NATIONAL ELECTRIC SAFETY CODE (ANSI C2 / NESC)

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NESC 2012

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NESC

COMMITTEE STRUCTURE

- Chairman and Vice Chairman
- Main Committee
- Executive Committee
- Interpretations Subcommittee
- Interim Amendment Subcommittee

Subcommittee 1 – Purpose, Scope, Application, Definitions, and Reference
Subcommittee 2 – Grounding Methods
Subcommittee 3 – Electric Supply Stations
Subcommittee 4 – Overhead Lines – Clearances
Subcommittee 5 – Overhead Lines – Strength and Loading
Subcommittee 7 – Underground Lines
Subcommittee 8 – Work Rules

NESC

Section 1 – Introduction (Scope, Purpose)

Section 2 – Definitions

Section 3 – References

Section 9 – Grounding Methods

NESC

Part 4

Work Rules for the Operation of Electric Supply and Communications Lines and Equipment

Subcommittee 8

NESC (2007) SCOPE

- **011. Scope**

  A. These rules cover supply and communication lines, equipment, and associated work practices employed by a public or private electric supply, communications, railway, or similar utility in the exercise of its function as a utility. They cover similar systems under the control of qualified persons, such as those associated with an industrial complex or utility interactive system.

NESC (2007) SCOPE

B. The NESC covers utility facilities and functions up to the service point.

NOTE: The National Electrical Code (NEC - NFPA 70, 2005 Edition) covers utilization wiring requirements beyond the service point.

C. NESC rules cover street and area lights (supplied by underground or overhead conductors) under the exclusive control of utilities (including their authorized contractors) or other qualified persons (such as those associated with an industrial complex).

NOTE: Luminaires not under such exclusive control are governed by the requirements of the NEC.

D. NESC rules do not cover installations in mines, ships, railway rolling equipment, aircraft, or automotive equipment, or utilization wiring except as covered in Parts 1 and 3.

NEC / NFPA - *old*

Are located in legally established easements, rights-of-way, ***or by other agreements*** either designated by or recognized by public service commissions, utility commissions, or other regulatory agencies having jurisdiction for such installations

NEC / NFPA - *new*

These installations shall be limited to Federal Lands, Native American Reservations through the U.S. Department of the Interior Bureau of Indian Affairs, Military bases, lands controlled by port authorities and State agencies and departments, and lands owned by railroads.

NESC 2012 – Part 4

Work Rules for the Operation of Electric Supply and Communications Lines and Equipment

- **Complete review to "clean up" language**
- **2 significant changes**
  - **Rule 410.3 on arc flash**
    - **Rewrite to clarify intent**
    - **Inclusion of <1000 volt exposures**
  - **Minimum Approach Distances (MAD)**
    - **Clean up Rule 441**
    - **Simplify MAD rules**

NEW RULE 410.3

- The employer shall ensure that an assessment is performed to determine potential exposure to an electric arc for employees who work on or near energized lines, parts, or equipment.
- If the assessment determines potential employee exposure, clothing made from acetate, nylon, polyester, or polypropylene shall not be worn, unless arc rated.

NEW RULE 410.3

- ***If the assessment determines a potential employee exposure greater than 2 cal/cm2 exists (see Neal, Bingham, and Doughty [B59]), the employer shall:***

a. Perform a detailed arc hazard analysis, or use Table 410- 1, 410-2, or 410-3 to determine the effective arc rating of clothing or a clothing system to be worn by employees working on or near energized lines, parts, or equipment at voltages 50 V to 800,000 V. The arc hazard analysis shall include a calculation of the estimated arc energy based on the available fault current, the duration of the arc (cycles), and the distance from the arc to the employee.

NEW RULE 410.3

- ***If the assessment determines a potential employee exposure greater than 2 cal/cm2 exists (see Neal, Bingham, and Doughty [B59]), the employer shall:***

b. Require employees to wear clothing or a clothing system with an effective arc rating not less than the anticipated level of arc energy.

NEW RULE 410.3

EXCEPTION: If the clothing or clothing system required by this rule has the potential to create additional or greater hazards than the possible exposure to the heat energy of the electric arc, then clothing or a clothing system with an effective arc rating less than that required by the this rule may be worn.

