STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS

FINK & CARROLL

TENTH EDITION

McGRAW-HILL

approximately the higher value. It is approximately the same for the standard strandings but with rope lay cables may be as low as 0.7. The values of e_o when used for 3-phase circuits apply to equilateral triangular spacing. For lines with flat configuration, whether horizontal or vertical, Peek states that e_o should be decreased 4% for the center conductor and increased 6% for the two outer conductors, the spacing used being $S_{1-2} = S_{2-3} = S_{1-3}/2$. e_o for **wet weather** is approximately **80%** of the fair-weather calculated values. Calculated values of $\sqrt{3}e_o$ (kilovolts line to line) at 25°C and 76 cm barometer are given in Table 13-11. Altitude corrections are given in Table 13-10. These and other tables based on the same formula have been used for many years as guides in avoiding excessive corona on transmission voltages up to 230 kV.

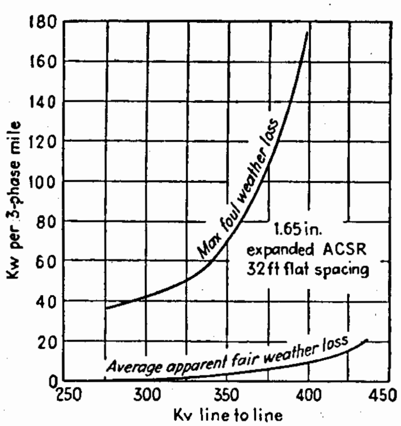

Fig. 13-21. Comparison of fair- and foul-weather corona loss. (*Gross, Wagner, Naef, and Tremaine, Trans. AIEE*, 1951, *Vol.* 70, *p.* 75.)

Peek determined empirical fair-weather loss formulas for a 2-mi test line. However, no foul-weather formulas were determined, and as fair-weather losses have little significance except at high altitudes, the loss formulas are omitted here.

Peek found that corona loss is proportional to the frequency. This holds true for the range of frequencies used in the tests (47 to 120 c/s). The law departs from the linear relation at low frequencies. At zero frequency, i.e., direct current, the loss is from one-fourth to one-half the 60-c loss for the maximum voltage. Humidity has no effect on the critical voltage or on the loss; smoke lowers the critical voltage and increases the loss; heavy winds have no effect on the critical voltage or on the loss; fog, sleet, rainstorms, and snowstorms all lower the critical voltage and increase the loss. Wet weather causes a very marked increase in the loss. This is shown by Fig. 13-21, which is plotted from data of a much later study.

To find the voltage limit at any other barometer reading b_h, in inches, with temperature remaining constant, multiply the voltage values by $b_h/29.92$. Table 13-10 gives approximate values of $b_h/29.92$ for various altitudes.

For temperatures other than 25°C, the voltage value, as modified by the barometric correction, must be corrected for the new temperature t_1, in degrees centigrade, by multiplying by the temperature-correction factor $298/(273 + t_1)$, where 298 = absolute temperature at 25°C, and $273 + t_1$ = new absolute temperature.

For 3-phase configurations with all conductors in the same plane, use 96% of the corrected values above for the center conductor and 106% for the two outer conductors. For **wet-weather** values, use 80% of the fair-weather values.

40. Later Corona Research. Peek's findings were accepted without question until the Boulder Dam–Los Angeles line came up for study in the early 1930's. It was then decided to conduct new corona investigations to check Peek's formulas. These tests were conducted at Stanford University, and it was determined that the formulas were not of sufficient accuracy for use on the large conductors under consideration. From the test results, W. S. Peterson[1] developed empirical formulas for fair-weather critical starting voltage and also for fair-weather corona losses. No foul-weather loss formulas were developed, and bundle conductors were not investigated.

Since then every step-up in transmission voltage has required extensive corona research, which has been extended to include radio interference (*RI*). However, no new corona loss formulas have been established to date. When the American Gas and Electric Company[2] decided to superimpose a higher voltage network upon their 138-kV

[1] Peterson, W. S. Discussion; *Trans. AIEE*, 1933, Vol. 52, p. 62.
[2] Sporn, Philip, Gross, I. W., Peterson, E. L., and St. Clair, H. P. The 300/315 KV Extra-high-voltage Transmission System of the American Gas and Electric Company; *Trans. AIEE*, 1951, Vol. 70, Pt. 1, p. 64.

