Standard – Distribution Stringing Tables

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Author	**Name:** Cameron Atkinson **Position:** Graduate Engineer Engineering and Project Services.		Digitally signed by Cameron Atkinson Date: 2026.08.07 10:19:41 +08'00'
Reviewed By	**Name:** Jaymin Moffatt **Position:** Standards Engineer		Digitally signed by Jaymin Moffatt Date: 2026.08.07 10:25:22 +08'00'
Endorsed By	**Name:** Johnathan Choi **Position:** Standards and Plant Manager		Digitally signed by Johnathan Choi Date: 2026.08.11 15:27:49 +08'00'
Approved By *	**Name:** Victor Cheng **Position:** Senior Manager Engineering and Project Services		Digitally signed by Victor Cheng Date: 2026.08.25 12:46:59 +08'00'
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STAKEHOLDERS *The following positions shall be consulted if an update or review is required:*	
Manager Engineering & Project Services	Asset Managers
Manager Systems & Network Planning	Manager Assets Services
Senior Manager Safety, Health and Wellbeing	Generation

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1. Overview

This document describes the Distribution Overhead Conductor tensioning and sag parameters for use in Horizon Power.

Horizon Power acknowledges the use of Western Power's Manual "Conductor Tensioning for New and Existing Distribution Lines" [10], for the development of this standard being appropriate for Horizon Power's requirements.

1.1 Purpose

The purpose of this document is to provide the Designers, construction and maintenance crews with methods to determine the set of tension, sag and beat tables found in "DCS Part 12 - (T) Stringing Charts" [11], to construct new lines as well as to re-regulate existing lines during maintenance.

1.2 Background

Horizon Power's "Stringing Tables for Aluminium and Steel Conductors for Distribution Lines – October 2011" provided stringing tensions for new conductors that were tensioned on the same day as stringing. Unfortunately, not all conductors are tensioned the day they are strung, i.e. they may be tensioned the next day after stringing or re-tensioned after a fault. Applying new conductor tensions to conductors that have been strung for more than 6 hours will result in over tensioning of the conductor.

1.3 Scope

This document provides guidance on the use of stringing tables for new lines and for lines that have been strung for more than 6 hours. The stringing tables in "DCS Part 12 - (T) Stringing Charts" [11] support the correct tensioning of existing conductors and LV ABC during maintenance work so that conductors and LV ABC are not over-tensioned.

Note: The stringing tables in the DCS were extracted from Western Power's stringing tables and do not cover Horizon Power's full temperature range. They also make use of calculated Modulus of Elasticity values for conductors and not actual values given by manufacturers.

2. Normative References

2.1 Standards

2.1.1 Australian Standards

The following standards are available at http://www.saiglobal.com.

[1]. *AS 1222.1, Steel conductors and stays-Bare overhead-Part 1: Galvanised (SC/GZ),* Standards Australia, 1992 (R2016)

[2]. *AS 1222.2, Steel conductors and stays-Bare overhead-Part 2: Aluminium clad (SC/AC),* Standards Australia, 1992 (R2016)

[3]. *AS 1531, Conductors-Bare overhead-Aluminium and aluminium alloy,* Standards Australia, 1991 (R2016)

[4]. *AS 1746, Conductors-Bare overhead-Hard-drawn copper,* Standards Australia, 1991 (R2016)

[5]. *AS 2848.1, Aluminium and aluminium alloys-Compositions and wrought products,* Standards Australia, 1998 (R2018)

[6]. *AS/NZS 3607, Conductors-Bare overhead-Aluminium and aluminium alloy-Steel reinforced,* Standards Australia, 1989 (R2016)

[7]. *AS/NZS 3822, Test methods for bare overhead conductors,* Standards Australia, 2002 (R2016)

[8]. *AS/NZS 7000, Overhead line design,* Standards Australia, 2016

2.1.2 Other Standards

[9]. *ENA C(b)1 – Guidelines for design and maintenance of overhead distribution and transmission lines, 2006*

[10]. *Western Power's Manual - Conductor Tensioning for New and Existing Distribution Lines, 2014*

[11]. *DCS Part 12 - (T) Stringing Charts*

2.2 Definitions and Abbreviations

For the purposes of this standard, definitions shall apply as in the relevant Australian Standards with the addition of a few general definitions listed below in alphabetical order.