NOTE 1: Assessments performed to determine potential exposure to an electric arc consider the affected employee's assigned tasks and/or work activities.

NOTE 2: A clothing system (multiple layers) that includes an outer layer of flame resistant material and an inner layer of non-flame resistant natural fiber material has been shown to block more heat than a single layer. The effect of the combination of these multiple layers may be referred to as the *effective arc rating* (e.g., E_{BT}, ATPV).

NOTE 3: Engineering controls can be utilized to reduce arc energy levels and work practices can be utilized to reduce exposure levels.

NESC 2012 – Rule 410.A.3

WHAT DOES RULE MEAN

AND

WHEN DOES IT APPLY?

Interpretation requests (IR)

asked these questions

NESC 2007 – Rule 410.A.3

(IR – 557)

Does this rule apply to insulated conductors in an underground manhole location. If an employee is working on a de-energized conductor in a manhole, does he need arc flash protection for the other energized, but insulated conductors, that are located in the same manhole.

While it is theoretically possible for an arc to occur whenever parts or equipment are energized, the likelihood – in part – is typically dependent upon the work being performed on energized facilities.

NESC 2007 – Rule 410.A.3

(IR – 558)

Does the term "potential exposure" mean "any possible exposure" or does it mean "an exposure with a strong possibility of occurring?"

"Potential exposure" can be interpreted as "any exposure existing in possibility" or it can be interpreted as "an exposure with a strong possibility" of actually occurring. After 1 January 2009, these differences in interpretation almost certainly will result in differences in application of the Rule.

See I.R. 557 - Rule 410A3 requires an assessment of the potential for an electric arc and the wearing of protective clothing as appropriate. The employer is responsible for determining potential employee exposure, based on what activities will occur and to what extent such activities may potentially initiate an arc.

NESC 2012

Low voltage arc exposure <1000 Volts

PROPOSED TO:

- Clarify interpretation issues
- Specifically include <1000 volt exposures
- Provide Table similar to existing Tables

NEW TABLE 410-1

	Nominal Voltage Range and Calories/Cm²		
Equipment Type	***50 – 250 V***	***251 – 600 V***	***601 – 1000 V***
Self-contained meters / Cabinets	**4[2]**	**20[4]**	**30[8]**
Pad-mounted transformers	**4[9]**	**4[9]**	**6[8]**
CT meters and control wiring	**4[2]**	**4[5]**	**6[8]**
Metal-clad Switchgear / Motor Control Centers	**8[3]**	**40[6]**	**60[8]**
Pedestals, Pull Boxes, Hand Holes	**4[2]**	**8[7]**	**12[8]**
Open Air (includes lines)	**4[2]**	**4[7]**	**6[8]**
Network Protectors	**4[10]**	**Note 11**	**Note 11**
Panel boards - single phase (all) / three phase (≤100 A)	**4[2]**	**8[12]**	**12[8]**
Panel boards – three phase (> 100 A)	**4[2]**	**Note 13**	**Note 13**

Footnotes To Table 410-1

1. This table was developed from fault testing based on equipment type and is independent of fault current unless otherwise noted.

   Calculations and test data are based on an 18 in separation distance from the arc to the employee. See IEEE Std 1584-2002.

   Other methods are available to estimate arc exposure values and may yield slightly different but equally acceptable results.

   The use of the table in the selection of clothing is intended to reduce the amount or degree of injury but may not prevent all burns.

Footnotes To Table 410-1

2. Industry testing on this equipment by two separate major utilities and a research institute has demonstrated that voltages 50 V to 250 V will not sustain arcs for more than 2 cycles, thereby limiting exposure to less than 4 cal/cm2.

3. Value based on IEEE 1584 formula for Motor Control Centers. (Gap = 1 in) (Xd = 1.641) (18 in distance) 51 kA (Based on a 208 V, 1000 kVA, 5.3% Z, served from a 500 MVA system) Maximum duration without circuit protective device operation from industry testing (see Ref [1]) is 10 cycles: 46.5 cal/s/cm2 x 0.167 s = 7.8 cal/cm2.

