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UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Utilities Service

RUS BULLETIN 1724E-151
RD-GD-2016-80

SUBJECT: **Mechanical Loading on Wooden Distribution Crossarms**

TO: RUS Electric Borrowers and RUS Electric Staff

EFFECTIVE DATE: Date of Approval

OFFICE OF PRIMARY INTEREST: Distribution Branch, Electric Staff Division

FILING INSTRUCTIONS: This bulletin replaces RUS Bulletin 1724E-151, "Mechanical Loading on Wooden Distribution Crossarms," issued November 21, 2002.

AVAILABILITY: This bulletin is available on the Rural Utilities Service website at http://www.usda.gov/rus/electric.

PURPOSE: To furnish design information needed to determine the permitted mechanical loading on wood distribution crossarms and crossarm assemblies.

fo Christopher A. McLean,
Assistant Administrator,
Electric Program

2/23/16
Date

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ABBREVIATIONS

ACSR	Aluminum conductor, steel reinforced
ANSI	American National Standards Institute
AWG	American Wire Gage
CFR	Code of Federal Regulations
IEEE	Institute of Electrical and Electronics Engineers
NESC	National Electrical Safety Code
RUS	Rural Utilities Service

1 PURPOSE

This bulletin presents equations, data and other information needed to determine the vertical and unbalanced longitudinal loads on wood distribution crossarms and assemblies. Sample solved problems that calculate the permitted loading on Rural Utilities Service (RUS) standard deadend crossarm assemblies are presented to help the reader understand and apply the equations and information presented within this bulletin. Exhibit A on page 15 of this bulletin is a table of ice and wind loading data for the most commonly used distribution line conductors.

National Electrical Safety Code: This bulletin references rules and presents selected data contained in the 2012 Edition of the National Electrical Safety Code (NESC). At the time this bulletin was written, the 2012 Edition was the latest edition of the NESC. Periodically the NESC is updated and revised. Users of this bulletin should use the rules and data, as may be revised and renumbered, from the most recent edition of the NESC. Copies of the NESC may be obtained from the Institute of Electrical and Electronics Engineers, Inc., (IEEE) at the following address:

IEEE Customer Service
445 Hoes Lane, P.O. Box 1331
Piscataway, NJ 08855-1331
Telephone: 1-800-678-IEEE (1-800-678-4333)

Throughout this bulletin, references to the NESC pertain specifically to the 2012 Edition of the National Electrical Safety Code.

2 GENERAL INFORMATION REGARDING CROSSARMS

a References to RUS Standard Crossarm Assemblies: Within the text of this bulletin are references to standard RUS distribution construction assemblies such as “VC5.21.” These assemblies are contained in RUS Bulletin 1728F-803 (D-803), “Specifications and Drawings for 24.9/14.4 kV Line Construction.” Crossarm dimensions, attachment spacing, and strength calculations pertaining to the example 24.9/14.4 kV assemblies are equally applicable to the corresponding RUS standard 12.47/7.2 kV crossarm assemblies.

b Crossarm Dimensions: A standard RUS wood distribution crossarm is 4-5/8 inches in the vertical (*v*) direction and 3-5/8 inches in the horizontal (*h*) direction. Since the manufacturing tolerances of crossarms are plus or minus 1/8 inch, the dimensions used for strength calculations in this bulletin are 4 ½ inches by 3 ½ inches. For further information reference RUS construction specifications (1728F-803 and 1728F-802) for drawing W1.2G which depicts standard dimensions and drilling guides for wood crossarms.

c Crossarm Installations: All RUS standard crossarms and crossarm assemblies are attached to the pole at the center of the crossarm or crossarm assembly. RUS standard crossarm assemblies are symmetrical on each side of the pole.

d Loads Applied to Crossarms: Loading on crossarms is the sum of the following forces when applicable: conductor tensions, weight of conductors and ice, and the force of the wind on conductors and the crossarm. NESC Rule 261D2a(1) states: "Crossarms and braces shall be designed to withstand the loads in Rule 252, multiplied by the load factors in Table 253-1 without exceeding their permitted stress." In order to determine the permitted stress, NESC Rule 261D2a(2) states: "The permitted stress level of solid sawn or laminated wood crossarms and braces shall be determined by multiplying their ultimate fiber stress by the strength factors in Table 261-1".

e Unbalanced Longitudinal Loading: Unbalanced longitudinal crossarm loading is the difference in loading from the front to the back of a crossarm. For example, as shown in Diagram 2.5, unbalanced loading is the difference between the loads $L_{1\text{-in}}$ and $L_{1\text{-out}}$. Unbalanced loading pertains to "double deadend" crossarm assemblies as shown in Diagram 2.5 and to "single deadend" assemblies as would be the case if $L_{1\text{-out}}$ and $L_{2\text{-out}}$ (and $L_{3\text{-out}}$) were omitted in Diagram 2.5. Conductors attached to the center of a crossarm assembly, (e.g., $L_{3\text{-out}}$) do not contribute to longitudinal or vertical loading on the crossarm(s) but do contribute to loading on the pole. RUS assumes that in the design and construction of distribution lines that the side-to-side loading on crossarm assemblies is balanced, for example in Diagram 2.5, $L_{1\text{-in}}$ minus $L_{1\text{-out}}$ equals $L_{2\text{-in}}$ minus $L_{2\text{-out}}$. (Sides mean right or left of the pole when looking down the line parallel to the conductors.)

