7762 AA Electrical Distribution (1)

Day 2

<u>Learning outcome 2.1 Identify relevant components used in overhead line design</u>

<u>Conductor support</u>

Wood poles
Steel poles
Concrete poles
Steel Towers

<u>Typical Pole</u>

Fig 2,1

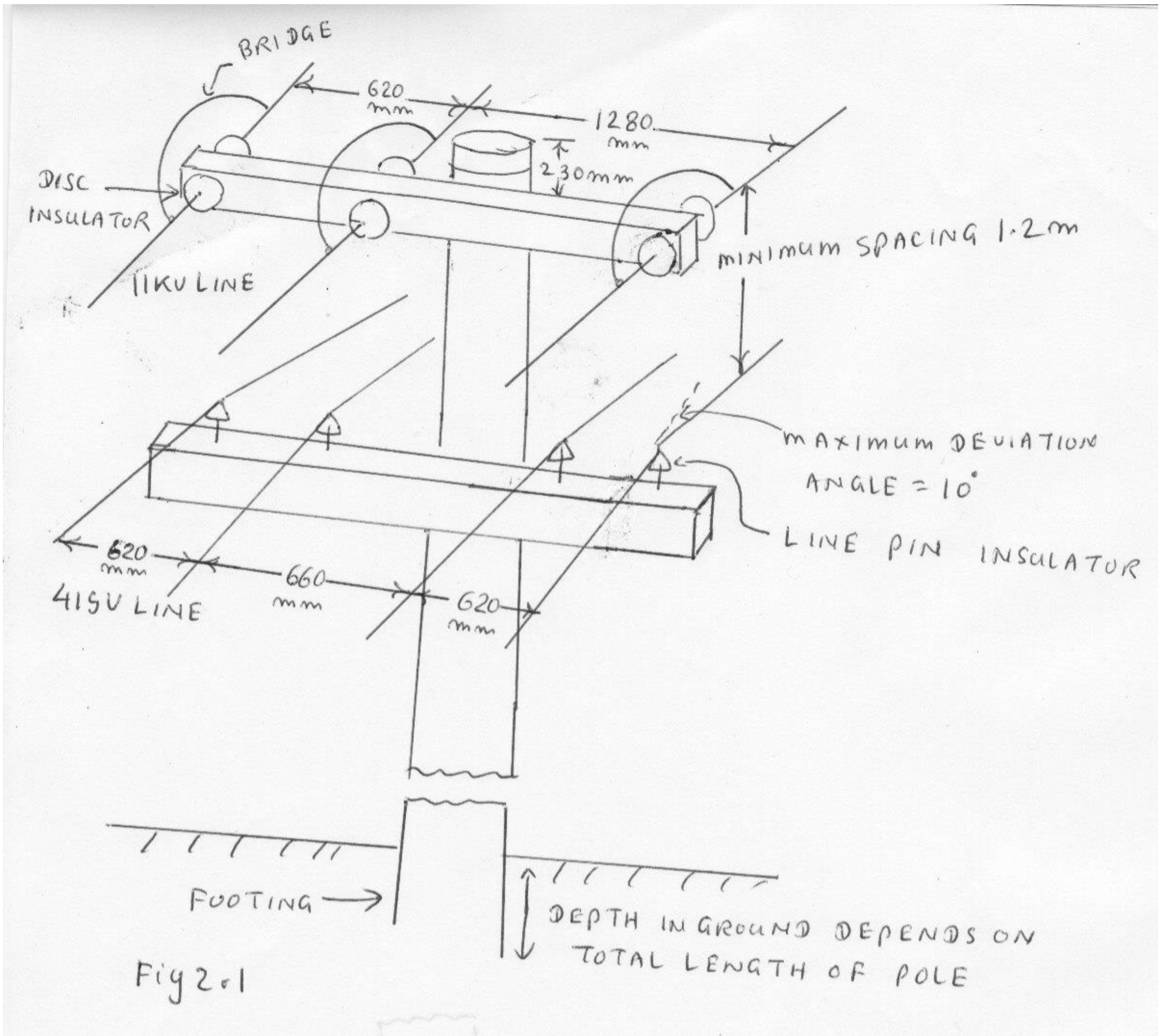


Fig 2.2

Fig 2.3