AAC: Aluminium Conductor

AAAC: Aluminium Alloy Conductor

ACSR/AC: Aluminium Conductor, Steel (Aluminium Clad) Reinforced

ACSR/AZ: Aluminium Conductor, Steel (Aluminised) Reinforced

CBL: Calculated Breaking Load

HDBC: Hard Drawn Bare Copper

LV ABC: Low Voltage Aerial Bundled Conductor

SC/AC: Aluminium Clad Steel Conductor

SC/GZ: Galvanised Steel Conductor

ULS: Ultimate Limit State

3. Design

3.1 Methodology

When conductors or LV ABC's are first strung, the tension applied causes the conductor or ABC to elongate. The elongation is caused by plastic deformation of the strands and strand setting. The elongation needs to be allowed for so when the conductor or ABC is in service the designed clearances and tensions are maintained.

For conductors / ABC strung for the first time the conductors or ABC are tensioned above the final tension requirements to compensate for subsequent conductor / ABC elongation. The higher tensioning ensures the final tension is correct. The higher tensioning is referred to as 'temperature compensation'.

The amount the conductor / ABC is tensioned above its final tension is dependent on the type of conductor and the duration that the conductor has been left hanging in the rollers. Higher tensioning is not required for steel conductors as limited conductor elongation takes place.

AS/NZS 7000 [8], Figure 4.2 shows a typical stress / strain curve for a conductor, tested in accordance with Section 6.4 of AS 3822 [7]. As this test is conducted over a 2.5 hour period, Horizon Power believes that the conductor under Ultimate Limit State (ULS) load will continue to operate in the linear operating region and the conductor maximum tension should be limited to 70% CBL.

The above stance can be justified due to the following:

AS/NZS 7000 [8] clause B3 states "*All structures shall be designed for a 3 second gust regional wind speed for the relevant return period wind as defined in AS/NZS 1170.2*".

Western Australia does not experience long term loads such as ice loading on conductors.

All Distribution conductors are suitable for use throughout the Distribution Network i.e. in Regions A through to D with wind pressure up to 1200 Pa (ULS).

Note: 7/2.50 AAC slightly exceeds the 70% CBL limit (74%) in the Outer Urban applications. However this conductor is rarely used in this application and the maximum conductor tension is well below the 90% CBL failure strength limit of the conductor.

This document considers the following three tensioning scenarios:

a) Initial stringing condition for new construction (0 – 6 hrs).

b) Next day initial stringing condition when the conductors have been left hanging in the rollers for a day (6 – 24 hrs).

c) Final conditions when conductor elongation has already taken place. This condition would typically be used for maintenance work on existing lines (24 hrs onwards).

3.2 Site Conditions

ENA C(b)1 - Overhead line design guide [9] and more recently AS/NZS 7000 [8] have traditionally used average season temperatures for determining the loading conditions rather than the extremes of temperature. For example, the Everyday load condition is defined as the loads on the structural system with a conductor temperature equal to the mean of local area temperatures in the coldest month. Similarly, the Sustained load condition is defined as the loads on the structural system with a conductor temperature equal to the mean of the winter season temperatures.

Review of weather data from the Bureau of Meteorology for Western Australia indicates the winter average minimum temperature as being generally above 5°C. Where a measured temperature is determined below this value, advice should be sought on the appropriate tensioning requirements.

3.3 Conductor Tensioning

The percentage tension of the calculated breaking load (CBL) for conductors, varies according to the conductor type and area that the conductor is to be used in. These percentages are the final condition tension that the conductor will experience after the conductor elongation has taken place (after a few years), and are also the tensions the Designer will use for clearance checks. These tensions are based on a 15°C everyday temperature (EDT) and are also the basis that were used to create the tables in “DCS Part 12 - (T) Stringing Charts” [11].