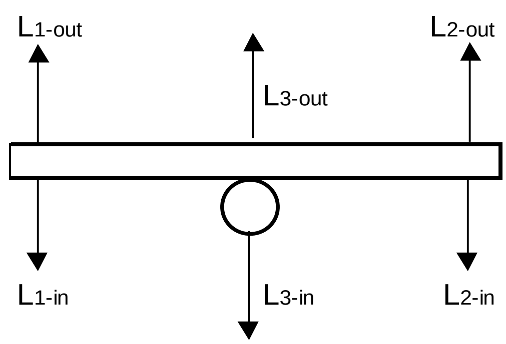

Diagram 2.5

Unbalanced loading can occur when the tensions in the conductors that are attached "into" and "out from" the crossarm assembly are unequal because of: (1) a change in conductor size or type; (2) different installation tensions; (3) unequal ice or wind loading; or, (3) different ruling spans.

f Grades of Construction: In Subpart E of 7 CFR Part 1724, RUS requires overhead distribution line components (poles, guys, etc.,) to be constructed to no less than NESC Grade C strength requirements. NESC Section 24 including Table 242-1 specifies where Grade B must be used in place of Grade C and includes where distribution lines cross over or overhang a railroad track, the traveled way of a limited access highway, or navigable waterways requiring waterway crossing permits. RUS recommends that crossarm assemblies used at deadends on Grade C constructed lines be constructed to meet NESC Grade B strength requirements.

(1) Distribution crossarms on transmission structures may be designed for NESC Grade C, except at angles where they are required to be designed to Grade B. See RUS Bulletin 1724E-200, Section 16 for a more complete discussion of distribution underbuild on transmission structures. Note that for distribution underbuild on transmission structures, the distribution loads are applied to the transmission structures using NESC Grade B load criteria.

3 CROSSARM MOMENT CAPACITIES

a Moment Capacities of Crossarms: The *moment capacity* of a crossarm, M_u, can be expressed as:

$$M_u = (F_b) \times (X) \text{ ft-lbs} \qquad \text{EQ-3.1a}$$

Where:

M_u = the moment capacity of a crossarm
F_b = the designated modulus of rupture for wood crossarms
X = the section modulus of the crossarm

b Section Moduli: The section moduli for resisting longitudinal and vertical loads, X_h and X_v respectively, are:

$$X_h = \frac{(d-a) \times (b^2)}{6} \text{ in}^3 \qquad \text{EQ-3.2a}$$

$$X_v = \frac{(d^3 - a^3) \times (b)}{6d} \text{ in}^3 \qquad \text{EQ-3.2b}$$

Where:

b = width (horizontal dimension) of the crossarm (= 3 ½ inches)
d = depth (vertical dimension) of the crossarm (= 4 ½ inches)
a = diameter of the crossarm mounting bolt hole (= $^{11}/_{16}$ inches)

Substituting the values given for d, a, and b into equations EQ-3.2a and EQ-3.2b yields the following values for the longitudinal and vertical section moduli for a RUS standard wood crossarm:

X_h = 7.784 in^3
X_v = 11.770 in^3

c Longitudinal and Vertical Crossarm Moment Capacities: The following longitudinal and vertical moment capacities, M_h and M_v, for single distribution crossarms are calculated by multiplying the section moduli, X_h and X_v, by the designated modulus of rupture for wood. The modulus of rupture for wood needs to be determined for the species of wood utilized in the crossarm construction. For the purpose of this bulletin, the modulus of rupture for wood is assumed to be 7,800 lbs/in^2. Thus,

$$M_h = (7.784 \text{ in}^3) \times (7{,}800 \text{ lbs/in}^2) = 60{,}715 \text{ in-lbs} = 5{,}060 \text{ ft-lbs}$$

$$M_v = (11.770 \text{ in}^3) \times (7{,}800 \text{ lbs/in}^2) = 91{,}806 \text{ in-lbs} = 7{,}650 \text{ ft-lbs}$$

4 VERTICAL LOADING ON CROSSARM ASSEMBLIES

a Assumptions: Rule 261D5b of the NESC specifies that "crossarms shall be supported by bracing, if necessary, to support expected loads, including line personnel working on them." RUS assumes that a lineworker and equipment may apply a weight of 250 pounds, 2 feet from the center of the pole. *(Note: Standard construction practices and RUS discourage lineworkers from standing on crossarms.)* For calculation purposes, RUS applies a load factor (F_{LF}) of 2.0 to the weight that might be caused by a lineworker. Thus, the vertical load moment due to the lineworker multiplied by the assumed load factor is 1,000 foot-pounds (2 feet x 250 pounds x 2.0).