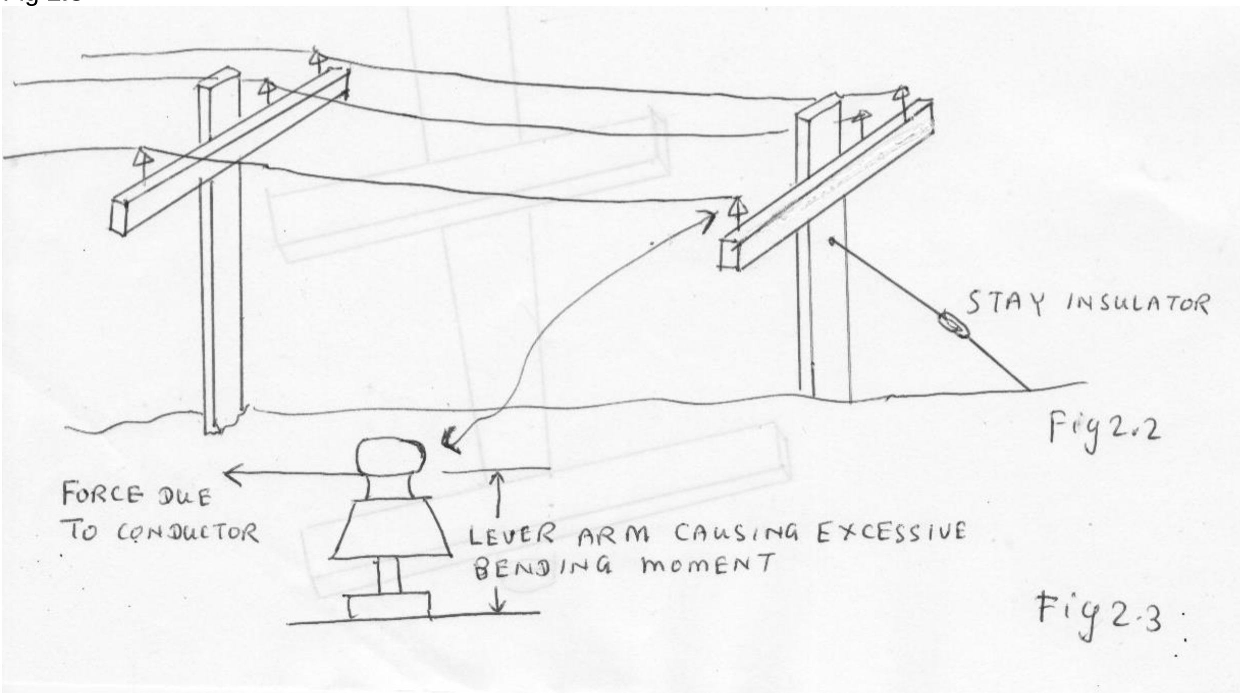
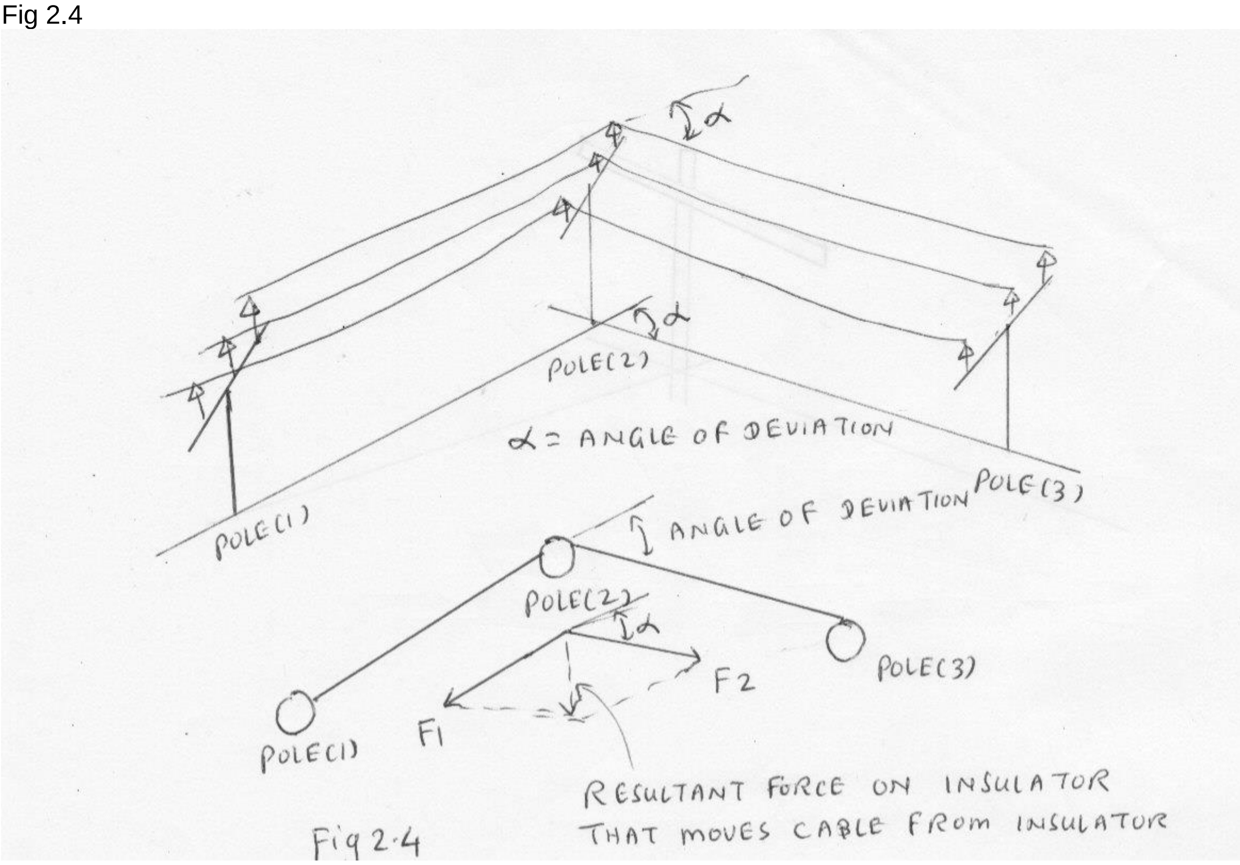
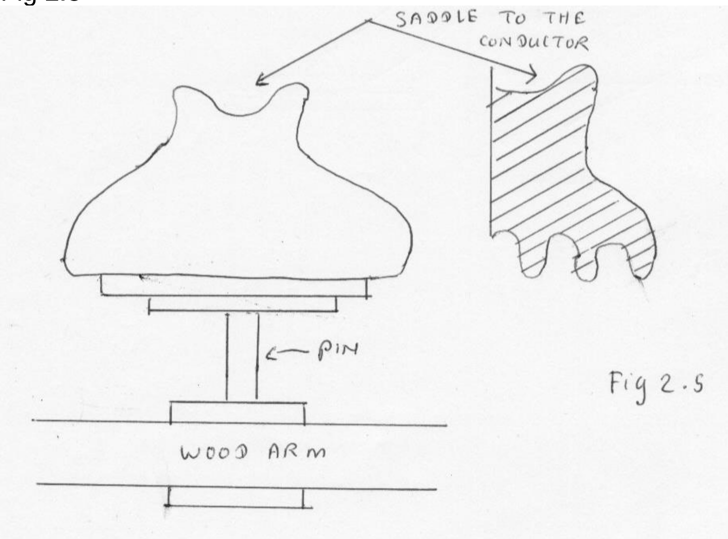


Fig 2.4



More angle of deviation causes the bigger resultant force to remove the cable from the pin insulator. The angle of deviation should not be more than 10 degree for pin insulator.

