SECTION 4

CONDUCTORS

CONDUCTOR

Primary (13 KV): - All Conductors are all aluminum (AAC) and the standard sizes are 2/0, 4/0 and 477; 2/0 will be used primarily for single-phase lines and short two or three phase taps. 477 will be used for main feeders near substations and 4/0 will be used for most all other three-phase lines.

Neutral: - 2/0 AAC shall be used as a neutral for all primary conductor sizes. One 2/0 AAC neutral is also sufficient for double circuit structures. For structures carrying more than two circuits a 4/0 AAC neutral conductor may be required.

Secondary: - The standard secondary conductors are 2/0 and 4/0 AAC bare. The 2/0 is used for transformer sizes up to and including 37.5 KVA, and 4/0 for transformer sizes over 37.5 KVA.

Secondary Leads: - Insulated 4/0 AAC will be used for all transformers secondary leads – more than one lead per wire is required for the larger transformers, see page 10-2.

Primary Leads: - #4 Solid Cu covered tap wire will be used for all transformer (HV) leads.

Ground Wire: - #4SDBC (soft drawn bare copper) will be used for all ground coils, transformer and structure grounding.

Service Cable (Triplex): - The standard sizes are #2 AAC, 2/0 AAC and 4/0 AAC.

Service Cable (Quadruplex): - The standard sizes are 2/0 AAC and 4/0 AAC.

CONDUCTOR PROPERTIES

WIRE: - A slender rod of drawn metal.

CONDUCTOR: - A wire or combination of wires, not insulated from one another, for carrying electrical current.

CABLE: - A stranded conductor or a combination of conductors insulated from one another.

STRAND: - One of the wires or groups of wires of a strand conductor.

CONCENTRIC STRAND: - A strand composed of a central core surrounded by one or more layers or helically laid wires.

CENTRIC-LAY CONDUCTOR: - A single conductor composed of a central core surrounded by one or more layers of helically laid wires or groups of wires.

WIRE SIZE: - The most commonly used gauge for electrical wires in North America is the American Wire Gauge (AWG). The most commonly used for steel wires is the Birmingham Wire Gauge (BWG).

AWG SIZES: - The electrical conductor sizes most commonly used are from #4/0 (largest) to #12.

MIL: - Is a term employed to measure wire diameters (1 mil is equal to one thousandth of an inch).

CIRCULAR MIL: - Is a term used to define cross-sectional area (one circular mil of area equals the area of a circle one mile in diameter). One circular mil has an area equal to 0.7854 square mils.

CONDUCTOR SIZE CONVERSION:

CIRCULAR MIL = Conductor Area (Square inch) times, 1,273,200
= Conductor Area (Square Millimeter) times 1,973.5

Circular mil designation normally thousands of circular mils (kcmil, previously MCM).

kcmil = 1273.2 Conductor Area (in^2)

= 1.9735 Conductor Area (mm^2)

<u>**Triplex and Quadruplex Service Cable**</u>

1. Triplex and quadruplex service cables typically consist of two or three insulated concentrically stranded conductors with a bare neutral messenger. However, cables with insulated neutrals may also exist within our system.

2. Terminate cables with PREFORMED DEADEND GRIPS specifically designed for the type of neutral conductor.

3. Our present cables have bare AAC or AAAC neutrals. Cables with insulated neutrals require grips designed for insulated conductors. Do not use grips designed for bare conductors on insulated neutrals.

4. Terminate service cables on spool insulators.

5. All our triplex and quadruplex service cables have full size bare neutrals, except for #2 triplex which has an insulated neutral.

6. It is suggested that the insulation on the triplex and quadruplex conductors be kept as close as possible to the crimpit, to minimize the amount of exposed service conductor.

7. It may also be advisable to add ADDITIONAL INHIBITOR to the crimpit; inhibiting compound has good weathering characteristics and remains intact for long periods, therefore protecting the aluminum conductor. Clean the conductor with wire brushes and apply inhibiting compound (PENETROX A-13, or equivalent) before making connections. Please read pages 4-4 to 4-6 on (a) ALUMINUM CONNECTORS and (b) OXIDES and OXIDE INHIBITING COMPOUNDS.