(1) Crossarm braces are primarily installed to stabilize the horizontal position of crossarms. RUS does not factor in any additional strength due to crossarm braces in its calculations. Furthermore, RUS ignores the weight of crossarms, pins, insulators and connectors in its calculations.

(2) RUS assumes that a conductor's longitudinal (tension) load does not contribute any vertical load to a crossarm assembly. This assumption is correct only if the conductor is perfectly horizontal. However, because of sag, nearly horizontal conductor tensions do exert small vertical loads on crossarm assemblies at the points of attachment. Since this additional vertical load cannot be precisely determined and is small compared with the vertical loading of the conductors and ice, it is ignored.

(3) Within this bulletin, RUS assumes that the distribution line sections adjacent to the assembly under consideration have level spans (i.e., the conductor attachments are at the same altitude).

b Applied Vertical Loads Equated to Crossarm Assembly Capacity: The NESC requires that the sum of each vertical load attached to a crossarm assembly, multiplied by the load's appropriate NESC vertical load factor and the load's distance to the center of the crossarm assembly, not exceed the permitted vertical moment capacity of the crossarm assembly. Mathematically, this statement is written:

$$\sum\left(S_i \times W_i \times D_j \times F_{LF}\right) + 1{,}000 \le N \times M_v \times F_s \quad \text{(ft-lbs)} \qquad \text{EQ-4.2a}$$

Where:

S_i = ½ of the span length of the conductor "into" plus ½ of the span length of the conductor "out from" the crossarm assembly (ft) ("*i*", the number of conductors, ranges from 1 to 4 for either side [half] of the crossarm) (ft)

W_i = unit weight of the conductor (or unit weight of conductor plus wind and ice loading, if applicable) "into" or "out from" the crossarms (lb/ft)

D_j = distance of load "L_i" from center of the crossarm(s) (ft) ("*j*", the number
of load attachment points, is 1 to 2 for either side [half] of the crossarm) (ft)

F_{LF} = NESC vertical load factor (Table 253-1 of the NESC)
= 1.90 for Grade C construction or 1.50 for Grade B construction

1,000 = vertical load moment times load factor attributed to the weight of a lineworker and equipment (ft-lbs) (See Paragraph 4.1 of this bulletin.)

N = number of crossarms (N equals 1, 2 or 3)

M_v = vertical moment capacity (= 7,650 ft-lbs) (See Paragraph 3.3 of this bulletin.)

F_s = NESC strength factor (Table 261-1 of the NESC)
= 0.85 for Grade C construction or 0.65 for Grade B construction

W_i for conductors with applicable NESC wind and ice loading, for each NESC loading district, can be found in Exhibit A on page 15 of this bulletin.

(1) All of the conductor spans "into" a crossarm assembly have the same length and all of the conductor spans "out of" a crossarm assembly have the same length. For purposes of this bulletin, when performing vertical loading calculations, the total length of ½ of the conductor span length "into" the assembly (S_{in}), plus ½ of the conductor span length "out from" the assembly (S_{out}) is called a "**weight span**" because the assembly bears the conductor weight of these two half spans.

(2) Standard RUS distribution crossarm assemblies have a maximum of 2 conductor attachment locations (D_j, where j = 1 or 2) on either side of the pole. Each attachment location has a maximum of 2 attached conductors; one "into" the crossarm and the other "out from" the crossarm as shown in

Diagram 4.2 below. Thus, standard RUS distribution crossarm assemblies have a maximum of 4 conductors (i = 1, 2 or 4) attached to the crossarm on either side of the pole.

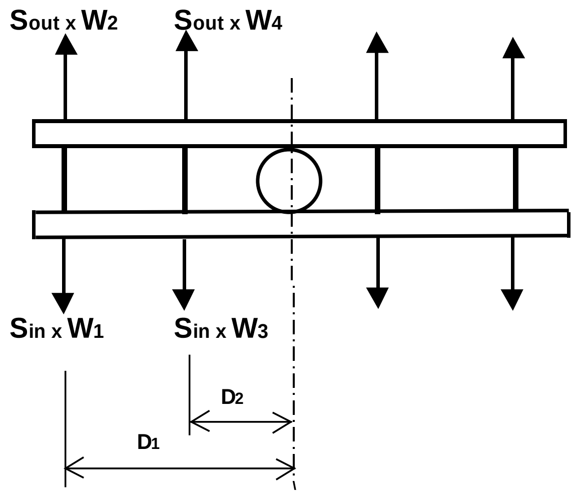

Diagram 4.2

(3) The induced vertical moments of a lineworker, conductors, and wind and ice loads (when applicable) on one side of a standard RUS distribution crossarm assembly equated to its permitted vertical moment is expressed as:

$$\sum \left(S_i \times W_i \times D_j \times F_{LF}\right) + 1{,}000 \leq N \times M_v \times F_s \ =$$

$$D_1 \times \left[\left(S_{in} \times W_1\right) + \left(S_{out} \times W_2\right)\right] \times F_{LF} + D_2 \times \left[\left(S_{in} \times W_3\right) + \left(S_{out} \times W_4\right)\right] \times F_{LF} + 1{,}000 \leq N \times M_v \times F_s \qquad \text{EQ-4.2b}$$