Fig 2.5



Arcing Horns

In the case of insulator flash over due to lightning strike, the porcelain is often cracked or broken by the power arc that follows the initial discharge.

To protect against this trouble, arcing horn or rings are installed on many overhead systems. These operate so that the arc is taken up by the electrode and held at sufficient distance from the porcelain to prevent the damage by the heat of the arc.

Fig 2.6

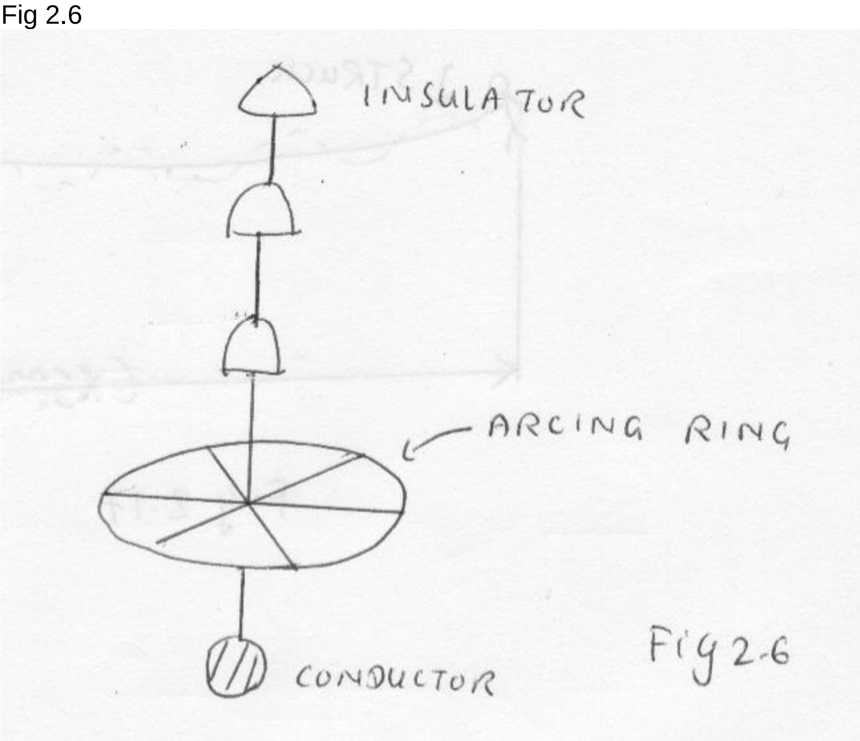


Fig 2.7

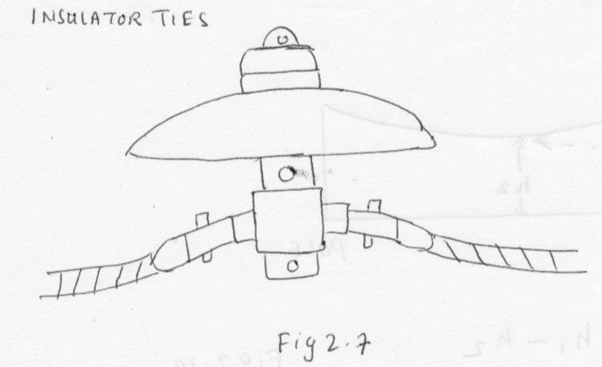
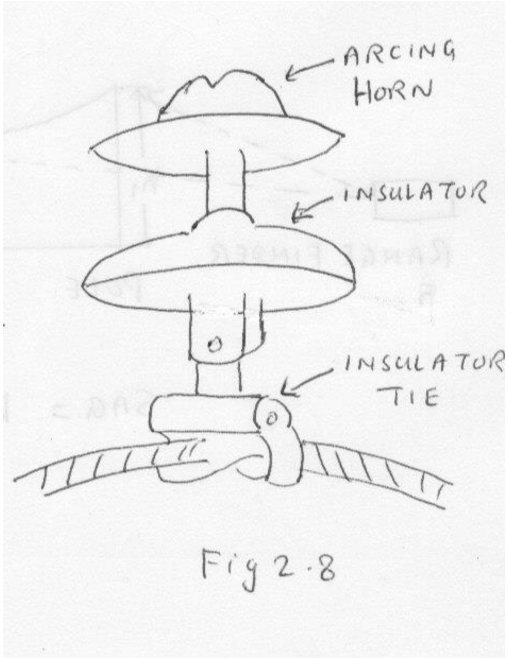


Fig 2.8



These consist of a number of helically formed rods , the central portions of which are shaped to provide attachment of the conductor on line pin insulator.

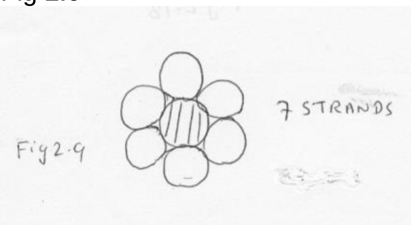
<u>Outcome 2.2 Outline relevant factors related to installation, maintenance of cross arms, pole types and choice of conductor sizes for commonly used configuration.</u>

<u>Conductor size</u>

SAA Wiring Rule

<u>Rule 3.13.2</u>
Every conductor installed as aerial conductor shall have not less than seven strands and shall not be smaller than 4 mm^2 copper or 16mm^2 aluminium.

