0.072
Metric 1.8	0.0071	0.1800	207.5000	680.550	0.43	0.072
34	0.0063	0.1600	260.9000	855.752	0.33	0.056
Metric 1.6	0.0063	0.1600	260.9000	855.752	0.33	0.056
35	0.0056	0.1422	329.0000	1079.12	0.27	0.044
Metric 1.4	0.0055	0.1400	339.0000	1114.00	0.26	0.043
36	0.0050	0.1270	414.8000	1360.00	0.21	0.035
Metric 1.25	0.0049	0.1250	428.2000	1404.00	0.20	0.034
37	0.0045	0.1143	523.1000	1715.00	0.17	0.0289
Metric 1.12	0.0044	0.1120	533.8000	1750.00	0.16	0.0277
38	0.0040	0.1016	659.6000	2163.00	0.13	0.0228
Metric 1	0.0039	0.1000	670.2000	2198.00	0.13	0.0225

39	0.0035	0.0889	831.8000	2728.00	0.11	0.0175
40	0.0031	0.0787	1049.0000	3440.00	0.09	0.0137

http://www.powerstream.com/Wire_Size.htm

All extension-cord jackets are marked with a code that indicates (among other information) the American wire gauge (AWG) as well as the jacket material and its properties, according to standards established by the National Electrical Code.

Then there's the challenging of deciphering that odd code on the side of most of your extension cords.

In the picture above, The **AWG 12-3** is telling you the American Wire Gauge (AWG) is 12 and there are 3 wires inside. The SEOW means... well, see below:

- **O:** Oil-resistant, usually synthetic-rubber jacket, more flexible in cold temperatures
- **OO:** Oil-resistant synthetic-rubber jacket and inner-conductor insulation
- **S:** Standard service (synthetic-rubber insulated, rated for 600v)
- **SE:** Extra-hard usage, elastomer
- **SEOW:** Oil-resistant and weather-resistant elastomer jacket, rated for 600v (photo above)
- **SJ:** Service junior (synthetic-rubber insulated, rated for 300v)
- **SJO**: Same as SJ but Neoprene, oil resist compound outer jacket, rated for 300v
- **SJOW:** Oil-resistant and weather-resistant synthetic rubber, rated for 300v
- **SJOOW:** Oil-resistant and weather-resistant synthetic rubber (jacket and conductor insulation), rated for 300v
- **SJT:** Hard service thermoplastic pr rubber insulate conductors with overall plastic jacket, rated for 300v
- **SJTOW:** Oil-resistant and weather-resistant thermoplastic, rated for 300v
- **SJTW:** Thermoplastic-jacketed, weather-resistant, rated for 300v
- **SO**: Extra hard service cord with oil resistant rubber jacket, 600v
- **SOOW**: Same as SOW but with oil resistant rubber conductor insulation and suitable for outdoor use.
- **SOW**: Rubber jacketed portable cord with oil and water resistant outer jacket
- **SPT-1:** All rubber, parallel-jacketed, two-conductor light duty cord for pendant or portable use, rated for 300v
- **SPT-2:** Same as SPT-1, but heavier construction, with or without third conductor for grounding purposes, rated for 300v
- **SPT-3:** Same as SPT-2, but heavier construction for refrigerators or room air conditioners, rated for 300v
- **ST:** Extra-hard usage, thermoplastic (PVC), 600v
- **STO**: Same as ST but with oil resistant and thermoplastic outer jacket, 600v
- **STOW**: Same as STO but with oil and water resistant thermoplastic outer jacket, 600v

- **SV**: Vacuum cleaner cord, two or three conductor, rubber insulated, rubber jacket, 300v
- **SVO**: Same as SV except neoprene jacket, 300v
- **SVT**: Same as SV except all thermoplastic construction, 300v
- **SVTO**: Same as SVT except with oil resistant jacket, 300v
- **THHN**: 600v nylon jacketed building wire
- **THW**: Thermoplastic vinyl insulated building wire, moisture and heat resistant
- **THWN**: Same as THW but with nylon jacket
- **W:** Extra-hard usage, weather-resistant

http://www.dot.ca.gov/hq/eqsc/QualityStandards/Electric/Electric-01.htm