8. In cases where the service cable is attached below the secondary it is suggested that the service cable conductors be wrapped around the secondary conductor, as shown below, to prevent the ingress of moisture inside the conductor. This is also advisable in areas where the service cable is subjected to wind and movement of the service cable.

9. It is recommended that service drops be installed in accordance with the following sags whenever practical: -

Up to 40’ drop	-	1’0” Sag
40’ to 50’ drop	-	1’6” “
50’ to 60’ drop	-	2’0” “
60’ to 70’ drop	-	3’0” “
70’ to 80’ drop	-	4’0” “

CONNECTIONS: -

All connections must be clean and tight to ensure the least possible resistance. Improperly installed connectors result in high resistance connections, which result in heating and possibly eventual failure. Therefore the proper selection and installation of connectors is of great importance; here at CUC, with the system growth and the magnitude of currents increasing, the installation is becoming more and more critical.

The **CONNECTION OF DISSIMILAR METALS** (i.e. copper & aluminum) must be avoided. However, where it cannot be avoided and is absolutely required it must be done in strict accordance with standards. Copper can be compressed in an aluminum sleeve provided the copper is installed in the bottom of the sleeve. A compression connection (sleeve) provides the only reliable connection between copper and aluminum and at CUC all copper to aluminum connections will be done this way. The crimpit, although professed to be a good copper to aluminum connector, does not provide the durability required in our salt corrosive atmosphere; the crimpit will however be used as our standard aluminum to aluminum connector.

Copper can be compressed in both ends of an aluminum sleeve when the conductors are insulated and the sleeve is covered with tape or heat shrink. All sleeves used for copper conductors must have a solid **CENTER** barrier.

In all copper to aluminum and aluminum to aluminum connections inhibiting compound and cleaning is a must; cleaning is also necessary for copper connections.

In summary: -

1) Select the **RIGHT CONNECTOR** for the conductor(s) being used.

2) **CLEAN THE CONDUCTOR,** jumper pads, spades, connectors etc.

3) Use **INHIBITING COMPOUND**

4) Install with the **PROPER TOOL & DIE** with the recommended number of crimps.

5) Always ensure your tools are working properly and are in adjustment.

6) Remember bolted connectors need to be cleaned as well – particularly those on cutouts, transformers, switches etc.

7) **CHECK** the completed connection.

SPLICES (FULL TENSION SLEEVE)

It should be kept in mind that a splice not only must be mechanically strong but must also carry the full load current of the conductor. Splices do not develop the full strength of the conductors but will develop close to rated strength if; the proper die is used, the correct number of crimps are used, and the tool is in proper adjustment. As with connectors the conductor should be cleaned with a wire brush and an inhibitor used. As with a connector a conductor that is not cleaned may result in an unnecessary resistance, which will cause heating and possibly eventual failure.

ALUMINUM SERVICE CONNECTIONS

1. Always use an aluminum connector for ALUM to ALUM or ALUM to COPPER connections (never use a copper connector on an aluminum conductor).

2. Select the right connector for the wire size you are using.

3. Remove the conductor insulation carefully, try not to nick or damage the wire; strip to the exact length required by the connector (do not over-strip).

4. Wire brush the conductor and/or the stripped portion of insulated conductors; it is of particular importance to clean existing weathered conductors before installing a cablelok crimpit for a service connection (apply inhibiting compound liberally).

5. Apply oxide inhibiting compound (Penetrox) liberally to the conductor to prevent the formation of surface oxides. Inhibitor should be applied as soon as the conductor is cleaned as oxides form very quickly on aluminum (the cleaning on new aluminum conductor scratches off this oxide coating so the connection can be made to the bare aluminum). Some suppliers suggest brushing the conductor with inhibitor to prevent the reforming of the oxide coating.

OXIDES & OXIDE INHIBITING COMPOUNDS

Thin oxide coating form when aluminum and copper is exposed to the atmosphere – this coating develops very quickly in the case of aluminum.

This oxidized coating protects these metals resulting in stability and long life under ordinary atmospheric exposure. However when aluminum is exposed to salt solutions, while in electrical contact with copper, severe galvanic attack of the aluminum occurs.