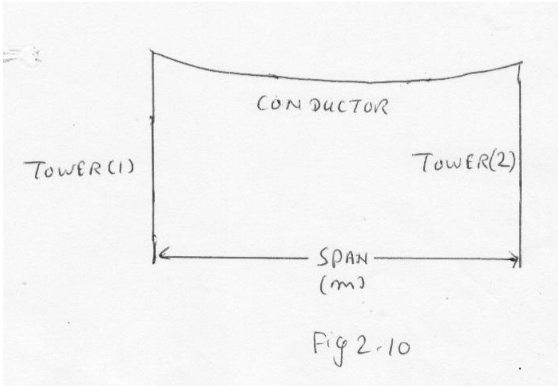
Fig 2.9



Total CSA = 4 mm^2 copper or 16mm^2 aluminium

The length of span of aerial conductor

Fig 2.10



Rule 3.13.9

The length of span of copper aerial conductor shall not exceed the values given below,

Type of conductor	Size mm^2	Maximum span (metres)
Bare hard drawn conductors	4 6 16 or over	25 30 60

Learning outcome 2.3 Determine mechanical limitations and physical dimensions of lines

Overhead line conductors

- Hard Drawn Copper Conductor
- All Aluminium Conductor (AAC)
- All Aluminium Alloy Conductor (AAAC)
- Aluminium Conductor Steel Reinforced (ACSR)
- Steel Conductor Galvanized (SC/GZ)
- Steel Conductor Aluminium Clad (SC/AC)

When steel is used as reinforcement or as a conductor or stay, it must be protected against corrosion.

Protection methods

- Galvanizing
- Coating with aluminium

Note
(1)An aluminium conductor steel reinforced should have some indication of the corrosion prevention method.

ACSR/GZ indicates that steel is galvanized

ACSR/AC indicates Aluminium Steel Core.

(2)Aluminium Conductors with Steel reinforcement provides the following advantages

- Most economical

- Shorter Span
- Not so frequently used for distribution work

Steel Conductor
- Very economical for rural distribution

Aluminium/ Aluminium Alloy Conductor
- Financial saving over copper
- Use in suburban work
- Span lengths are relatively short allowing for lower line tension

Conductor current rating

The current rating of overhead conductor depends on

- Heating
- Voltage drop
- Power losses

The current carrying capacity of an overhead conductor is limited by

- Annealing temperature of conductor
- The expansion due to temperature rise which causes a reduction of statutory clearance
- A temperature rise which might occasion injury to any insulation

Reasonably accepted values for the maximum operating temperature

75° C for continuous rating
100° C for one hour rating

Conditions affecting maximum conductor temperature

- Ambient temperature
- Wind velocity
- Heat absorbed from solar radiation
- Heat lost by convection
- Heat lost by radiation

Fault current carrying capacity

Fig 2.11

Voltage
The conductor must operate so that when the maximum current is being conveyed the fall in voltage along the line is within the certain limit.

The consumer's main to any point on the installation does not exceed five percent of the voltage at the commencement when full current is flowing

For medium voltages, the variation at the consumer's terminals should not exceed six percent and for higher voltages, the variations should not exceed ten percent.

Power loss

$$\text{Power Loss} \propto I^2 \propto \frac{1}{\text{Cross Sectional Area}}$$

Where Power loss means consumer power loss and line power loss.

Cross sectional area of the conductor determines the capital cost.

Materials for over head line conductors

Materials for overhead line conductor is determined by
- Electrical properties such as resistance, reactance, current carrying capacity of the conductor
- Mechanical properties such as strength and weight
- Price of the material relation to the return in the investment

Factors to be taken for installation of insulator

- Minimum mechanical strength
- Minimum impulse withstand voltage
- Minimum wet withstand voltage at power frequency
- Minimum puncture voltage at power frequency
- Minimum creepage distance between conductor tie and pin

The minimum failing load for any line pin insulator is 7KN.

Designation of insulator

Line Pin Insulator

First letter	S- Standard F-Foy type A-Aerodynamic
Next letter	LP- Line pin insulator First number- Nominal voltage (KV) Second number- Minimum creepage distance

Example

ALP 33/920

A- Aerodynamic type
LP- Line pin insulator
33- 33 KV
920- 920mm (Minimum) creepage distance

Example

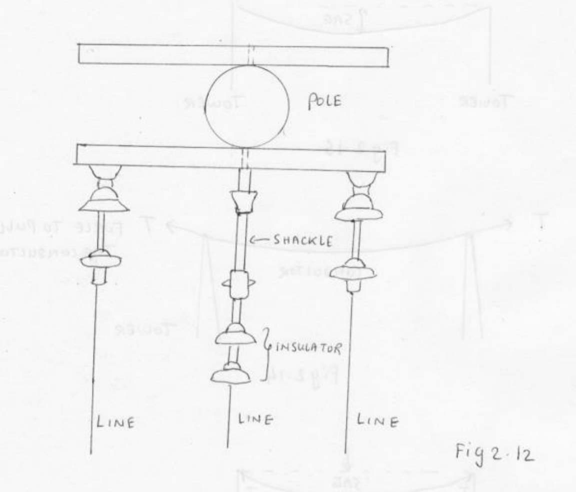
SLP 11/180

S-Standard type
LP-Line pin insulator
11-11KV
180- 180 mm (Minimum) creepage distance

Shackle Insulator

Shackle insulators are used for terminating and angle construction on mainly on low voltage lines. The high voltage shackle insulators are now replaced by disc insulator.

Fig 2.12



SH LV1- Minimum failing load 9KN
SH LV2- Minimum failing load 20KN

Disc Insulator

Disc insulators are used in high voltage lines for both intermediate and strain construction

1 disc- 11KV
2 disc- 22KV
3 disc- 33KV

Minimum failing loads of 44 KN and 66 KN

S-Suspension A- Anchor shackle B- Hanger bracket D- Disc E- Eye bolt N- Eye nut
P1-Pole band termination P2- Pole band through construction G- Straight torque

Example

EA 2/D

E- Eye bolt
A- Anchor shackle
2-2 discs
D- Disc

Stay Insulator

Stay insulator type	Line voltage	Steel wire size	Minimum failing load (KN)
GY1	LV and 11KV	7/2.75	27
GY2	11KV	19/2.00	71
GY3	22KV	19/2.75	222
GY4	33KV	19/2.75	222

Insulator pin

- Made of hot rolled carbon steel and galvanized
- Alloy lead -- 95% lead and 5% antimony
- Pattern A, B ,C

- A- Used for both medium and high voltage insulators
- B-Used for insulator of voltage up to 600V
- C- Used for high voltage insulator

Interpretation

Type/ Stem length / Failing load

Pin Type	Shank Size
B / 100 / 3.5	140 x 16 mm
A / 130 / 7	165 x 20 mm
C / 150 / 7	165 x 20 mm
C / 150 / 11	165 x 24 mm
C / 200 / 11	165 x 24 mm
B / 300 / 7	165 x 24 mm

<u>Example</u>

C / 300 / 7
C Type Stem length 300 mm Transversed failing load 7 KN.