4. Industry testing on 480 V equipment indicates exposures for self-contained meters do not exceed 20 cal/cm2.

5. Industry testing on 480 V equipment indicates exposures for CT meters and control wiring does not exceed 4 cal/cm2.

Footnotes To Table 410-1

6. Value based on IEEE 1584 formula for Motor Control Centers. (Gap = 1 in) (Xd = 1.641) (18 in distance) 12.7 kA at 480 V (worst-case energy value from testing). (See Ref [2].) Maximum duration without circuit protective device operation from tests is 85 cycles: 26.2 cal/s/cm2 x 1.42 s = 37 cal/cm2.

7. Incident analysis on this equipment indicates exposures do not exceed the values in the table.

8. Engineering analysis indicates that applying a 150% multiplier to the 480 V exposure values provides a conservative value for equipment and open air lines operating at 601 V to 1000 V.

9. Industry testing on 480 V equipment indicates exposures on pad-mounted transformers do not exceed 4 cal/cm2. (See Ref [2].)

10. Industry testing on 208 V network protectors indicates exposures do not exceed 4 cal/cm2. (See Ref [1].)

Footnotes To Table 410-1

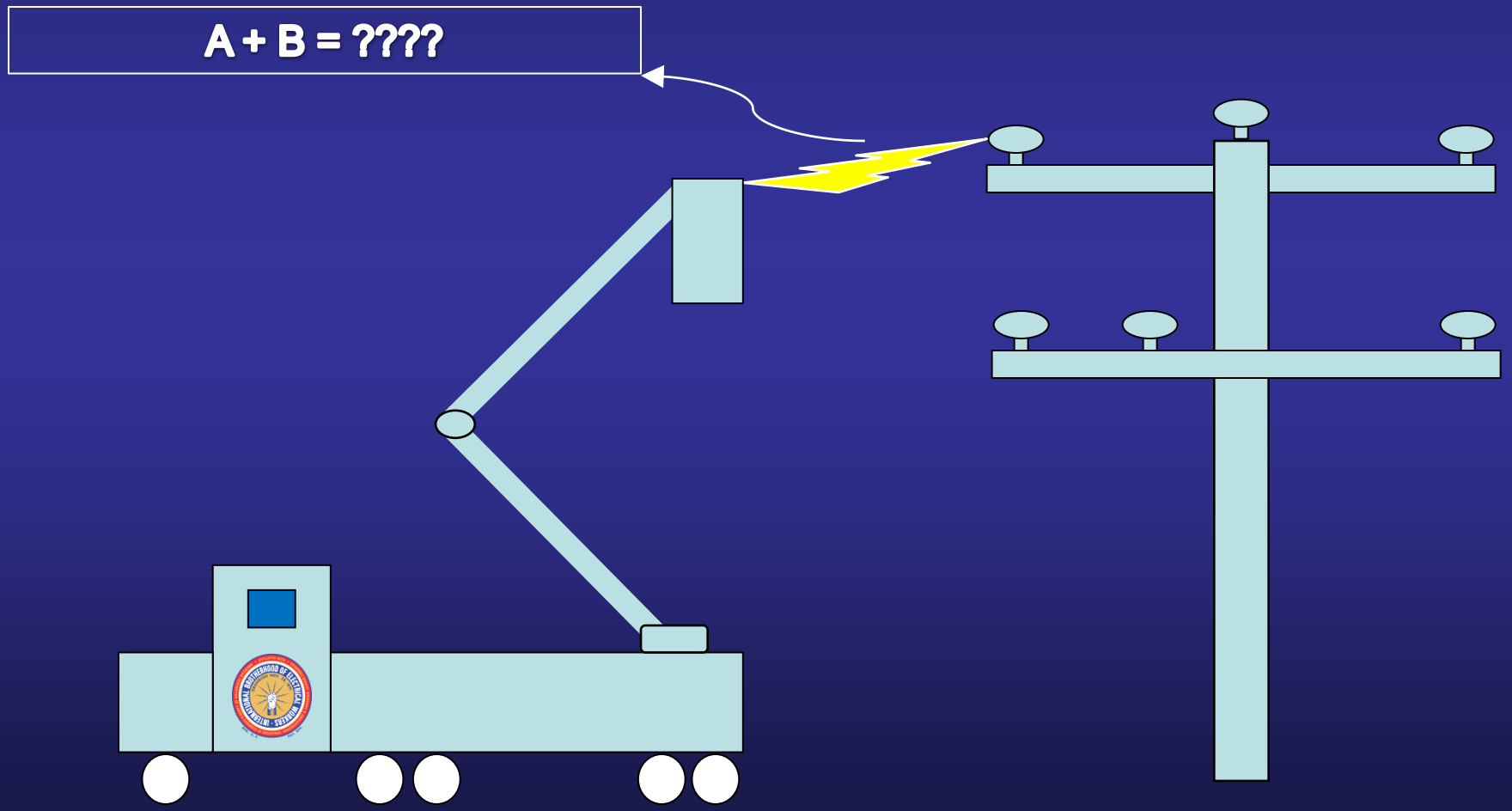
11. Industry testing on 480 V network protectors indicates arcs will not self-extinguish and heat flux rates will exceed 60 cal/cm2/s at 24 in working distance. Perform arc hazard analysis. (See Ref [2].)