To provide low contact resistance with these conductors the oxide coating must be removed and oxide inhibiting compounds used to prevent the reforming of these oxide coatings.

There are several oxide inhibiting joint compounds (a) a petroleum based compound with zinc particles for alum to alum and alum to Cu connections but not recommended for rubber or polyethylene insulation (b) a synthetic based compound with zinc particles which is compatible with rubber and polyethylene insulating materials and (c) a synthetic based compound with copper particles for copper to copper applications.

Oxide inhibiting compounds help to produce low initial contact resistance, seals out air and moisture and prevents oxidation and corrosion. The compounds contain metal particles, which assist in penetrating the oxide films, act as a bridge between strands, improves the electrical conductivity, extends the life of the connection and enhances the integrity of the connection.

We have standardized on the synthetic base compound in 8-ounce tubes.

CONDUCTOR TEMPERATURES & AMPACITIES

It is generally recommended that conductor temperatures be limited to 75°C (167°F) for Electrical Conductor (EC) grade aluminum, as this grade of aluminum starts to anneal at about 75°C. Annealing is dependent on temperature and time; therefore conductors can be operated at higher temperatures for short time emergency overload conditions. For our standard feeder conductor sizes of 4/0 & 477 the current carrying capacity at 75°C, using an ambient temperature of 35°C (95°F), is 339 & 563 amperes respectively. However it should not be necessary to operate conductors in excess of 75°C at CUC as 477 MCM will carry the normal load of two feeders without exceeding the recommended temperature limit.

We must however consider the conductor operating temperatures when designing for ground clearances and vertical clearances between conductors. The NESC recommends that we design for a conductor limit of: (a) 50°C (120°F) or (b) the actual operating temperature if over 50°C (120°F).

The current carrying capacities for our standard conductor sizes of 2/0, 4/0 & 477, for an ambient temperature of 35°C (95°F) and a conductor temperature of 50°C (120°F), is 170, 225 & 380 amperes respectively; this results in loads of approximately 3,800, 5,000 & 8,500 kVA. Therefore there should be no need for conductor temperatures in excess of 50°C (120°F) with the exception of areas near the feeder source where particular feeders may be required to carry the load of two feeders for short periods.

For single circuit lines we need to check the clearance between the phase conductors and the neutral. Since the current in the neutral, under balanced feeder conditions, is near zero; the conductor temperature of the neutral will be less than the phase conductors, and therefore will have less sag. Assuming a 2/0 AAC neutral conductor ambient temperature of 35°C (95°F) and a 477 AAC phase conductor temperature of 50°C (120°F), the final sag for a 225 ft span with a 200 ft ruling span will be 3.3 ft for the neutral and 4.7 ft for the phase. If the neutral is attached at 3.0 ft below the X-arm, then the separation between the neutral and the center phase conductor is approximately 2.6 ft, depending on the structure type. Since the neutral on new construction is much lower, there will be more than adequate clearance between the phase and the neutral.

If we use this feeder under emergency conditions, to carry the maximum load of two feeders (each 300 amperes) with a diversity factor of 0.9, the resultant load will be 540 amperes; the conductor temperature would then be about 71°C (160°F) with a final sag of 5.8 ft. The clearance between the neutral and the center phase conductor is now reduced to approximately 1.5 ft at mid span. Still adequate clearance under emergency conditions, however we would be approaching the NESC limit for mid-span clearance for this arrangement. Again, since the neutral on new construction is much lower, there will be more than adequate clearance between the phase and the neutral.

Based upon the above current ratings for 2/0 and 4/0 bare conductors of 170 and 225 amperes respectively, this limits the maximum load to 40.8 and 54.0 kVA, respectively when used for secondary circuits. Thus, for transformers larger than 50 kVA, the maximum load in a run of 4/0 secondary shall be limited to 54 kVA. For example, a fully loaded 100 kVA transformer must be centrally located such that no more than 54 kVA is fed in any one direction from the transformer. Where this is not possible and the load must exceed the 54 kVA limit, the conductor temperature at the maximum load must be determined. The secondary conductor’s maximum sag for the given span length at this new temperature limit can then be determined and spacing between power and communication circuits can be adjusted. Where the existing poles cannot accommodate the increased spacing requirements taller poles will be required.