Table 13-11. Fair-weather Corona Limits of Voltage, in Kilovolts, between Conductors (3-phase) at Average Sea Level, 76 Cm (29.92 In.) Barometer and 25°C (77°F) Temperature. Equilateral Spacing

A.W.G. and cir mils	No. of wires	O.D., in.	Spacing, ft												
			3	4	5	6	8	10	12	14	16	20	24	28	32
Stranded Conductors (From formula $e_0 = \sqrt{3}\, g_0 m_0 r \delta \log_e \frac{S}{r}$, where $m_0 = 0.87$)															
4	7	0.232	..	56	59	60	63	65	67	68	69	72			
3	7	0.260	..	62	64	66	69	72	74	75	77	79			
2	7	0.292	..	..	71	73	77	79	81	83	85	87			
1	7	0.328	..	..	78	81	84	87	90	92	94	97			
0	19	0.373	..	..	..	90	94	97	100	102	104	108			
00	19	0.419	..	..	..	99	104	107	111	113	115	119			
000	19	0.470	..	..	..	..	114	118	122	125	127	132			
0,000	19	0.528	..	..	..	..	126	130	134	138	141	145	149		
250,000	19	0.574	..	..	..	..	135	140	144	148	151	156	160	164	
300,000	19	0.629	..	..	..	..	...	151	156	160	163	169	173	177	
350,000	19	0.679	..	..	..	..	...	161	166	170	174	180	185	189	
400,000	19	0.726	..	..	..	..	...	170	175	180	184	190	196	200	204
450,000	19	0.770	..	..	..	..	...	179	184	189	193	200	206	211	215
500,000	37	0.813	..	..	..	..	...	187	193	198	202	209	215	221	225
800,000	37	1.029	..	..	..	..	...	...	234	241	246	255	263	269	275
1,000,000	61	1.152	..	..	..	..	...	...	257	264	270	281	289	296	302
Solid wires, $m_0 = 0.93$															
4	..	0.204	51	54	56	58	60	62	64	65	66	68			
3	..	0.229	..	59	62	64	66	68	70	72	74	76			
2	..	0.258	..	..	69	70	74	76	78	80	82	84			
1	..	0.289	..	..	75	77	81	83	86	88	90	92			
0	..	0.325	..	..	..	85	89	92	95	97	99	102			
00	..	0.365	..	..	..	94	98	102	105	107	110	113			
000	..	0.410	..	..	..	..	109	113	116	119	121	124			
0000	..	0.460	..	..	..	..	120	125	128	131	134	138			

network system, they set up the 500-kV Tidd test line to conduct research leading to the selection of the most suitable voltage. This research continued for a period in excess of 3 years, and continuous corona observations were made over this period. Also, for the first time, extensive investigations were made of radio interference and radio-interference voltages (*RIV*). From the overall test results, annual corona kilowatthour losses were estimated which, together with kilowatt demands at times of heaviest foul-weather losses, were used to determine the most economical voltage and conductor. Other considerations entered into the selection, such as ice melting.

Final result was the selection of 315 kV (now rated 345 kV) and an expanded ACSR conductor of 1,269,300 cmils and 1.6 in in diameter. Since the Tidd line research, all systems from 460 to 700 kV have had the benefit of corona research before construction. In this research, *RI* and *RIV* have had an increasingly important part, and in some cases this has been the factor determining the conductor characteristics.

Radio-influence voltage is a radio-frequency emanation set up by the transmission line which is of appreciable magnitude at voltages below which corona becomes measurable. It is greatly increased by heavy corona. It has been found that *RI* is more readily minimized by the use of bundle conductors on voltages 500 kV and above. The Bonneville Power Administration has chosen a single 2.5-in-diameter expanded ACSR conductor for its 500-kV system.[1]

Many other research projects have been carried out since the Tidd project and have been reported in the *Transactions of the AIEE* and *IEEE*. Project engineers of new EHV systems may find information to fit their conditions in these published results.

41. References to Literature on Corona

Cozzens, Bradley, and Peterson, Wm. S. Symposium on Operation of the

[1] Osipovich, A. A., and Poland, M. G. First 500 kV Transmission Line Designs for the Bonneville Power Administration's Grid; *Trans. IEEE Power Group*, January, 1964, p. 28.