3.3.1 Span Ratios

From a structural loading perspective, the Designer should ensure the following adjacent span ratios are not exceeded when placing poles:

- In urban areas span lengths should not exceed a maximum adjacent span ratio of 2:1 (due to lower conductor tensions applied). For example, where the typical span length is 40 m span, the other spans in the tension section should not be shorter than 20 m.
- In outer urban and rural areas, the maximum adjacent span ratio should be 5:4. For example, where the typical span length is 100 m, the adjacent spans should not be shorter than 80 m.
- In Rural areas where galvanised steel conductor (SC/GZ) or Steel aluminium clad conductor (SC/AC) is used, span lengths should not exceed a maximum adjacent span ratio of 2:1 (due to the low impact a change in temperature has on the horizontal tension in steel conductors).

3.3.2 Strain Sections

Strain sections shall not exceed 1.5 km for AAC and AAAC type conductors and 3 km for SC/AC steel conductor, due to construction constraints. Field experience has proven that longer sections are more difficult to tension correctly due to friction on the rollers.

3.3.3 Tensioning Design

When performing design, the Designer will be expected to use the current Poles'n'Wires line profiling software to determine the conductor clearances and sags.

Designers are to specify the ruling span of each strain section and the distance between each pole, on the design, so the construction staff can use any of the tension methods given.

4. Construction and Maintenance

4.1 On Site Considerations

The preferred method is to place the stem of a stainless-steel dial type thermometer in the core of a section of the same conductor and measure the temperature. Where a conductor thermometer is not available, the ambient temperature is to be measured.

The actual conductor temperature for an energised line requires a contact type thermometer (thermocouple) mounted on an insulated hot stick.

If the measured temperature is between two temperature values on the table, then the lower temperature on the table is to be used.

4.2 Temporary Tensioning of Strain Sections

Temporary ground straining to the base of a pole is not permitted due to the potential loss of tension in the conductors. When a temporary ground strain to the base of a pole is raised to the pole top there is a potential loss of tension in the conductors from:

- The length of the conductor from the adjacent pole top to the pole base at the strain is longer than from pole top to pole top.
- There is slack in the loop of conductor left at the strain point at the base of the pole.
- Conductors on either side of the strain point may be at differing stages of the "bedding in" period.

4.3 Conductor Tensioning Methods

The following tension methods can be used for the construction of new lines as well as for re-regulation of existing lines.

The initial step in the tensioning process is to calculate the ruling span for the strain section. The ruling span is calculated using the following formula:

$$RS = \sqrt{\frac{(S1^3 + S2^3 + S3^3 + \cdots)}{(S1 + S2 + S3 + \cdots)}}$$

where S indicates the relevant spans in the strain section, i.e. from strain to strain structure.

Note: the ruling span is not the average span length.

The temperature of the conductor must then be determined. It is important to note that the temperature of the conductor can differ from that of the ambient temperature. See Section 5 of this document for more details.

For new projects, the design documentation will indicate which conductor must be used and at what percentage CBL the conductor is to be tensioned.

Once this information is known, together with the calculated ruling span and conductor temperature, the construction crew can decide which one of the three methods to use during tensioning.

4.3.1 Using a Dynamometer

The dynamometer is installed in series with the conductor at either end of the strain section. The tension is increased until the desired tension is obtained. The conductors are then tied in. This is the preferred method for bare conductors and shall be used when stringing insulated conductors such as LV ABC.

4.3.2 Using the Beat (Wave) Method

This method relies on the speed at which a mechanical pulse propagates along the conductor and is not suitable for insulated conductors like LV ABC. For accuracy of this method, a span as close as possible to the ruling span within the strain section needs to be selected to measure the time.

The conductor is struck at one end of the span and at the same instance, a stopwatch is started. The pulse will be reflected at the other end of the span back to the striker which is called a wave return. The time for five wave returns is recorded as a beat time.

The tension needs to be adjusted until the recorded beat time matches the relevant beat time in the tables, see the DCS [11].

4.3.3 Using Sag Boards

To implement this method a horizontal sag board is fitted to the structure at each end of the span where the span is as close as possible to the ruling span length.