<u>Causes of insulator failure</u>

1. Cracking of porcelain
2. Porosity of porcelain
3. Puncture of weak porcelain
4. Shattering of insulatoir caused by power arc
5. Flash over of insulator caused by dust/ salt deposits
6. Failure of insulator from excessive mechanical stress
7. Short circuit caused by birds or animals

<u>Maximum tension of conductor</u>

Maximum tension should not be more than 50% of ultimate tensile strength under a wind loading of 500 Pascal at 15 ^{o} C

The maximum conductor tension in still air at 5 ^{o} C is not to exceed the followings

15%- Ultimate Strength for hard drawn copper conductor
18% Ultimate Strength for hard drawn all aluminium conductor, steel core aluminium conductor and hard drawn cadium copper conductor
18% Ultimate Strength for all aluminium alloy conductors

<u>Vibration dampers</u>

33 $^{1}/_{3}$ % for hard drawn copper conductor
25% for hard drawn aluminium steel core and hard drawn cadium copper conductor.

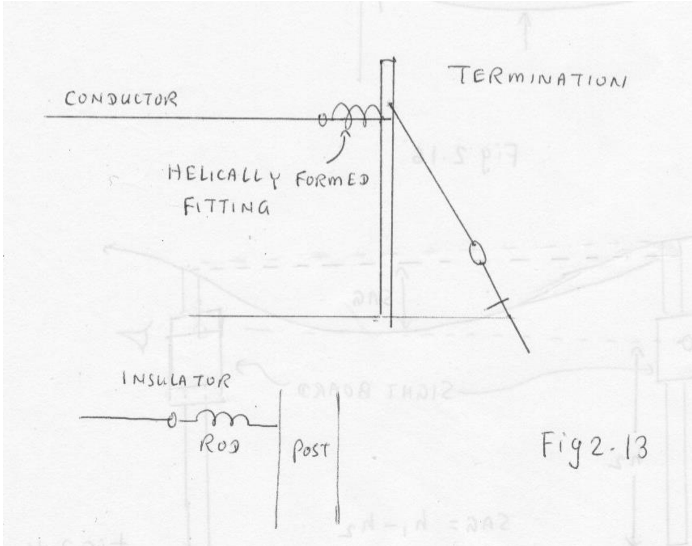
Vibration dampers are fitted to transmission lines rather than distribution feeders

<u>Armour rod and vibration dampers</u>

Over head line conductors are subject to mechanical vibration caused by change of wind pressure causing swing and ultimately causing failure of the conductor.
Such failure is reduced greatly where conductor is reinforced at the point of support and by designed conductor clamp.

Helically formed fittings

Fig 2.13



Helically formed fitting is applied to a conductor at the support point.

Line Guard

Features:

- Shorter in length
- Smaller diameter wire
- Used at conductor support
- To protect the conductor against flash over burn

Termination or dead ends

- Helically formed wires
- Leaving loop to which tension is applied

Insulation material for conductor

Polyvinyl Chloride (PVC)

- Low temperature, tearability, oil resistance, termite resistance
- Fuse / protective devices must be sufficiently sensitive to prevent PVC approaching softening point.

Ethylene Propylene Rubber (EPR)

- Thermosetting, excellent thermal electrical properties
- Higher dielectric , greater resistance to corona

Impregnated Paper

- Must be free from inperfection , High dielectric strength

Cross Linked Polyehylene (XLPE)

- Used for power cables
- Extremely good chemical resistant insulation
- Short time operation at 130 º C

- Continuous operation at 90 º C
- Short circuit performance at 250 º C
- Lightness

Compacted conductors
- Used for 1.9/ 3.3 KV cables
- HV XLPE cables are compacted to reduce the size of intersticies.

Overhead line consideration

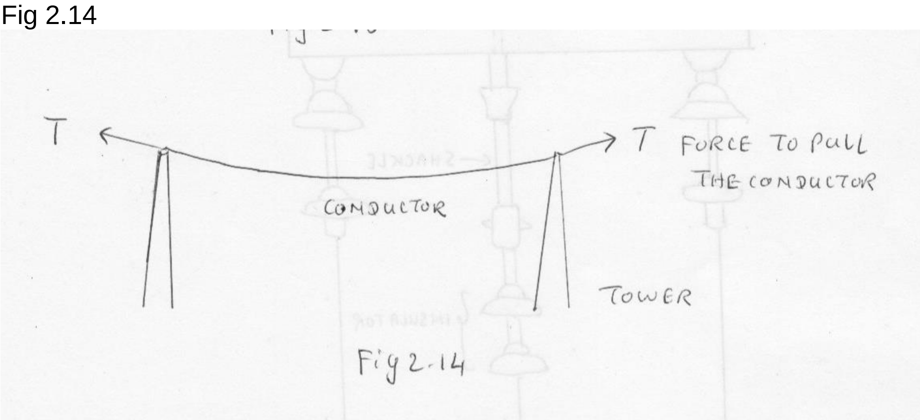
AC transmission is mostly used. Overhead line construction are much less expensive than under ground line construction.. Steel towers are used to support the conductors. They are protected by lightning arresters.

