TSDOS TRANSMISSION & SUBSTATION DESIGN & OPERATION SYMPOSIUM

THE UNIVERSITY OF TEXAS AT ARLINGTON

Market Variability Trends Among Copper Grounding Products

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Copperweld

Is there variability in the copper market?

If so, what does that mean for performance versus the expected standard?

What is the Problem?

- CDEGS published a paper by Jeffrey Jordan, PE

  SHORT CIRCUIT (ISC) PERFORMANCE CONSIDERATIONS FOR CCS

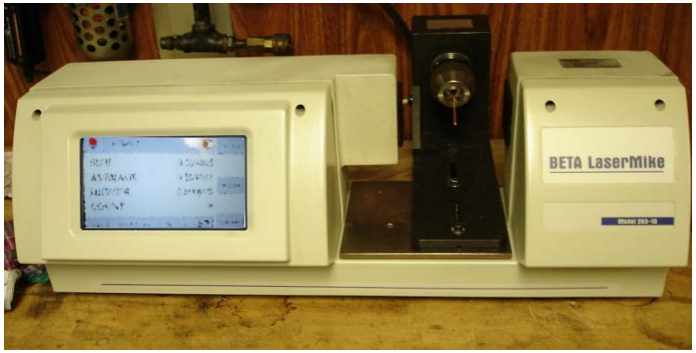
- Copperweld 19 No 9 (4/0 copper equivalent)

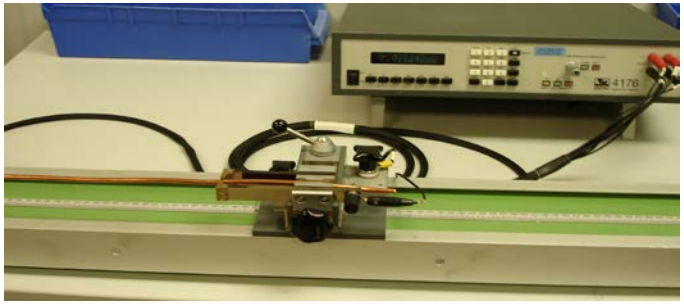
Conductor	Shot #	Sample #	Voltage (kV)	Current (kA)	Duration (ms)	Comment
CCS 19 No. 9	1-1	1	3.9	33.5	508	No fusing
CCS 19 No. 9	2-1	1	4.2	36.2	508	No fusing
CCS 19 No. 9	3-1	2	4.1	53.8	225	Fuse at lug
CCS 19 No. 9	4-1	3	3.8	47.2	258	No fusing

Assessment Overview

- 5 Manufacturers:
  - CME, Nehring, Southwire, Republic, Cerro and Encore
- 42 total Samples:
  - 4/0, 2/0, #4, #6 wire
- Standards Referenced:
  - IEEE Standard 80 (substation grounding and short-circuit rating)
  - ASTM B-3 (Soft or Annealed Copper Wire)
  - ASTM B-8 (Concentric-Lay Stranded Copper)
  - ASTM B-787 (19 Wire Combination Unilay-Stranded)

Testing & Measurement Overview





1. **Sample** – cut at approximately 2 ft lengths
2. **Wire diameter** – measured by a laser micrometer
3. **Resistance** – measured using a resistance bridge
4. **Break load** – measured by taking the sum of the individual strands

Application: 4/0 Substation Grounding

Sample #	Brand	Strands	Overall Diameter (in)	Total Area (in^2)	Cross-sectional Area (kcmil)	Total Break Load (lb)	IEEE Short Circuit (KA)
4/0							
1	A	19	0.499	0.159	203.0	6304	41.02
8	A	19	0.506	0.165	210.4	6317	42.50
21	A	19	0.499	0.164	208.9	6226	42.20
23	B	19	0.497	0.157	199.9	5956	40.38
26	B	19	0.493	0.157	200.4	6077	40.49
24	B	7	0.511	0.164	208.3	6041	42.09
26	C	7	0.518	0.167	212.2	9566	42.87
22	C	7	0.499	0.166	211.9	9105	42.81
20	D	19	0.502	0.160	203.4	6095	41.08