12. Industry testing on 480 V panels with non-edge mounted bus bars indicates exposures do not exceed 8 cal/cm2. (See Ref [2].)

13. Industry testing on panelboards with edge-mounted, parallel bus bars indicate arcs will not self-extinguish and heat flux rates will exceed 60 cal/cm2/s at 18 in working distance. Perform arc hazard analysis. (See Ref [2].)

14. IEEE 1584 original test data indicates there is no significant difference between heat flux rates for 400 V class equipment verses 600 V class equipment.

Minimum Approach Distance (MAD)



Minimum Approach Distance (MAD)

- OSHA - in 1910.269 and 1926 Subpart V (and others)
- NESC - in Part 4 - Rules for the Operation of Electric Supply and Communication Lines and equipment

- IEEE 516 - IEEE Guide for Maintenance Methods on Energized Power Lines

Minimum Approach Distance (MAD)

- OSHA – the closest distance an employee is permitted to approach an energized or a grounded object
- NESC – the closest distance a qualified employee is permitted to approach either an energized or a grounded object, as applicable for the work method being used
- IEEE 516 - the minimum air insulation distance (MAID) plus a factor for inadvertent movement

Minimum Approach Distance (MAD)

- In NESC since early 1900's
- Recent years based on IEEE 516 calculation method
- IEEE 516 repeatedly changed since inception
- NESC has followed those changes
- IEEE 516 2009 changes begs the question "Why change again?"

NESC - 1914

OPERATING VOLTAGE		DISTANCE IN FEET
750 – 7500	.....	6 inches
7500	.....	1
15000	.....	2
50000	.....	3
70000	.....	5
Distances for intermediate voltages to be determined by interpolation		

Minimum Approach Distance (MAD)

- Error discovered in phase-to-phase calculations
- Phase-to-ground air saturation factor used to calculate phase-to-phase MAD
- Discovered error deemed some OSHA and NESC MAD values incorrect
- Must correct in OSHA and 2012 edition of the NESC

Minimum Approach Distance (MAD)

- Most significant changes occur in phase-to-phase voltages above 230 kV
- Phase-to-phase increases perceived as problems by some SC8 members
- Distribution voltage levels also revised
- Are users/can users calculate TOV
- Engineering analysis of system is critical to application of MAD

IEEE 516
MINIMUM APPROACH DISTANCE

MAID
MINIMUM AIR INSULATION DISTANCE

IEEE 516
MINIMUM APPROACH DISTANCE

What is MAD?