Using the ruling span and relevant conductor temperature, the required sag needs to be obtained from the tables, see the DCS [11].

The conductor is then tensioned until the lowest point of the sag is in the line of sight between the two sag boards. This method of stringing is not suitable for insulated conductors like LV ABC.

4.4 Conductor Final Make-off

Once the correct tension in the conductor has been achieved the final make-off must be co-ordinated to prevent a drop in tension when the come-along is removed.

This can be achieved by:

- Initially installing the eyebolts at the end of the eyebolt thread.
- Pulling the pre-formed dead-end towards the conductor to remove any slack in the insulator string.

- Keeping the insulator horizontal during the pre-formed dead-end installation.
- Tighten the nut on the eyebolt to remove any slack in the conductor between the come-along and the structure.

Once the slack has been removed, the come-along and dynamometer can be removed.

Note: When using a dynamometer, tightening up the nut on the eyebolt can be ceased as soon as the dynamometer tension starts to drop.

4.5 Slack Span Tensioning

Slack Span conductor to be applied by hand. Such tensions are too small to be measured using the dynamometers currently held by linesmen. The conductor is instead to be pulled "hand tight", which amounts to a maximum 0.5 kN force on the conductor as the maximum weight that is able to be applied on the conductor by hand is some 50 kg.

In summary:

- 0.5 kN conductor tension should be used to check mid-span conductor clashing to cover the worst case scenario.
- 0.5 kN conductor tension should be used to check pole loading as the worst case scenario.

Note: that ground clearance, mid-span conductor clashing, and pole strength needs to be checked to determine the governing factor for any slack span under design.

5. Using Stringing Tables

Using stringing tables is best illustrated using an example as detailed in Figure 1.

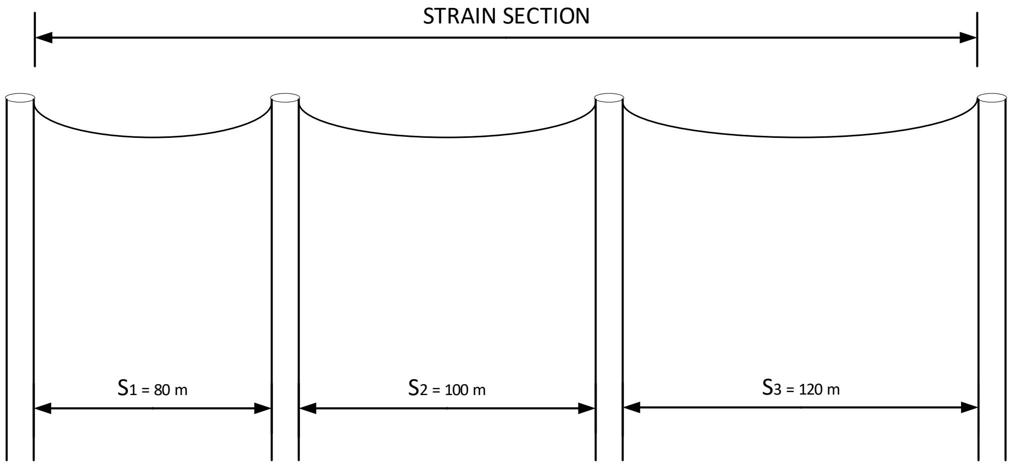

Figure 1: Pole Spacing

Stringing: 19/3.25 AAAC (Krypton)

Pole spacing: as shown in Figure 1

Conductor temperature: 30˚C

5.1 Determine the Ruling Span

The ruling span is required to determine the string tension.

$$RS = \sqrt{\frac{(S1^3 + S2^3 + S3^3 + \cdots)}{(S1 + S2 + S3 + \cdots)}}$$

$$RS = \sqrt{\frac{(80^3 + 120^3 + 100^3 + \cdots)}{(80 + 120 + s100 + \cdots)}}$$

$$RS = 103.9\,m$$

RS (rounded up) = <u>105 m</u>

5.2 New Conductor – Initial Tension

The conductor has not been hanging in the rollers for an extended period of time, i.e.; conductor is to be tensioned within 6 hours since hanging in the rollers.