IEEE table 6	max variability
44 kA	8%

Standard IEEE 80 simplified formula:

$$A_{kcmil} = I * k_f * \sqrt{t_c}$$

		Table 1	98%	
ASTM B-787	4/0	211.6	207.4	kcmil
& ASTM B-8	2/0	133.1	130.4	kcmil

Sample #	Brand	Strands	Overall Diameter (in)	Total Area (in^2)	Cross-sectional Area (kcmil)	Total Break Load (lb)	IEEE Short Circuit (KA)
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1	A	19	0.499	0.159	203.0	6304	41.02
8	A	19	0.506	0.165	210.4	6317	42.50
21	A	19	0.499	0.164	208.9	6226	42.20
23	B	19	0.497	0.157	199.9	5956	40.38
26	B	19	0.493	0.157	200.4	6077	40.49
24	B	7	0.511	0.164	208.3	6041	42.09
26	C	7	0.518	0.167	212.2	9566	42.87
22	C	7	0.499	0.166	211.9	9105	42.81
20	D	19	0.502	0.160	203.4	6095	41.08

IEEE table 6	max variability
44 kA	8%

Standard ASTM B-787:

12.1 The cross-sectional area of the completed conductor shall be not less than 98 % of the area indicated in Column 1 of Table 1.

Standard ASTM B-8-11:

11.1 The area of cross section of the completed conductor shall be not less than 98 % of the area indicated in Column 1 of Table 1.

Application: 2/0 Substation Grounding

Sample #	Brand	Strands	Overall Diameter (in)	Total Area (in^2)	Cross-sectional Area (kcmil)	Total Break Load (lb)	IEEE Short Circuit (KA)
2/0							
2	A	19	0.391	0.102	129.4	3948	26.15
9	A	18	0.395	0.103	130.7	3860	26.40
15	A	19	0.395	0.104	132.7	3950	26.81
14	B	18	0.393	0.097	124.1	3691	25.06
16	B	19	0.392	0.100	127.6	3794	25.77
17	B	7	0.385	0.102	130.2	3807	26.31
18	B	19	0.398	0.103	130.8	3919	26.43
19	C	19	0.412	0.103	130.8	3883	26.43

IEEE table 6	max variability
28 kA	8%

Standard IEEE 80 simplified formula:

$$A_{kcmil} = I * k_f * \sqrt{t_c}$$

		Table 1	98%	
ASTM B-787	4/0	211.6	207.4	kcmil
& ASTM B-8	2/0	133.1	130.4	kcmil

Sample #	Brand	Strands	Overall Diameter (in)	Total Area (in^2)	Cross-sectional Area (kcmil)	Total Break Load (lb)	IEEE Short Circuit (KA)
2/0							
2	A	19	0.391	0.102	129.4	3948	26.15
9	A	18	0.395	0.103	130.7	3860	26.40
15	A	19	0.395	0.104	132.7	3950	26.81
14	B	18	0.393	0.097	124.1	3691	25.06
16	B	19	0.392	0.100	127.6	3794	25.77
17	B	7	0.385	0.102	130.2	3807	26.31
18	B	19	0.398	0.103	130.8	3919	26.43
19	C	19	0.412	0.103	130.8	3883	26.43

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Standard ASTM B-8-11:

11.1 The area of cross section of the completed conductor shall be not less than 98 % of the area indicated in Column 1 of Table 1.

Preliminary Findings

- 40% of the samples tested out of spec
  - 2 wire samples met the upper limit
  - the remaining 50% met the lower limit of ASTM
- **None** met the ultimate short circuit rating in IEEE standard 80 table 6
  - 4/0 had 3-8% variability range
  - 2/0 had 4-8% variability range

Application: #4 Pole Grounding

Sample #	Brand	Strands	Overall Diameter (in)	Total Area (in^2)	Cross-sectional Area (kcmil)	Total Break Load (lb)	IEEE Short Circuit (KA)
#4							
3	A	7	0.226	0.034	43.2	1324	8.74
11	A	7	0.221	0.033	42.5	1275	8.59
6	A	1	0.206	0.033	42.5	1150	8.58
10	A	1	0.204	0.033	41.5	1151	8.38
28	A	1	0.203	0.032	41.2	1149	8.32
29	B	1	0.201	0.032	40.6	1114	8.19
32	B	1	0.201	0.032	40.5	1119	8.18
30	B	7	0.223	0.032	41.0	1207	8.28
33	B	7	0.220	0.032	41.3	1181	8.35
0	E	7	0.221	0.032	40.6	1210	8.20
31	E	1	0.203	0.032	41.3	1159	8.35
34	C	1	0.205	0.033	41.9	1099	8.46
27	D	1	0.204	0.033	41.4	1189	8.37