The right-hand side of the equation (N x M_v x F_s) is defined as an assembly's "*permitted vertical load moment.*" The units for both sides of the equation are "ft-lbs."

c Vertical Loads on RUS Standard Tangent and Small Angle Crossarm Assemblies: The conductors on RUS standard tangent and small angle crossarm assemblies are attached to the crossarms with crossarm pins and insulators or post type insulators. Each side (half) of the crossarm assembly may support 1 or 2 conductors that "feed through," or literally, feed over the assembly. Thus, the conductors into and out from the assembly are the same type and size and, as shown in Diagram 4.2, $W_1 = W_2$ and $W_3 = W_4$

(1) After substituting the values for W_i that are equal (i equals 1 through 4) and rearranging the terms, equation EQ-4.2b in Paragraph 4.2.3 of this bulletin, for **"two feedthrough conductors"** on each side of the pole, (e.g., "VC1.41") becomes:

$$D_1 \times W_1 \times (S_{in} + S_{out}) \times F_{LF} + D_2 \times W_3 \times (S_{in} + S_{out}) \times F_{LF} + 1{,}000 \le N \times M_v \times F_s \quad \text{(ft-lbs)} \qquad \text{EQ-4.3a}$$

Where: N = 1 or 2 crossarms (*Only 10-foot crossarms are used on these assemblies*)
D_1 = 4-ft, 8-in (4.666 ft); D_2 = 1-ft, 7-in (1.583 ft)

If both of the conductors are the same size and type, then $W_1 = W_3$ and equation EQ-4.3a simplifies to:

$$W_1 \times (D_1 + D_2) \times (S_{in} + S_{out}) \times F_{LF} + 1{,}000 \le N \times M_v \times F_s \quad \text{(ft-lbs)} \qquad \text{EQ-4.3b}$$

(2) For tangent or small angle assemblies that support **"one feedthrough conductor"** on each side of the pole (e.g., "VC1.11"), $D_2 = 0$ and equation EQ-4.3b simplifies to:

$$D_1 \times W_1 \times (S_{in} + S_{out}) \times F_{LF} + 1{,}000 \le N \times M_v \times F_s \quad \text{(ft-lbs)} \qquad \text{EQ-4.3c}$$

Where: N = 1 or 2 crossarms (*Only 8-foot crossarms are used on these assemblies*)
D_1 = 3-ft, 8-in (3.666 ft)

d Vertical Loads on RUS Standard Single and Double Deadend Crossarm Assemblies: On RUS standard deadend crossarm assemblies the conductors are attached to the crossarms with suspension insulators. Each half of the crossarm assembly (on either side of the pole) may support 1, 2 or 4 conductors "into" or "out from" the assembly.

(1) On double deadend crossarm assemblies, the conductors are attached back-to-back on the crossarms as shown in Diagram 4.2 in Paragraph 4.2.2 of this bulletin. Following is the equation for applied vertical crossarm load moments relative to an assembly's permitted vertical moment capacity for assemblies that support 4 conductors (2 "into" and 2 "out from") on each side of the pole (e.g., "VC6.51"):

$$D_1 \times [(S_{in} \times W_1) + (S_{out} \times W_2)] \times F_{LF} + D_2 \times [(S_{in} \times W_3) + (S_{out} \times W_4)] \times F_{LF} + 1{,}000 \le N \times M_v \times F_s \qquad \text{EQ-4.4a}$$

Where: N = 2 or 3 crossarms (*Only 10-foot crossarms are used on these assemblies.*)
D_1 = 4-ft, 6-in (4.5 ft); D_2 = 1-ft, 9-in (1.75 ft)

The units of measure for each side of the equation are "ft-lbs."

(2) For 1 conductor "into" and 1 conductor "out from" the assembly (back to back) on each side of the pole (e.g., "VC6.21"), $D_2 = 0$ and equation EQ-4.4a is simplified to:

$$D_1 \times \left[\left(S_{in} \times W_1 \right) + \left(S_{out} \times W_2 \right) \right] \times F_{LF} + 1{,}000 \le N \times M_v \times F_s \quad \text{(ft-lbs)} \qquad \text{EQ-4.4b}$$

Where: N = 2 or 3 crossarms (*Only 8-foot crossarms are used on these assemblies.*)
D_1 = 3-ft, 6-in (3.5 ft)

(3) On single deadend crossarm assemblies the conductors deadend in only one direction on the crossarm assembly (see "VC5.21"). Thus, the term (S_{out} x W_2) is omitted from the crossarm vertical load moment equations.

(4) RUS has no standard crossarm single deadend assemblies that only support 2 "in" conductors on each side of the pole. Thus, no equations are offered for this arrangement.