Using the table T-031-1 in “DCS Part 12 - (T) Stringing Charts” [11] with a ruling span of 105 m (rounded to the next higher value in the table) and a temperature of 30˚C found in the “*New Conductor (Initial)”* row, the required stringing tension, the time for five wave returns for the beat method, and the sag values can be read in the 30˚C column.

Conductor Condition		19/3.25 AAAC (KRYPTON) @ 18% Temperature (Degree's C											
New (Initial)		15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40	42.5
New (Initial) Next Day		12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40
Existing (Final)		5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5
Ruling Span													
105	Tension (kg)	839	799	760	723	687	652	621	590	562	535	511	487
	Time (s)	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.1	9.3	9.5	9.8	10.0
	Sag (m)	0.71	0.75	0.79	0.83	0.87	0.91	0.96	1.01	1.07	1.12	1.17	1.23

Figure 2: New – Initial @ 30˚C

These values are 621 kg, 8.8 seconds, and 0.96 m, respectively.

By using these values, it will cater for the conductor elongation and will allow the conductor strands to settle to 18% final tension over time.

5.3 New Conductor – Initial Tension Next Day

The conductor has been hanging in the rollers for a day before it is to be tensioned.

Using the table T-031-1 in "DCS Part 12 - (T) Stringing Charts" [11] with a ruling span of 105 m and a temperature of 30˚C found in the "*New Conductor / ABC (Initial) Next Day*" row, the required stringing tension, the time for five wave returns for the beat method, and the sag values can be read in the 30˚C column.

Conductor Condition		19/3.25 AAAC (KRYPTON) @ 18% Temperature (Degree's C											
New (Initial)		15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40	42.5
New (Initial) Next Day		12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40
Existing (Final)		5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5
Ruling Span													
105	Tension (kg)	839	799	760	723	687	652	621	590	562	535	511	487
	Time (s)	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.1	9.3	9.5	9.8	10.0
	Sag (m)	0.71	0.75	0.79	0.83	0.87	0.91	0.96	1.01	1.07	1.12	1.17	1.23

Figure 3: New – Initial Next Day @ 30˚C

These values are 590 kg, 9.1 seconds, and 1.01 m, respectively.

These values differ from the previous case since the conductors have had time to undergo elongation and therefore are not required to be tensioned as highly.

5.4 Existing Conductor – Re-tensioning

Using the table T-031-1 in "DCS Part 12 - (T) Stringing Charts" [11] with a ruling span of 105 m and a temperature of 30˚C found in the "*Existing Conductor / ABC (Final)*" row, the required tension, the time for five wave returns for the beat method, and the sag values can be read in the 30˚C column.

Conductor Condition		19/3.25 AAAC (KRYPTON) @ 18% Temperature (Degree's C											
New (Initial)		15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40	42.5
New (Initial) Next Day		12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40
Existing (Final)		5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5
Ruling Span													
105	Tension (kg)	839	799	760	723	687	652	621	590	562	535	511	487
	Time (s)	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.1	9.3	9.5	9.8	10.0
	Sag (m)	0.71	0.75	0.79	0.83	0.87	0.91	0.96	1.01	1.07	1.12	1.17	1.23

Figure 4: Existing – Final @ 30˚C

These values are 511 kg, 9.8 seconds, and 1.17 m, respectively.

These values also differ from the previous cases since the conductors have had much more time to undergo elongation and hence require to be tensioned at the final tension.

APPENDIX A. REVISION INFORMATION

(Informative) Horizon Power has endeavoured to provide standards of the highest quality and would appreciate notification of errors or queries.

Each Standard makes use of its own comment sheet, which is maintained throughout the life of the standard, which lists all comments made by stakeholders regarding the standard.

A comment sheet found in **DM# 42708883** can be used to record any errors or queries found in or pertaining to this standard. This comment sheet will be referred to each time the standard is updated.

Date	Rev No.	Notes
25/01/2024	0	Initial Document Creation
30/07/2026	1	Stringing Charts Removed – replaced with reference to DCS Part 12, Updated to new template