IEEE table 6	max variability
9	9%

Standard IEEE 80 :

$$A_{kcmil} = I * k_f * \sqrt{t_c}$$

Sample #	Brand	Strands	Overall Diameter (in)	Total Area (in^2)	Cross-sectional Area (kcmil)	Total Break Load (lb)	IEEE Short Circuit (KA)
#4							
3	A	7	0.226	0.034	43.2	1324	8.74
11	A	7	0.221	0.033	42.5	1275	8.59
6	A	1	0.206	0.033	42.5	1150	8.58
10	A	1	0.204	0.033	41.5	1151	8.38
28	A	1	0.203	0.032	41.2	1149	8.32
29	B	1	0.201	0.032	40.6	1114	8.19
32	B	1	0.201	0.032	40.5	1119	8.18
30	B	7	0.223	0.032	41.0	1207	8.28
33	B	7	0.220	0.032	41.3	1181	8.35
0	E	7	0.221	0.032	40.6	1210	8.20
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34	C	1	0.205	0.033	41.9	1099	8.46
27	D	1	0.204	0.033	41.4	1189	8.37

IEEE table 6	max variability
9	9%

		Table 1	98%	
ASTM B-787 & ASTM B-8	#4	41.74	40.91	kcmil
	#6	26.24	25.72	kcmil

ASTM B-3	#4	0.2023 in
	#6	0.16039 in

Standard ASTM B-3:

5.3 …. And for diameters of 0.100 in (.254 mm) and over the wire shall not vary from the specified diameter by more than +/- 1%, expressed to the nearest 0.0001 in (or 0.001 mm).

Standard ASTM B-8:

11.1 … not less than 98 % of the area indicated in Column 1 of Table 1.

Application: #6 Pole Grounding

Sample #	Brand	Strands	Overall Diameter (in)	Total Area (in^2)	Cross-sectional Area (kcmil)	Total Break Load (lb)	IEEE Short Circuit (KA)
#6							
7	A	1	0.162	0.021	26.2	748	5.29
12	A	1	0.164	0.021	26.8	766	5.41
35	A	1	0.162	0.021	26.2	739	5.29
36	A	1	0.161	0.020	25.8	752	5.21
5	A	7	0.181	0.021	26.2	768	5.29
13	A	7	0.180	0.021	26.4	765	5.33
40	B	7	0.220	0.021	26.1	785	5.27
37	B	1	0.160	0.020	25.7	738	5.20
39	B	1	0.161	0.020	25.9	733	5.22
41	C	1	0.162	0.021	26.2	701	5.30
36	E	1	0.161	0.020	26.0	815	5.26
red	F	1	0.164	0.021	26.7	761	5.40

IEEE table 6	max variability
6	13%

Standard IEEE 80 :

$$A_{kcmil} = I * k_f * \sqrt{t_c}$$

Sample #	Brand	Strands	Overall Diameter (in)	Total Area (in²)	Cross-sectional Area (kcmil)	Total Break Load (lb)	IEEE Short Circuit (KA)
#6							
7	A	1	0.162	0.021	26.2	748	5.29
12	A	1	0.164	0.021	26.8	766	5.41
35	A	1	0.162	0.021	26.2	739	5.29
36	A	1	0.161	0.020	25.8	752	5.21
5	A	7	0.181	0.021	26.2	768	5.29
13	A	7	0.180	0.021	26.4	765	5.33
40	B	7	0.220	0.021	26.1	785	5.27
37	B	1	0.160	0.020	25.7	738	5.20
39	B	1	0.161	0.020	25.9	733	5.22
41	C	1	0.162	0.021	26.2	701	5.30
36	E	1	0.161	0.020	26.0	815	5.26
red	F	1	0.164	0.021	26.7	761	5.40

IEEE table 6	max variability
6	13%

		Table 1	98%	
ASTM B-787 & ASTM B-8	#4	41.74	40.91	kcmil
	#6	26.24	25.72	kcmil

ASTM B-3	#4	0.2023 in
	#6	0.16039 in

Standard ASTM B-3:

5.3 …. And for diameters of 0.100 in (.254 mm) and over the wire shall not vary from the specified diameter by more than +/- 1%, expressed to the nearest 0.0001 in (or 0.001 mm).

Standard ASTM B-8:

11.1 … not less than 98 % of the area indicated in Column 1 of Table 1.