The following table lists the safe maximum conductor sustained load or continuous current for various conductors. Bare aluminum conductor temperature is limited to 75°C and the bare copper conductor temperature is limited to 85°C with an ambient temperature of 40°C. These values for bare conductors can be increased under emergency conditions for short periods of time, without serious conductor damage (annealing).

The majority of our service cable purchased in the past has a polyethylene insulation with a temperature rating of 75°C and increasing the loading on these insulated conductors may result in damage to the insulation. The 2/0 AAC Quadruplex currently being purchased has an XLPE insulation which is rated at 90°C. It is proposed to have all service cables with XLPE insulation our standard for future purchases.

The values in ( ) represent typical customer service conductor sizes which will be serviced by our standard service cables and the maximum load that could be expected with this service entrance conductor size; the actual load on these service cables will normally be much less than the indicated maximum.

SAFE MAXIMUM CONDUCTOR LOADING

(A) Bare Conductors – Aluminum (40°C ambient, 75°C conductor temp.)

2 AAC …………………………………….. 150 amperes
2/0 AAC …………………………………….. 235 amperes
4/0 AAC …………………………………….. 310 amperes
477 AAC ……………………………………. 520 amperes

(B) Bare Conductors – Copper (40°C ambient, 85°C conductor temp.)

2 copper ………………………………….…... 225 amperes
2/0 copper …………………………………… 350 amperes
4/0 copper …………………………………… 475 amperes

(C) Insulated Conductors[1] – Single installed in free air (40°C ambient, 90°C conductor temp.)

2 copper ……….………………………….... 173 amperes
2/0 copper …………………………………… 274 amperes
4/0 copper …………………………………… 370 amperes
500 copper …………………………………… 639 amperes

(D) Insulated Conductors – Not more than 3 conductors installed in duct (40°C ambient, 90°C conductor temp.)

2 copper …………………………………….. 119 amperes
2/0 copper …………………………………….. 178 amperes
4/0 copper …………………………………….. 237 amperes
500 copper ……………………………………. 393 amperes

(E) Triplex Service Cable - (40°C ambient, 90°C conductor temp.)

2 AAC (2/0 CU – 178 amperes) …………… 150 [120][2] amperes
2/0 AAC (4/0 CU – 237 amperes) …………… 235 [185] amperes
4/0 AAC ……………………………………..... 315 [245] amperes

(F) Quadruplex Service Cable - (40°C ambient, 90°C conductor temp.)

2/0 AAC (250 CU – 264 amperes) …………… 205 amperes
4/0 AAC (350 CU – 319 amperes) …………… 275 [210] amperes

[1] Insulated conductors including triplex and quadruplex cables noted above are rated 600 volts or less.
[2] Ampere readings in square brackets are limits for existing polyethylene insulated conductors rated 75°C.

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DATE: June 26, 2018	**DISTRIBUTION STANDARDS**	
DRAWN: C. Rose		
REV.:	**STANDARD CONDUCTORS**	
DATE:		
	APPROVED BY:	STANDARD NO.
	DATE:	**4-9**

Conductor Tensions

The following table indicates the tensions for our standard conductor sizes, under various loading conditions; #2 AAC is also included as we have many miles of this in service. These tensions were calculated for a ruling span length of 200 ft and should be adequate for most of our distribution lines.

INITIAL TENSIONS (LBS)					RATED TENSILE STRENGTH (LBS)
Conductor Size	**No Load**		**Wind Load**		
			60 MPH	**Hurricane**	
	90°F	**70°F**	**60°F**	**80°F**	
2/0	471	627	851	1240	2510
4/0	713	958	1253	1742	3830
477	1250	1672	2183	2971	8360
2	257	338	484	742	1350

The conductor tensions listed under hurricane wind loading are the tensions that we must design for in our structure guying.

The tensions listed under no load at 90°F are actual tensions that can be expected under normal everyday conditions; the tensions that could be expected under hurricane wind conditions are at least 2.5 times the tensions under normal everyday conditions.