- Safe working distance
- Equal to the MAID + Inadvertent movement factor (worker movement)
  - < 72.5 kV= 1 foot
  - ≥ 72.5 kV = 2 feet
- Different voltages – different equations
- Add a tool and add a factor
- Add a helicopter and add a factor

CALCULATING MAD

Line-to-ground and line-to-line voltages above 750 V and below 5.0 kV

When the line-to-ground and line-to-line voltage is between 750 V and 5.0 kV, sufficient test data are not available to calculate the MAID, which is less than 2 cm or 0.07 feet. This guide recommends the following:

a) MAID, line-to-ground and line-to-line

1) $D_M = 0.02$

2) $D_{FT} = 0.07$

b) MAD, line-to-ground and line-to-line

1) $D_M = 0.63$

2) $D_{FT} = 2.07$

CALCULATING MAD

Line to ground above 72.5 kV

- $D_{MAD} = ((C_1)+a)(V_{L-G})(T)(A))+M$
- $D_{MADforTools} = (((C_1)(C_2)+a)(V_{L-G})(T)(A))+M$
- $D_{MHAD} = (((C_1)+a)(V_{L-G})(T)(A))+M)(H)$

- C_1 = 60 Hz rod gap withstand
- C_2 = tool factor (tool in air gap)
- a = air saturation factor
- V_{L-G} = line to ground voltage
- T = maximum anticipated per-unit TOV
- A = altitude correction factor
- M = inadvertant movement factor
- H = helicopter factor

CALCULATING MAD

***TOV*$_{Peak}$ equal to or greater than 27.00 kV – MAD Line-to-ground**

$$D_{FT} = \left(3.28 \left(\frac{\left(\frac{\left(TOV_{L\text{-}GPeak} - 36.7 \right)}{5.6} + 2.75 \right)}{100} \right) \right) + M$$

CALCULATING MAD

MAD, line-to-line, for line-to-line voltages equal to and less than 242 kV

$$D_{Ft} = \left[3.281 \left(\frac{8}{\left(\frac{4621}{\left((1.35)(T) + 0.45 \right)(V_{L-L})} \right) - 1} \right) (A) \right] + M$$

MAD, line-to-line, for line-to-line voltages greater than 242 kV

$$D_{Ft} = \left[3.281 \left(\frac{8}{\left(\frac{4875}{\left((1.35)(T) + 0.45 \right)(V_{L-L})} \right) - 1} \right) (A) \right] + M$$

EXAMPLE OF
MAD TABLE 2007 NESC

T p.u.)	Line-to-ground work					Line-to-line work		
	MAID (ft)	MTID (ft)	MAD (ft)	MAD for Tools (ft)	MHID (ft)	MAID (ft)	MAD (ft)	MHID (ft)
1.5	1.26	1.39	2.26	2.39	2.49	2.22	3.22	3.54
1.6	1.34	1.48	2.34	2.48	2.58	2.35	3.35	3.68
1.7	1.43	1.57	2.43	2.57	2.67	2.48	3.48	3.83
1.8	1.51	1.66	2.51	2.66	2.76	2.61	3.61	3.97
1.9	1.60	1.75	2.60	2.75	2.85	2.75	3.75	4.12
2.0	1.68	1.85	2.68	2.85	2.95	2.88	3.88	4.27
2.1	1.76	1.94	2.76	2.94	3.04	3.02	4.02	4.42
2.2	1.85	2.03	2.85	3.03	3.13	3.16	4.16	4.58
2.3	1.93	2.12	2.93	3.12	3.22	3.30	4.30	4.73
2.4	2.01	2.22	3.01	3.22	3.32	3.44	4.44	4.89
2.5	2.10	2.31	3.10	3.31	3.41	3.59	4.59	5.04
2.6	2.18	2.40	3.18	3.40	3.50	3.73	4.73	5.20
2.7	2.27	2.49	3.27	3.49	3.59	3.88	4.88	5.36
2.8	2.35	2.58	3.35	3.58	3.68	4.02	5.02	5.52
2.9	2.43	2.68	3.43	3.68	3.78	4.17	5.17	5.69
3.0	2.52	2.77	3.52	3.77	3.87	4.32	5.32	5.85
3.1	2.60	2.86	3.60	3.86	3.96	4.47	5.47	6.02
3.2	2.68	2.95	3.68	3.95	4.05	4.63	5.63	6.19
3.3	2.77	3.04	3.77	4.04	4.14	4.78	5.78	6.36
3.4	2.85	3.14	3.85	4.14	4.24	4.94	5.94	6.53
3.5	2.94	3.23	3.94	4.23	4.33	5.09	6.09	6.70