Preliminary Findings

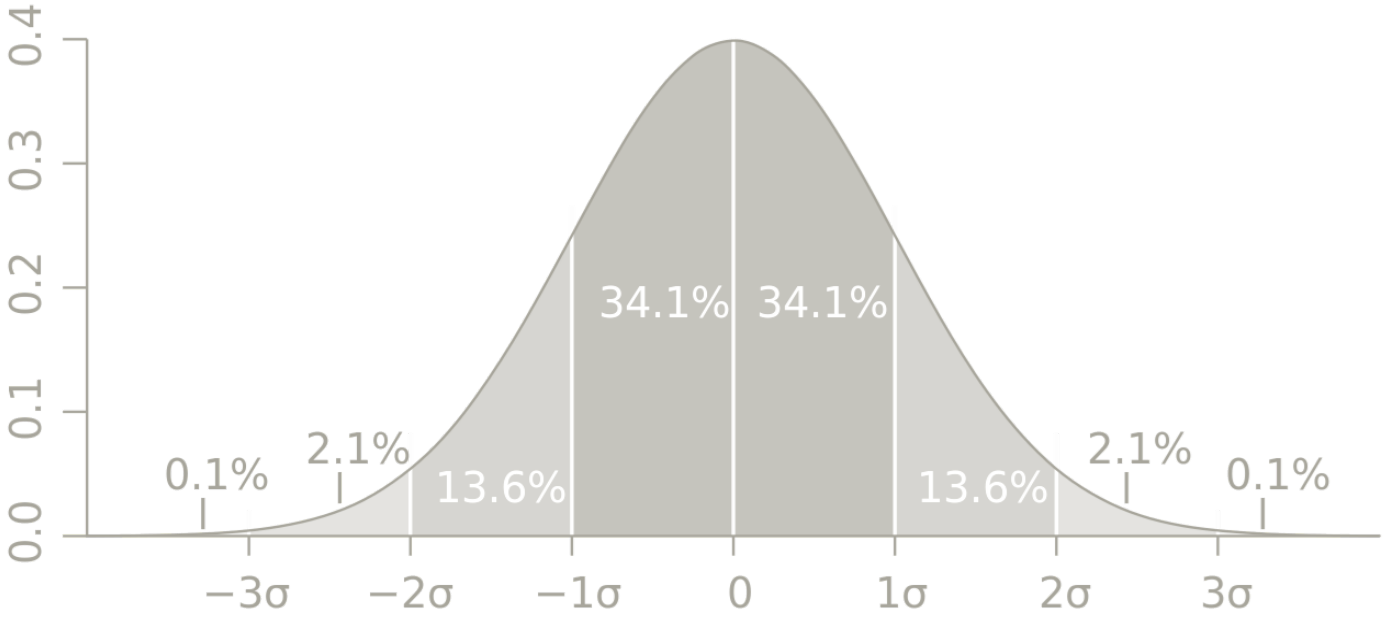
- 10% of the samples tested out of spec
  - 70% met or exceeded the upper limit