Cable
Majority of cable used for underground distribution work are Impregnated Paper insulated with lead or lead alloy sheath. Cables up to 33KV are covered by AS 1026. Copper and aluminium are used as conductors.

Learning Outcome 2.2 Outline relevant factors related to installation

Ultimate Tensile Strength

Fig 2.14



The following regulations are extracted from Overhead Line Construction Regulations of NSW (1983)

Regulation 28.1

The ultimate tensile strength of an aerial conductor operating voltage of 650V or less shall not be less than 3000N.

Hard Drawn Copper Conductor	7/1.75 at 3610 N Ultimate Strength (UTS)
All Aluminium Conductor	7/1.75 at 3010 N Ultimate Strength (UTS)
All Aluminium Alloy Conductor	7/1.75 at 4710 N Ultimate Strength (UTS)

Regulation 28.2

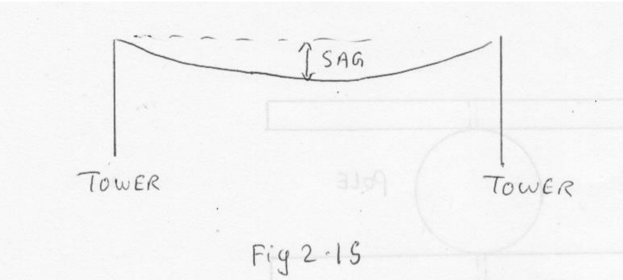
The Ultimate Tensile Strength of an aerial conductor operating voltage exceeding 650V must not be less than 5000N.

Copper	7/1.75	at	6840 N Ultimate Strength
Aluminium	7/2.50	at	5750 N Ultimate Strength
Aluminium Alloy	7/2/25	at	7780 N Ultimate Strength

Learning Outcome 2.3 Determine Mechanical & Physical dimension of line

Sag

Fig 2.15



When distribution lines are erected, the sag allowed in a conductor at the time of erection must be such that the maximum tension allowable for the particular conductor is not exceeded under the condition specified in the regulations.

Four sag conditions

1. Sag and tension in conductor at 15ºC with wind loading of 500 Pascal on the projected area of conductor
2. Sag and tension at no wind and ambient temperature of 5ºC .
3. Sag at 5ºC which determines the support weight to maintain the statutory clearance above the ground.
4. Sag of erection which will ensure that the above conditions are fulfilled.

Fig 2.16

$$S = \frac{W\ L^2}{8\ T}$$

Where

S = Sag in metres
L = Length of span in metres
W = Combined load of gravitational force and wind force on conductor at one metre length
T = Tension in conductor (Newton)

$$\text{Length of cable (Metre)} = L + \frac{8 \times S^2}{3 \times L}$$

Problem

Calculate allowable sag for a 7/ 3.50 hard drawn copper over head line conductor span of 150 m. The wind loading is 500 Pascal. Minimum tension is 50% of Ultimate Strength.

Ultimate tensile strength = 26600N
Gravitational force = 5.949N / m
Diameter of conductor =10.5 mm
Wind loading per metre =diameter in metre x wind loading in Pascal

$= 10.5 \times 10^{-3} \times 500$
$= 5.25$ N/ m

Combined load of gravitational force and wind force on conductor at one metre length $= \sqrt{Wo^2 + Wl^2}$

$= \sqrt{5.949^2 + 5.25^2}$

$= 7.934$ N/ m

$$\text{Sag} = \frac{W L^2}{8T} = \frac{7.934 \times 150^2}{8 \times 26600 \times 0.5} = 1.678 \text{ m}$$

Erection Sag

It is necessary to calculate the tension and sag under conditions at the time of erection.

Factors to vary sag and tension

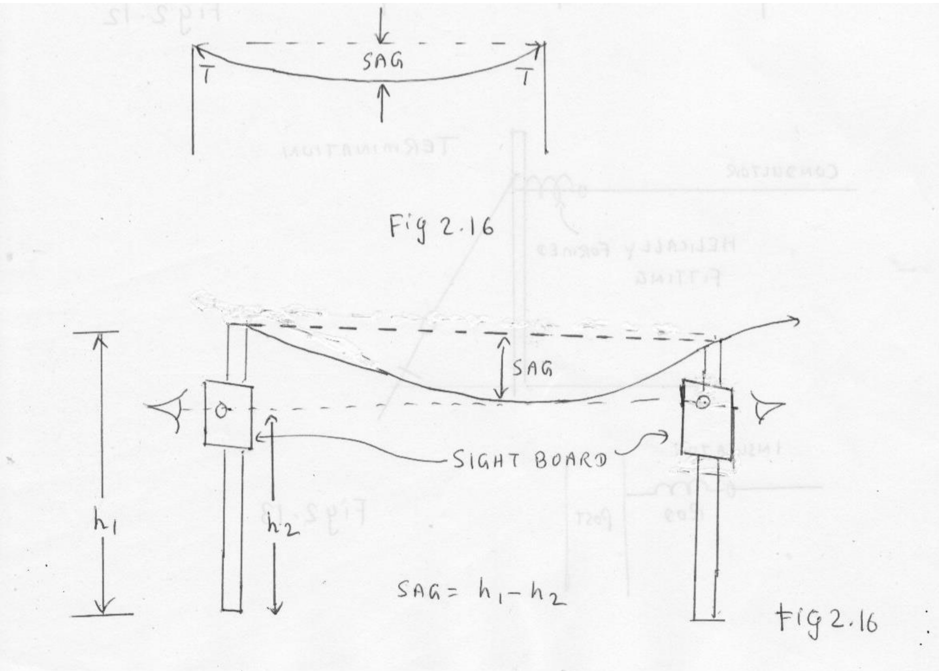
- Elasticity
- Temperature

An increase in temperature will cause the length of the conductor to increase so that the sag will increase.