STANDARD DISTRIBUTION CONDUCTORS

COND. SIZE AWG	TYPE	CODE NAME	STRANDING NO. AL.	STRANDING NO. STEEL	STRANDING NO. CU	COND. DIA. BARE (in)	RTS (lb)	WEIGHT (lb/ft)	INSUL. THICK (in)	REMARKS	REEL SIZE (in)	STD. LENGTH (ft)	STOCK NO.	AMPS**
#2*	AAC	IRIS	7			0.292	1350	0.062					210-00001	150
#2/0	AAC	ASTER	7			0.414	2510	0.125					210-00002	235
#4/0	AAC	OXLIP	7			0.522	3830	0.198					210-00003	310
#477	AAC	COSMOS	19			0.792	8360	0.447					210-00004	520
#4	Copper	SDBC			1	0.2043	1213	0.1264		Risers & Grd. Wire		200	983-00010	155
#2*	Copper	600V Insulated			7	0.292		0.234	0.040	Risers		1000	983-00001	173/119***
#2/0	Copper	600V Insulated			19	0.418		0.463	0.050	Risers & Grd. Wire			983-00003	274/178***
#4/0	Copper	600V Insulated			19	0.528		0.719	0.050	Risers			983-00004	370/237***
#500	Copper	600V Insulated			37	0.814		1.652	0.060	U/G Services		500	983-00005	639/393***
#6*	Duplex	Vizsla/XLP	7			0.184		0.068	0.045	AAC with Bare AAAC Mess.			137-00011	85
			7			0.198	1110							
#4*	Duplex	Whippet/XLP	7			0.232		0.103	0.045	AAC with Bare AAAC Mess.			137-00005	115
			7			0.250	1760							
#4*	Duplex	Whippet	7			0.232		0.103	0.045	AAC with Bare AAAC Mess.			137-00016	90
			7			0.250	1760							
#2*	Triplex	CLAM	7			0.292	1350	0.258	0.045	Insulated Mess.				120
#2	Triplex	CLAM/XLP	7			0.292	1350	0.258	0.045	Insulated Mess.			137-00004	150
#2/0*	Triplex	NASSA	7			0.414	2510	0.462	0.060	Bare Mess.				185
#2/0	Triplex	NASSA/XLP	7			0.414	2510	0.462	0.060	Bare Mess.			137-00008	235
#2/0*	Triplex	Dungenese	7					0.483	0.060	AAC with Bare AAAC Mess.			137-00012	185
			7			0.447	5390							
#4/0*	Triplex	Lepas	18					0.728	0.060	AAC with Bare AAAC Mess.				245
			7			0.563	8560							
#4/0	Triplex	Lepas/XLP	18					0.728	0.060	AAC with Bare AAAC Mess.			137-00009	315
			7			0.563	8560							
#2/0	Quadruplex	Thoroughbred/XLP	11					0.639	0.060	AAC Compressed with AAAC Bare Str. Mess.			137-00006	205
			7			0.447	5390							
#4/0*	Quadruplex	Oldenburg	18					0.945	0.060	AAC Compressed with Bare Stranded Mess.				210
			19			0.522	4020							
#4/0*	Quadruplex	Walking	18					0.977	0.060	AAC Compressed with Bare AAAC Str. Mess.				210
			7			0.563	8560							
#4/0	Quadruplex	Walking/XLP	18					0.977	0.060	AAC Compressed with Bare AAAC Str. Mess.			137-00007	275
			7			0.563	8560							
#4	Soft Drawn	Tie Wire	1			0.2043	369	0.0384			12x4	200	983-00007	

* Indicates substandard conductor listed for maintenance purposes.

** Bare AAC conductor temperature of 75°C; ambient temperature of 40°C; 2 ft./sec. wind in sun. Insulated plex conductors based on conductor temperature of 90°C for XLP, 75°C for Poly; ambient temperature of 40°C; emissivity 0.9; 2 ft./sec. wind in sun.

*** Ampacity based on either single conductor in free air or not more than three current carrying conductors in raceway as applicable at 40°C ambient and 90°C conductor. See drawing 4-8 for more detail.

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