(5) For single deadend assemblies that support 1 conductor into the assembly on each side of the pole (e.g., "VC5.21"), the equation for permitted vertical loading is simply:

$$D_1 \times \left(S_{in} \times W_1 \right) \times F_{LF} + 1{,}000 \le N \times M_v \times F_s \quad \text{(ft-lbs)} \qquad \text{EQ-4.4c}$$

e <u>Example Problem – Permitted Vertical Loading on Crossarms:</u> Determine the maximum "weight span" (S_{in} + S_{out}) for a 3-phase, # 4/0 aluminum conductor, steel reinforced (ACSR) primary distribution line with a # 1/0 ACSR neutral deadending in both directions on the "VC6.51" crossarm assembly shown in Diagram 4.2 in Paragraph 4.2.2 of this bulletin. The structure is installed to NESC Grade C construction requirements in the NESC Heavy Loading District. The following data is found in Exhibit A on page 15, Diagram 4.2 in Paragraph 4.2.2, and in Section 4.2 of this bulletin.

W_1 = 0.9520 lb/ft (# 4/0 ACSR; conductor plus .50 inches of ice)
W_3 = 0.7036 lb/ft (# 1/0 ACSR; conductor plus .50 inches of ice)
N = 2 (10-foot crossarms)
D_1 = 4.50 ft; D_2 = 1.75 ft (deadends on 10-foot crossarms)
F_{LF} = 1.90; F_s = 0.85 (NESC Grade C)
M_v = 7,650 ft-lbs (See Paragraph 3.3 of this bulletin)

The critical vertical loading on this assembly is the half of the assembly that supports the two heavier primary conductors. All of the conductors now under consideration are identical #4/0 ACSR and thus in equation EQ-4.4a in Paragraph 4.4.1 of this bulletin, $W_1 = W_2 = W_3 = W_4$. After setting all of the W_i terms equal to W_1 and rearranging, the equation can be simplified to:

$$\left(D_1 + D_2 \right) \times W_1 \times \left(S_{in} + S_{out} \right) \times F_{LF} + 1{,}000 \le N \times M_v \times F_s \quad \text{(ft-lbs)} \qquad \text{EQ-4.5a}$$

$$\left(S_{in} + S_{out}\right) = \frac{\left(2 \times 7{,}650 \times 0.85\right) - 1{,}000}{\left(4.5 + 1.75\right) \times 0.9520 \times 1.9} = \frac{12{,}005}{11.305} \quad \text{(ft)}$$

$(S_{in} + S_{out})$ = 1,062 ft/ phase

f Remarks Regarding Vertical Loads on Distribution Crossarm Assemblies: For the example problem in Paragraph 4.5 of this bulletin assume that 477 kcmil (Pelican, 18/1) ACSR primary conductors are to be installed to NESC Grade B strength requirements. Thus:

W_1 = 1.3350 lb/ft (conductor plus .50 inches of ice)

F_{LF} = 1.50; F_s = 0.65 (NESC Grade B) and

$$\left(S_{in} + S_{out}\right) = \frac{\left(2 \times 7{,}650 \times 0.65\right) - 1{,}000}{\left(4.5 + 1.75\right) \times 1.3350 \times 1.50} = \frac{8{,}945}{12.516} = 715 \text{ ft/phase}$$

The sum $(S_{in} + S_{out})$ can be thought of as an average total span length “into” and “out from” the assembly.

5 LONGITUDINAL LOADING ON CROSSARM ASSEMBLIES

a Combined Vertical and Longitudinal Loads on Crossarm Assemblies: In Section 4 of this bulletin it was assumed that longitudinal loads did not contribute to the vertical loading on crossarm assemblies. (See Paragraph 4.1.2 of this bulletin.) However, applied vertical loads do have to be considered when determining the permitted longitudinal load of a crossarm assembly. The following relationship needs to be satisfied to avoid overstressing the wood fibers of crossarms:

$$\frac{\sum \textit{Applied Vertical Load Moments}}{\textit{Permitted Vertical Moment (Capacity)}} + \frac{\sum \textit{Applied Longitudinal Load Moments}}{\textit{Permitted Longitudinal Moment (Capacity)}} \leq 1 \quad \text{EQ-5.1a}$$

For RUS standard deadend crossarm assemblies:

$\sum$ *Applied Vertical Load Moments* =

$$D_1 \times \left[\left(S_{in} \times W_1\right) + \left(S_{out} \times W_2\right)\right] \times F_{LF} + D_2 \times \left[\left(S_{in} \times W_3\right) + \left(S_{out} \times W_4\right)\right] \times F_{LF} + 1{,}000 \quad \text{EQ-5.1b}$$

Permitted Vertical Moment of Assembly = $N \times M_v \times F_s$ (ft-lbs)

Permitted Longitudinal Moment of Assembly = $N \times M_h \times F_s$ (ft-lbs)

See Paragraph 4.2 of this bulletin for an explanation of the above equations and definition of the terms. See the various paragraphs of Section 4.4 of this bulletin for simplification of the “applied vertical load moments” equation for specific assembly types. The determination of the "applied longitudinal load moments" is discussed in Section 5.2 of this bulletin.