Sag measurement

(a) Sight Board Method

Fig 2.16

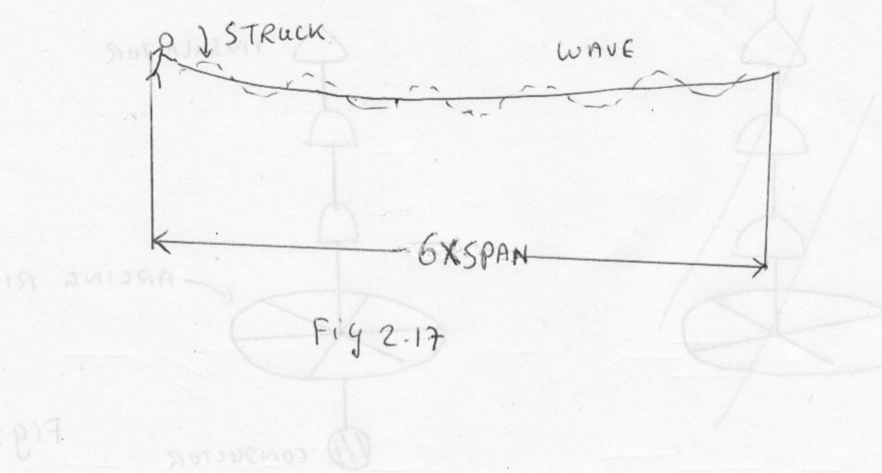


Sag= $h_1 - h_2$

Sight boards are fixed to two poles of the span at the appropriate height for desired sag. The conductor is then pulled up to line with a sight taken between two boards.

(b) Wave Timing Method

Fig 2.17



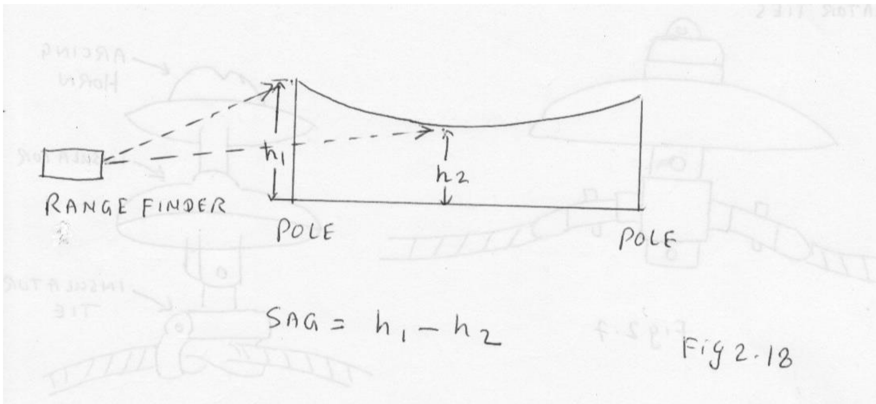
For this method, the conductor is struck at one end of the span and the time taken for the wave to travel the span six times is measured. Sag is then calculated from the formula.

$t = \sqrt{\text{Sag in metre}}$

t= Time in seconds for 3 return waves

(c) Optical Range Finder Method

Fig 2.18



Sag= $h_1 - h_2$

Measure the height of the conductor at the pole . The height of the conductor at mid span.

Sag= Height of conductors at pole = Height of conductor at mid span

Wood poles

- Cheapest
- Made from larch, sprace, cedar, pine, fir trees
- Southern Yellow Pine , Dogulas Pine are mostly used.

Review Questions

Review Questions are extracted from EA 153 - 7762 AA Electrical Distribution Module Book

Review Questions for Section 2-Over Head Line

Review questions for Section 2

1. Name the factors that are used in the selection for overhead line conductors.

2. Name **six** commonly used materials for overhead lines.

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   -

3. Name the **three** factors that determine conductor current rating.

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   -
   -

4. What are the factors that determine the maximum conductor temperature?

Answers for Q1 to 4

Section 2

1.
   - electrical properties such as resistance, reactance and current carrying capacity
   - mechanical properties such as tensile strength and weight
   - Initial cost of the material used

2.
   - hand drawn copper
   - all aluminium conductor (AAC)
   - all aluminium alloy conductor (AAAC)
   - aluminium conductors steel reinforced (ACSR)
   - steel conductors galvanised (SC/GZ)
   - steel conductors aluminium clad (SC/AC)

3.
   - conductor size
   - permissible operating temperature
   - Maximum likely ambient temperature

4.
   - ambient temperature
   - wind velocity
   - heat absorbed from solar radiation
   - heat loss by convection
   - heat loss by radiation
   - heat generated by the line current

Review questions for Section 2

5. Name the standard methods used for protecting the steel against corrosion when it is used as reinforcement or as a conductor.

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6. Name the types of supports for conductors. Describe the one that is commonly used in distribution.

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7. Describe how wood poles are being protected against weather and fungal attack.

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8. State the governing factors that determine the stability of a pole.

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Review questions for Section 2

9. Define pole rake.

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10. Draw simple sketches of the following pole footings and describe their usages.
- plain footing
- concrete slab footing
- concreted footing
- baulk footing

Answers for Q5 to 10

5. The standard methods are:
   - galvanising
   - coating with aluminium (aluminium clad)

6.
   - wood poles
   - steel poles
   - concrete poles
   - steel towers

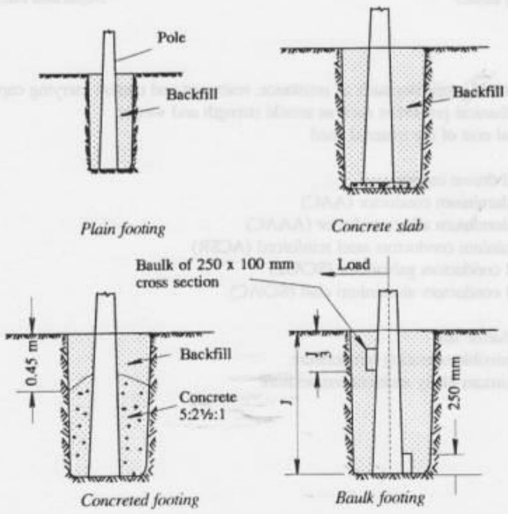
   Wood poles are the most economical for distribution work.