Voltage in kilovolts phase-to-phase[1,2,3]	Distance to employee[4]					
	Phase-to-ground			Phase-to-Phase		
	(m)	(ft–in)		(m)	(ft-in)	
0 to 0.050	Not specified			Not specified		
0.051 to 0.300	Avoid contact			Avoid contact		
0.301 to 0.750	0.32	1 - 1		0.32	1 – 1	
0.751 to 15	0.64	2 – 2		0.67	2 - 3	
15.1 to 36.0	0.73	2 - 5		0.84	2 - 10	
36.1 to 46.0	0.79	2 - 7		0.94	3 - 1	
46.1 to 72.5	0.89	3 – 0		1.15	3 - 9	

Voltage in kilovolts phase-to-phase	Distance to employee from energized part[4,5,6,10]					
	Without tools phase-to-ground		With tools phase-to-ground[7,9]		Without tools phase-to-phase[8]	
	(m)	(ft-in)	(m)	(ft-in)	(m)	(ft-in)
72.6 to 121	0.94	3 – 1	1.01	3 – 4	1.37	4 – 7
121.1 to 145	1.07	3 – 7	1.15	3 – 10	1.62	5 – 4
145.1 to 169	1.20	3 – 11	1.29	4 – 3	1.88	6 – 3
169.1 to 242	1.58	5 – 3	1.71	5 – 8	2.77	9 – 2
242.1 to 362	2.56	8 – 5	2.75	9 – 1	4.32	14 – 3
362.1 to 550	3.38	11 – 1	3.61	11 – 11	6.01	19 – 9
550.1 to 800	4.54	14 - 11	4.82	15 - 10	8.87	29 - 2

MAD
NEW TERMINOLOGY

Without tools phase-to-ground	With tools phase-to-ground	Without tools phase-to-phase

Voltage in kilovolts phase-to-phase	Distance to employee from energized part[4,5,6,10]					
	Without tools phase-to-ground		With tools phase-to-ground[7,9]		Without tools phase-to-phase[8]	
	(m)	(ft-in)	(m)	(ft-in)	(m)	(ft-in)
72.6 to 121	0.94	3 – 1	1.01	3 – 4	1.37	4 – 7
121.1 to 145	1.07	3 – 7	1.15	3 – 10	1.62	5 – 4
145.1 to 169	1.20	3 – 11	1.29	4 – 3	1.88	6 – 3
169.1 to 242	1.58	5 – 3	1.71	5 – 8	2.77	9 – 2
242.1 to 362	2.56	8 – 5	2.75	9 – 1	4.32	14 – 3
362.1 to 550	3.38	11 – 1	3.61	11 – 11	6.01	19 – 9
550.1 to 800	4.54	14 - 11	4.82	15 - 10	8.87	29 - 2

MAD
NEW TERMINOLOGY

How MAD is affected

Voltage in kilovolts phase-to-phase	Without tools phase-to-ground	With tools phase-to-ground
230 kV	5 – 3	5 – 8
345 kV	8 – 5	9 – 1
500 kV	11 – 1	11 - 11

NESC 2012
MINIMUM APPROASCH DISTANCE PROPOSAL

SIGNIFICANT NEW FOOTNOTES

- Distances for live-line tools in the air gap were calculated by adding a tool factor to the electrical component (IEEE 516 *C*2 1.1 tool factor).
- Phase-to-phase live-line tool in the air gap values are not available. If this situation exists, an engineering evaluation should be performed.
- *With tools* means a live-line tool bridging the air gap to the employee from the energized part.

MINIMUM APPROACH DISTANCES

WHAT'S IN THE FUTURE

- **OSHA 1926 Subpart V and 1910.269**

  MAD tables are incorrect
- **OSHA re-opened rulemaking record to specifically address MAD**
- **NESC not completed when record closed - IEEE 516 was**
- **OSHA should adopt 516 concepts and distances**
- **IEEE and IEC being revised**

QUESTIONS

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