Transmission Line Ampacity and Heat Balance Equations
Bare Overhead Aluminum Conductors

Transmission line ampacity depends on many factors.

line heat generated + line heat absorbed < line heat lost to surroundings … must be True

$$I^2R \quad + \quad Q_s \quad = \quad Q_c \quad + \quad Q_R$$

$I = conductor\ current$
$R = conductor\ AC\ resistance$

solar absorbed

$$Q_s(A, \lambda, \theta, q_s)$$

$A =\ projected\ area\ of\ conductor$
$\lambda = coefficient\ of\ solar\ absorption$
$\theta = effective\ angle\ of\ sun\ rays$
$q_s = total\ solar\ and\ sky\ radiated\ heat$

convection loss

$$Q_c(D, \rho, V, \mu, k, T_c, T_a)$$

$D = diameter\ of\ conductor$
$\rho = density\ of\ air$
$V = velocity\ of\ air$
$\mu = viscosity\ of\ air$
$k = thermal\ conductivity\ of\ air$
$T_c = temperature\ of\ conductor$
$T_a = ambient\ temperature$

radiated loss

$$Q_R(D, \epsilon, T_c, T_a)$$

$D = diameter\ of\ conductor$
$\epsilon = coefficient\ of\ emissivity$
$T_c = temperature\ of\ conductor$
$T_a = ambient\ temperature$

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Definitions of Terms

$I = conductor\ currrent\ (amps\ at\ 60Hz)$

$R_{AC} = conductor\ resistance\ at\ 60Hz\ \left(\frac{\Omega}{ft}\right)$

$Q_C = convected\ heat\ loss\ \left(\frac{watts}{ft}\right)$

$Q_R = radiated\ heat\ loss\ \left(\frac{watts}{ft}\right)$

$Q_S = heat\ gain\ from\ sun\ \left(\frac{watts}{ft}\right)$

$D = conductor\ diameter\ (inches)$

$T_a = ambient\ temperature\ (°C)$

$T_c = conductor\ temperature\ (°C)$

$T_f = air\ film\ temperature = \frac{T_c + T_a}{2}\ (°C)$

$\rho = air\ density\ \left(\frac{lbs}{ft^2}\right)$

$V = air\ velocity\ \left(\frac{ft}{hr}\right)$

$\mu = air\ viscosity\ \left(\frac{lbs}{hr \cdot ft}\right)$

$k = air\ thermal\ conductivity\ \left(\frac{watts}{ft^2}\right)$

$\epsilon = coefficient\ of\ emissivity$

$\lambda = coefficient\ of\ solar\ absorption$

$q_s = total\ solar\ and\ sky\ radiated\ heat\ \left(\frac{watts}{ft^2}\right)$

$A = \ projected\ area\ of\ conductor = \frac{D}{12}\ \left(\frac{ft^2}{per\ ft}\right)$

$\theta = effective\ angle\ of\ sun\ rays\ (degrees)$

$H_c = altitude\ of\ sun\ (degrees)$

$Z_c = azimuth\ of\ sun\ (degrees)$

$Z_L = azimuth\ of\ line\ (degrees)$

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Choose conductor related values

795 26/7 ACSR Drake

$D = 1.107"$

$A = 0.09225 = \frac{D}{12}$

$R_{AC} = 0.0000263\ \Omega\ \ @\ \ 75°\ C$

$conductor\ loation = 35.0°\ N\ latitude$

$\epsilon = 0.5 \quad (new = 0.23, black = 0.91, average = 0.5)$

$\lambda = 0.5 \quad (new = 0.23, black = 0.95, average = 0.5)$

$Z_L = 270° \quad (East - West = 270° \quad North - South = 180°)$

$T_c = 100°\ C \quad (for\ this\ example)$

Drake	795	26/7	.1749	.136	.408	1.107	749	344	1093	68.51	31.49	31500	.0214	.0263	907

Ω/kft

Adjust R_{AC} to max conductor temperature

$$R'_{AC} = 0.000028492\ \Omega = 0.0000263\left(\frac{100 + 225}{75 + 225}\right)\ \ @\ \ 100°\ C$$

$H_c = 78°$

$Z_c = 180°$

Get sun related values

$q_s = 95.64$

DEGREES NORTH LATITUDE	LOCAL SUN TIME					
	10:00 A.M.		12:00 NOON		2:00 P.M.	
	H_c	Z_c	H_c	Z_c	H_c	Z_c
20	62	78	87	0	62	282
25	62	88	88	180	62	272
30	62	98	83	180	62	262
35	61	107	78	180	61	253
40	60	115	73	180	60	245
45	57	122	68	180	57	238
50	54	128	63	180	54	232
60	47	137	53	180	47	223
70	40	143	43	180	40	217

SOLAR ALTITUDE, H_c, DEGREES	Q_s, WATTS/SQ FT	
	CLEAR ATMOSPHERE	INDUSTRIAL ATMOSPHERE
5	21.7	12.6
10	40.2	22.3
15	54.2	30.5
20	64.4	39.2
25	71.5	46.6
30	77.0	53.0
35	81.5	57.5
40	84.8	61.5
45	87.4	64.5
50	90.0	67.5
60	92.9	71.6
70	95.0	75.2
80	95.8	77.4
90	96.4	78.9