7.
   - fitting galvanised pole caps to prevent deteriation from atmospheric condition
   - using preservative oils and waterborne preservatives for full length treatment of poles
   - creosote, tanalith and pentachlorophenol are used for preservative treatment.

8.
   - depth of pole in the ground
   - bearing properties of the soil

9. Pole rake is the inclination of the pole for a rake of pole diameter at the top of the pole when the pole is used for angle and termination poles which are stayed.

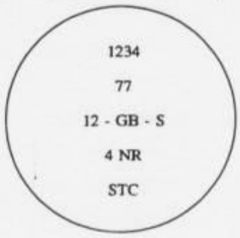
10.



Review questions for Section 2

11. State the factors that determine the life of poles.

12. For the wood pole label shown, describe the meaning of each term.



Label

13. Describe how pole strength is classified.

Review questions for Section 2

14. A crossarm is listed as 2.7P/16/100x100. Describe the meaning of each term in the list.

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15. Describe the **three** common types of insulators used in distribution systems.

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- ____

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- ____

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16. The designation of an insulator is ALP 33/920. Describe the meaning of each term.

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Review questions for Section 2

17. For the designation of an insulator: EA/2D, describe the meaning of each term.

18. Sketch 'creepage' of an insulator.

19. Describe the use of 'arcing horns.'

20. Briefly describe the **three** determining factors for the mechanical properties of overhead conductors.

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-
-

Answers for Question 11 to 20

11.
- weather condition
- probability of fungus or termite attack
- original preservative treatment
- maintenance program

12. 1234 - pole identification number
77 - year of felling (1977)
12-GB-S - pole length is 12 metres, species of timber is Grey Box, Timber is from South Coast
4 NR - strength is 4 kN, pole type is naturally round
STC - name of supplier

13. According to ultimate extreme fibre stress that is allowed.

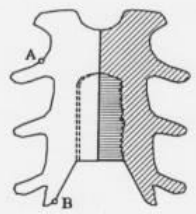
14. 2.7 - the cross is 2.7 metres long
P/16 - four pin type insulators of 16 mm pin diameter
100 x 100 - cross section is 100 mm deep by 100 mm wide

15.
- pin
- shackle
- disc

16. ALP - aerodynamic type line pin insulator
33 - use for 33 kV
920 - the minimum creepage distance is 920 mm

17. EA - use eye bolt support
2D - has two disc insulator

18.



Creepage is the distance between A and B

19. Use to prevent the cracking of porcelain for an insulator in the case of flashover due to lightning. The electrodes of an 'arcing horn' provide a discharging path for the arcing caused by lightning.

20.
- the working strength of the material used
- maximum tensions to be exerted on the conductor
- armour rods and vibration dampers used for reinforcing

Review questions for Section 2

21. Describe briefly the two methods used in sag measurement.
- ______________________________
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- ______________________________
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22. Sketch the following stay anchorages.
- used in solid rock formation
- used in weak rock formation
- used in soil

23. Using the attached table, calculate the allowable sag for a 7/3.50 hard drawn copper overhead conductor with a span of 150 metres. The wind loading is 500 pascals and the maximum conductor tension is to be 50 percent of the ultimate tensile strength.

BARE STRANDED HARD DRAWN COPPER CONDUCTORS

Stranding	*Sectional area mm²*	*overall diameter mm*	*Ultimate tensile strength N*	*Mass kg/m*	*Gravitational force (N/m)*	*Wind load at 500 Pa (N/m)*	*Resultant load at 500 Pa (N/m)*	*Resistance per Km at 20°C (OHMS)*
7/1.00	5.50	3.00	2310	0.049	0.483	1.500	1.576	3.25
7/1.25	8.59	3.75	3610	0.077	0.754	1.875	2.021	2.09
7/1.75	16.84	5.25	6890	0.151	1.480	2.625	3.013	1.06
7/2.00	21.99	6.00	9020	0.197	1.931	3.000	3.568	0.815
7/2.75	41.58	8.25	16700	0.375	3.675	4.125	5.525	0.433
7/3.50	67.35	10.50	26600	0.607	5.949	5.250	7.934	0.268
19/1.75	45.70	8.75	18300	0.413	4.047	4.375	5.960	0.395
19/2.00	59.69	10.00	23900	0.538	5.272	5.000	7.266	0.302
19/2.75	112.90	13.80	44500	1.020	9.996	6.900	12.146	0.160
19/3.00	134.30	15.00	52800	1.210	11.858	7.500	14.031	0.134

TABLE 1

TEMPERATURE COEFFICIENT OF RESISTANCE = 0.00381 PER °C AT 20°C

Working:

Answer for Question 21 to 23

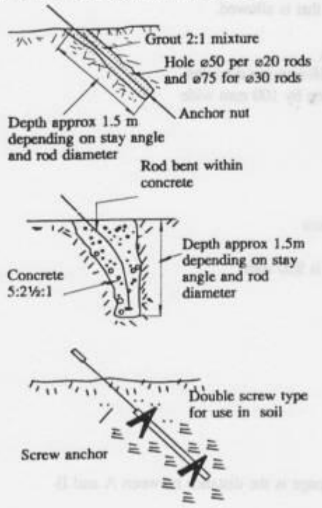
21. *Sight boards*
They are fixed to two poles of the span at the appropriate height for the desired sag. The conductor is then pulley up to line with a sight taken between the two boards.

Wave timing
With this method the conductor is struck at one end of the span and the time taken for the wave to travel the span six times is measured. The sag can then be calculated from the formula

$$t = \frac{\sqrt{Sag\ in\ metres}}{0.03408}$$

t = time in seconds for 3 return waves

22.



23. Sag = 1.678 metres