(1) Example Problem of Combined Vertical and Longitudinal Loads on a Crossarm Assembly: Assume the same conditions as those given for the example problem in Paragraph 4.5 of this bulletin. Also assume a weight span (S_{in} + S_{out}) that equals 300 feet. Thus,

$$\sum \textit{Applied Vertical Load Moments} = (D_1 + D_2) \times W_1 \times (S_{in} + S_{out}) \times F_{LF} + 1{,}000 \text{ ft-lbs}$$

$$= (4.5 + 1.75) \times 0.9520 \times (300) \times 1.9 + 1{,}000 \text{ ft-lbs}$$

$$= 4{,}392 \text{ ft-lbs}$$

$N \times M_v \times F_s$ = 2 x 7,650 x 0.85 = 13,005 ft-lbs

$N \times M_h \times F_s$ = 2 x 5,060 x 0.85 = 8,602 ft-lbs

The *maximum* or *permitted* sum of the "applied longitudinal load moments" (L_{PL}), for the specific given and assumed conditions can be calculated as follows:

$$\frac{4{,}392 \quad ft-lbs}{13{,}005 \quad ft-lbs} + \frac{L_{PL} \quad ft-lbs}{8{,}602 \quad ft-lbs} \leq 1$$

$\sum$ Applied Longitudinal Load Moments = $L_{PL} \leq$ 5,697 ft-lbs

b Applied Longitudinal Loads Equated to Crossarm Assembly Capacity: The sum of each longitudinal load attached to a crossarm assembly, multiplied by its appropriate NESC longitudinal load factor and by its distance to the center of the crossarm assembly, can not exceed the permitted applied longitudinal load moment (L_{PL}) as determined in Paragraphs 5.1 and 5.1.1 of this bulletin. Mathematically, this statement is expressed as follows for RUS standard **double deadend crossarm assemblies that support 2 phases** on each side of the pole. See Diagram 5.2 that follows.

$$[D_1 \times (L_{1-in} - L_{1-out}) + D_2 \times (L_{2-in} - L_{2-out})] \times F_{LF} \leq L_{PL} \quad \text{(ft-lbs)} \qquad \text{EQ-5.2a}$$

Where:

L_i = load (conductor tension) "into" or "out from" the crossarm assembly (ft) (i = 1, 2 or 4: See Paragraph 4.2 of this bulletin)

D_j = distance of load "L_i" from center of the crossarm(s) (ft) ("j" = 1 or 2: See Paragraph 4.2 of this bulletin)

F_{LF} = NESC longitudinal overload factor (Table 253-1 of the NESC)
= 1.30 for Grade C; 1.65 for Grade B: (At Deadends)

L_{PL} = permitted longitudinal moment of all applied loads (Paragraph 5.1.1 of this bulletin)

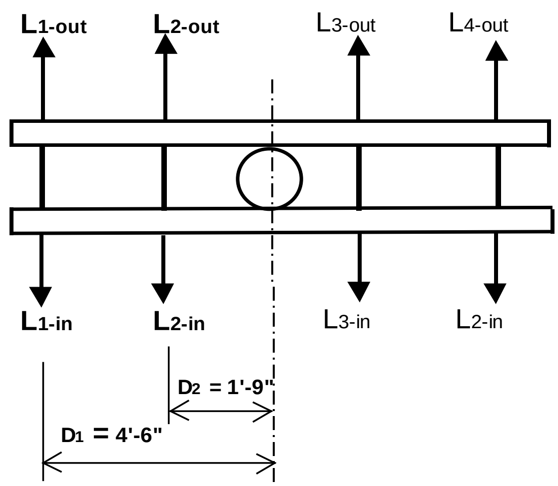

Diagram 5.2

(1) If the two conductors "into" the assembly are at the same tension, and the two conductors "out from" the assembly are at the same tension, (but the "into" and "out" tensions are not the same), then: $L_{1\text{-}in} = L_{2\text{-}in}$, $L_{1\text{-}out} = L_{2\text{-}out}$, and ($L_{1\text{-}in}$ - $L_{1\text{-}out}$) equals ($L_{2\text{-}in}$ - $L_{2\text{-}out}$). Equation EQ-5.2a in Paragraph 5.2 of this bulletin can be rewritten and rearranged as:

$$\left[(D_1 + D_2) \times (L_{1-in} - L_{1-out})\right] \times F_{LF} \leq L_{PL} \quad \text{(ft-lbs)} \qquad \text{EQ-5.2b}$$

(2) For one conductor "into" and 1 conductor "out from" the assembly (back to back), on each side of the pole (e.g., "VC6.21"), $D_2 = 0$ and equation EQ-5.2b is simplified to:

$$\left[D_1 \times (L_{1-in} - L_{1-out})\right] \times F_{LF} \leq L_{PL} \quad \text{(ft-lbs)} \qquad \text{EQ-5.2c}$$

Where: N = 2 or 3 crossarms (*Only 8-foot crossarms are used on these assemblies.*)

D_1 = 3-ft, 6-in (3.5 ft);

(3) RUS has no standard, single deadend crossarm assemblies that only support two "in" conductors on each side of the pole. Thus, no equations are offered for this arrangement.