78 → 95.64

Calculate effective sun angle

$$\theta = \cos^{-1}[\cos(H_c)\cos(Z_c - Z_L)]$$
$$\theta = \cos^{-1}[\cos(78°)\cos(180° - 270°)]$$
$$\theta = \cos^{-1}(0)$$
$$\theta = 90°$$

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Choose air related values

$$T_a = 40\ °C\ (104\ °F)$$
$$V = 2.0\ \frac{ft}{sec} = 7200\frac{ft}{hr}$$
$$\therefore T_f = 70°\ C = \frac{100+40}{2} = \frac{T_c + T_a}{2}$$

Get other air related values

$$\mu = 0.0494$$
$$\rho = 0.0643$$
$$k = 0.00898$$

TEMPERATURE			$\frac{K}{100}$ *	ABSOLUTE VISCOSITY, μ_f	DENSITY, ρ_f				THERMAL CONDUCTIVITY, k_f
°F	°C	°K			SEA LEVEL	5,000 FT	10,000 FT	15,000 FT	
32	0	273	55.55	0.0415	0.0807	0.0671	0.0554	0.0455	0.00739
41	5	278	59.73	0.0421	0.0793	0.0660	0.0545	0.0447	0.00750
50	10	283	64.14	0.0427	0.0779	0.0648	0.0535	0.0439	0.00762
59	15	288	68.80	0.0433	0.0765	0.0636	0.0526	0.0431	0.00773
68	20	293	73.70	0.0439	0.0752	0.0626	0.0517	0.0424	0.00784
77	25	298	78.86	0.0444	0.0740	0.0616	0.0508	0.0417	0.00795
86	30	303	84.29	0.0450	0.0728	0.0606	0.0500	0.0411	0.00807
95	35	308	89.99	0.0456	0.0716	0.0596	0.0492	0.0404	0.00818
104	40	313	95.98	0.0461	0.0704	0.0586	0.0484	0.0397	0.00830
113	45	318	102.26	0.0467	0.0693	0.0577	0.0476	0.0391	0.00841
122	50	323	108.85	0.0473	0.0683	0.0568	0.0469	0.0385	0.00852
131	55	328	115.74	0.0478	0.0672	0.0559	0.0462	0.0379	0.00864
140	60	333	122.96	0.0484	0.0661	0.0550	0.0454	0.0373	0.00875
149	65	338	130.52	0.0489	0.0652	0.0542	0.0448	0.0367	0.00886
158	70	343	138.41	0.0494	0.0643	0.0535	0.0442	0.0363	0.00898
167	75	348	146.66	0.0500	0.0634	0.0527	0.0436	0.0358	0.00909
176	80	353	155.27	0.0505	0.0627	0.0522	0.0431	0.0354	0.00921
185	85	358	164.26	0.0510	0.0616	0.0513	0.0423	0.0347	0.00932
194	90	363	173.63	0.0515	0.0608	0.0506	0.0418	0.0343	0.00943
203	95	368	183.40	0.0521	0.0599	0.0498	0.0412	0.0338	0.00952
212	100	373	193.57	0.0526	0.0591	0.0492	0.0406	0.0333	0.00966

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Calculate conductor ampacity

$$I^2R + Q_s = Q_c + Q_R$$

$$I = \sqrt{\frac{Q_c + Q_R - Q_s}{R'_{AC}}}$$

$$Q_c = \left[1.01 + 0.371\left(\frac{D\rho V}{\mu}\right)^{0.52}\right]k(T_c - T_a)$$

$$-or-$$

$$Q_c = \left[0.1695\left(\frac{D\rho V}{\mu}\right)^{0.60}\right]k(T_c - T_a)$$

whichever is greater

$$Q_R = 0.138D\epsilon\left[\left(\frac{T_c + 273}{100}\right)^4 - \left(\frac{T_A + 273}{100}\right)^4\right]$$

$$Q_s = A\lambda q_s \sin\theta$$

$$Q_c = \left[1.01 + 0.371\left(\frac{(1.107)(0.0643)(7200)}{0.0494}\right)^{0.52}\right]0.00898(100 - 40)$$

$$Q_c = 25.04062$$

$$-or-$$

$$Q_c = \left[0.1695\left(\frac{(1.107)(0.0643)(7200)}{0.0494}\right)^{0.60}\right]0.00898(100 - 40)$$

$$Q_c = 23.45178$$

$$Q_R = (0.138)(1.107)(0.5)\left[\left(\frac{373}{100}\right)^4 - \left(\frac{313}{100}\right)^4\right]$$

$$Q_R = 7.45418$$

$$Q_s = (0.09225)(0.5)(95.64)\sin(90°)$$

$$Q_s = 4.41140$$

$$I = \sqrt{\frac{25.04062 + 7.45418 - 4.41140}{0.000028492}} = 992.8\ Amps$$

<--- Max amps @ 100° C

3ΦEE

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Questions or Comments …

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