- **None** met the ultimate short circuit rating in IEEE Standard 80 Table 6

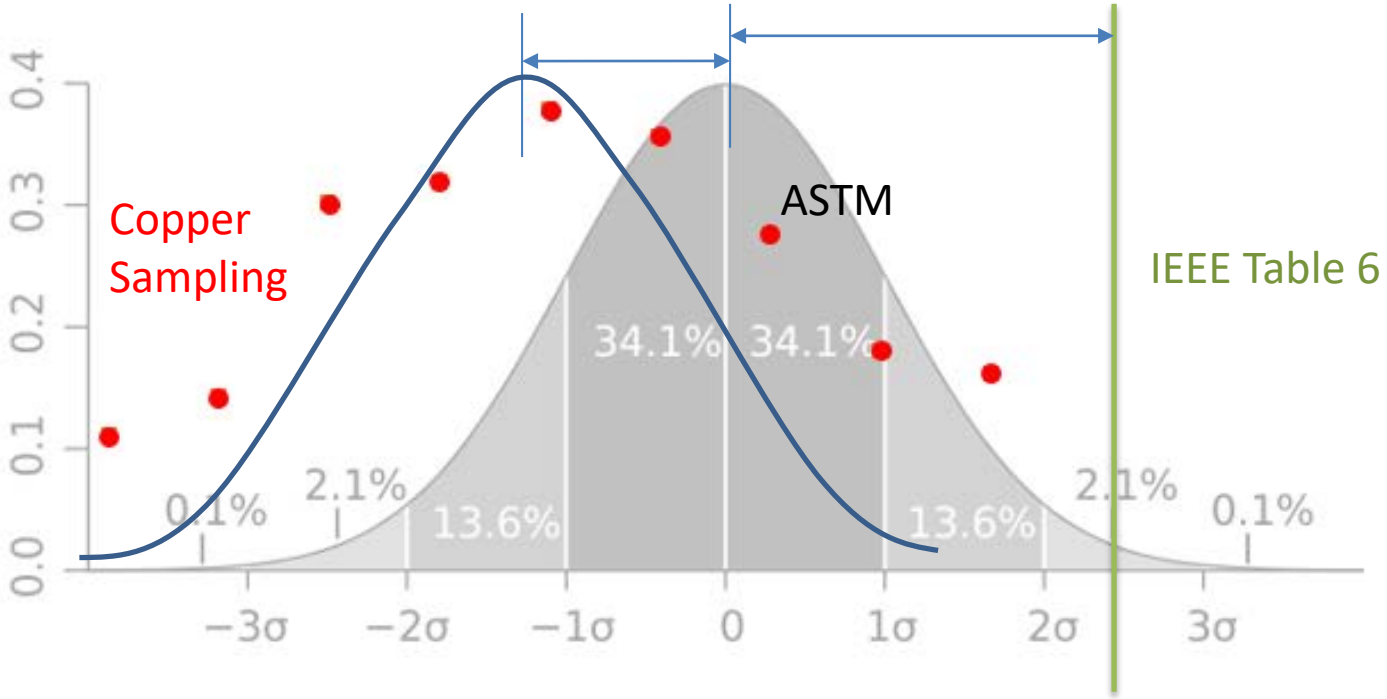
  #4 had 3-9% variability range

  #6 had 10-13% variability range

Normal Distribution Model

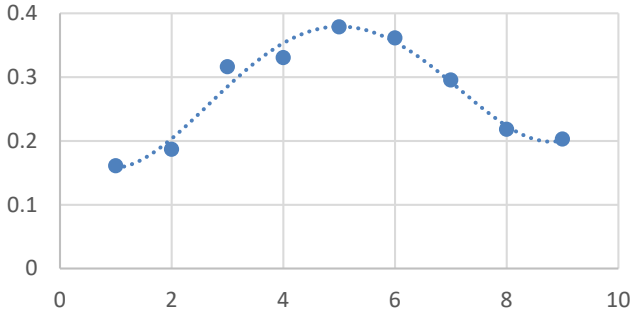


4/0 Distribution Model



Data

4/0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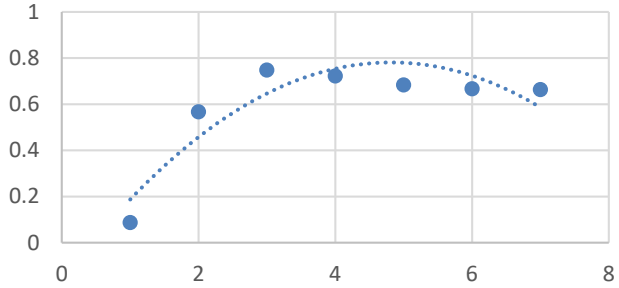
4
6
8
10

2/0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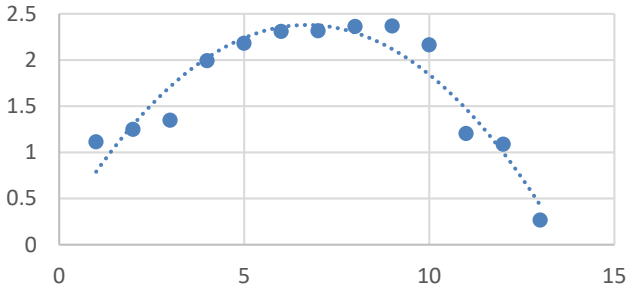
2
4
6
8

#4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1.5
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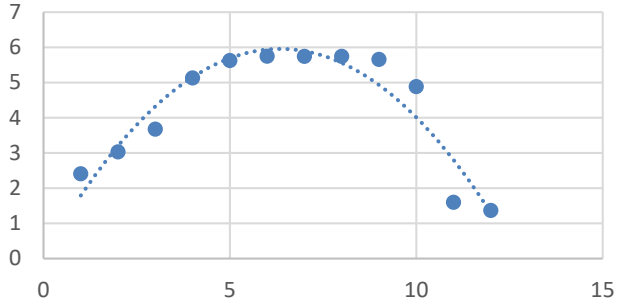
15

#6


7
6
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10
15

Key Take-Aways

- Variability in the market exists
  - Variability of up to 13% from IEEE short circuit standard
  - Approximately 25% of samples did not meet ASTM
- Further studies necessary
  - Larger sample size
  - Experimental replicates

Questions?

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