(4) Single deadend crossarm assemblies have no conductors "out from" the assemblies and so the term "$L_{x\text{-}out}$" is set to 0. Equation EQ-5.2b in Paragraph 5.2.1 of this bulletin simplifies to:

$$D_1 \times L_{1-in} \times F_{LF} \leq L_{PL} \quad \text{(ft-lbs)} \qquad \text{EQ-5.2d}$$

Where: N = 2 or 3 crossarms (*Only 8-foot crossarms are used on these assemblies.*)

D_1 = 3-ft, 6-in (3.5 ft); (D_2 = 0)

c <u>Example Problem – Unbalanced Longitudinal Loads on a Single Deadend:</u> Determine the permitted unbalanced load of a 280 foot span, 3-phase, #2/0 ACSR distribution line that deadends on a "VC5.21" (2 crossarm) assembly in the NESC Medium Loading District for NESC Grade C construction. Exhibit A on page 15 of this bulletin lists unit weight (W_1) of this conductor plus the NESC wind and ice loading as 0.3998 lbs/ft. By combining equations EQ-4.4c and EQ-5.1a from Paragraphs 4.4.2.2 and 5.1 of this bulletin, respectively, the problem can be solved as follows:

$$\frac{D_1 \times (S_{in} \times W_1) \times F_{LF} + 1{,}000}{N \times M_v \times F_s} + \frac{L_{PL}}{N \times M_h \times F_s} \le 1$$

$$\frac{3.5 \times (140 \times .3998) \times 1.9 + 1{,}000}{2 \times 7{,}650 \times .85} + \frac{L_{PL}}{2 \times 5{,}060 \times .85} \le 1$$

$$\frac{1{,}372}{13{,}005} + \frac{L_{PL}}{8602} \le 1 \quad \text{and thus: } L_{PL} = 7{,}695 \text{ ft-lbs}$$

$$D_1 \times L_{1-in} \times F_{LF} \le L_{PL}$$

$$3.5 \times L_{1-in} \times 1.30 \le 7{,}695$$

$$L_{1-in} \le 1{,}691 \text{ lbs}$$

d <u>Example Problem – Unbalanced Multiple Longitudinal Loads:</u> Calculate the permitted unbalanced longitudinal loads per phase for the double deadend "VC6.51" assembly as shown in Diagram 5.2 in Paragraph 5.2 of this bulletin. Assume NESC Heavy Loading District and Grade B construction. The following information is given:

- All of the conductors into the assembly are #4/0 ACSR (W_1 = .9520 lb/ft) and are installed at the same tension. The span length into the assembly is 240 feet.
- All of the conductors out from the assembly are #1/0 ACSR (W_2 = .7036 lb/ft) and are installed at the same tension. The span length out from the assembly is 260 feet.
- NESC Grade B construction: F_S = 0.65; F_{LF} = 1.50 (vertical loads); F_{LF} = 1.65 (longitudinal loads at deadends).

The sum or the terms for determining all of the applied vertical load moments is given in equation EQ-4.2b in Paragraph 4.2.3 of this bulletin as:

$$D_1 \times [(S_{in} \times W_1) + (S_{out} \times W_2)] \times F_{LF} + D_2 \times [(S_{in} \times W_3) + (S_{out} \times W_4)] \times F_{LF} + 1{,}000 \text{ (ft-lbs)} \qquad \text{EQ-5.4a}$$

Since all of the "in" conductors are the same, $W_1 = W_3$; and since all of the "out" conductors are the same, $W_2 = W_4$. After substitution and rearranging, the sum of the terms of equation EQ-5.4a can be rewritten as:

$$(D_1 + D_2) \times [(S_{1n} \times W_1) + (S_{out} \times W_2)] \times F_{LF} + 1{,}000 \text{ (ft-lbs)} \qquad \text{EQ-5.4b}$$

Substituting the values given in this example problem yields:

$$(4.5 + 1.75) \times [(120 \times .9520) + (130 \times .7036)] \times 1.50 + 1{,}000 = 2{,}929 \text{ ft-lbs}$$

The *maximum* or *permitted* sum of the "applied longitudinal load moments" (L_{PL}), for the specific conditions given is as follows: (See Paragraph 3.3 of this bulletin for the values of the moment capacities M_v and M_h.)

$$\frac{2{,}929}{N \times M_v \times F_s} + \frac{L_{PL}}{N \times M_h \times F_s} \le 1$$

$$\frac{2{,}929}{2 \times 7{,}650 \times .65} + \frac{L_{PL}}{2 \times 5{,}060 \times .65} \le 1$$

$$\frac{2{,}929}{9{,}945} + \frac{L_{PL}}{6{,}578} \le 1$$

$$L_{PL} \le 4{,}641 \text{ ft-lbs}$$

The permitted longitudinal loads are calculated using equation EQ-5.2b given in Paragraph 5.2.1 of this bulletin as follows:

$$[(D_1 + D_2) \times (L_{1-in} - L_{1-out})] \times F_{LF} \le L_{PL} \text{ (ft-lbs)}$$

$$(L_{1-in} - L_{1-out}) \le \frac{L_{PL}}{(D_1 + D_2) \times F_{LF}} \text{ lbs}$$

$$(L_{1-in} - L_{1-out}) \le \frac{4{,}641}{(4.5 + 1.75) \times 1.65} \text{ lbs}$$

$(L_{1\text{-}in} - L_{1\text{-}out}) \le$ 450 lbs (*for each of the 2 pairs of phase conductors*)

EXHIBIT A

NESC DISTRICT ICE AND WIND LOADS FOR CONDUCTORS

Vertical Loads – lbs / ft

Conductor			NESC Loading District		
Name	**Size***	**Strand**	**Light**	**Medium**	**Heavy**
ACSR CONDUCTORS					
Swante	4	7/1	0.0670	0.2247	0.5379
Sparrow	2	6/1	0.0913	0.2673	0.5989
Sparate	2	7/1	0.1067	0.2855	0.6199
Raven	1/0	6/1	0.1452	0.3467	0.7036
Quail	2/0	6/1	0.1831	0.3998	0.7719
Pigeon	3/0	6/1	0.2309	0.4647	0.8539
Penguin	4/0	6/1	0.2911	0.5439	0.9520
Waxwing	266.8	18/1	0.2894	0.5565	0.9789
Partridge	266.8	26/7	0.3673	0.6446	1.0774
Merlin	336.4	18/1	0.3653	0.6557	1.1015
Linnet	336.4	26/7	0.4630	0.7649	1.2222
Pelican	477.0	18/1	0.5180	0.8488	1.3350
Hawk	477.0	26/7	0.6570	1.0015	1.5014
Osprey	556.5	18/1	0.6040	0.9550	1.4614
Dove	556.5	26/7	0.7660	1.1319	1.6533
Kingbird	636.0	18/1	0.6910	1.0610	1.5864
Grosbeak	636.0	26/7	0.8750	1.2605	1.8014
Drake	795.0	26/7	1.0940	1.5162	2.0938
Tern	795.0	45/7	0.8960	1.3042	1.8678
6201 ALUMINUM ALLOY CONDUCTORS					
Azusa	123.3	7	0.1157	0.3172	0.6741
Anaheim	155.4	7	0.1459	0.3626	0.7347
Amherst	195.7	7	0.1837	0.4175	0.8067
Alliance	246.9	7	0.2318	0.4846	0.8927
Butte	312.8	19	0.2936	0.5709	1.0037
Canton	394.5	19	0.3703	0.6722	1.1295
Darien	559.5	19	0.5252	0.8697	1.3696
Elgin	652.4	19	0.6124	0.9783	1.4997
Flint	740.8	37	0.6954	1.0812	1.6225
Greely	927.2	37	0.8704	1.2926	1.8702
Light Loading District: *0.00 in. ice; 9 lbs. Wind*					
Medium Loading District: *0.25 in. ice; 4 lbs. Wind*					
Heavy Loading District: *0.50 in. ice; 4 lbs. wind*					

* Conductor size: AWG or kcmil

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EXHIBIT B

CONTRIBUTORS

The members of the Overhead Distribution Lines Subcommittee of the National Rural Electric Cooperative Association, Transmission and Distribution Engineering Committee provided invaluable assistance in preparing this document:

- Robby Hamlin, CoServ Electric, Corinth, TX
- Chad Kirkpatrick, Fort Loudoun Electric Cooperative, Vonore, TN
- Kevin Mara, GDS Associates, Inc., Marietta, GA
- Ernest Neubauer, Southern Rivers Energy, Barnesville, GA
- Matthew O'Shea, STAR Energy Services, LLC, Alexandria, MN
- Ken Raming, Ozark Electric Cooperative, Mt. Vernon, MO
- Terry Rosenthal, Laclede Electric Cooperative, Lebanon, MO
- Hank Zarandi, Northern Virginia Electric Cooperative, Gainesville, VA
- Robert Harris, NRECA, Arlington, VA
- Rob Hall, Southern Rivers Energy, Barnesville, GA
- Stan Moore, Fisher and Arnold, Inc., Memphis, TN
- Kevin Jordan, Horry Electric Cooperative, Conway, SC
- Wilson Johnson, Rural Utilities Service, USDA, Washington, DC

EXHIBIT C

METRIC CONVERSION FACTORS

To Convert From	To	Multiply by
Foot (ft.)	Meter (m)	0.3048
Ft2	M2	0.092903
Inch (in)	Centimeter (cm)	2.54
In^2	Cm^2	6.452
Degrees Fahrenheit (X°F)	Degrees Celsius (°C)	5/9 (X° - 32)
Pound (lb)	Kilogram (kg)	0.45359
Foot-pound (ft-lb)	Newton-meter (n-m)	1.355818