OVERHEAD NETWORK CONDITION ASSESSMENT MANUAL

ABN 40 078 849 055

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PREFACE

The Lines Classification Defects Manual has been produced to provide guidance to the Asset Inspector for determining:

- the presence of a defect exists in relation to poles and associated attachments including conductors and the effects of growing vegetation and
- determining the defect priority.

In support of this:

- EATA documentation indicates the types of defects that may be considered for various asset classes in the job cards
- the defects identification and defect priority allocation has been incorporated into an ESITrain course that the AI must undertake.

This manual incorporates supporting explanatory information relating to common pole related defects.

There are a number of appendices attached that provide more detailed background for timber biology and metal corrosion.

DEFINITIONS AND ABBREVIATIONS

Term	Definition
AAC	All Aluminium Conductor
ABS	Air Break Switch
ACSR	Aluminium Conductor Steel Reinforced
Asset Inspector	A person charged with the responsibility to inspect an asset, identify defects, assign defect priority, recommend corrective actions, record and report the findings
BBCC	Broadband Communications Cable
Backstay	A cable appropriately connected between a pole and earth to stabilise and support the pole.
BPM	Base Plate Mounted - Ragbolt type foundation for streetlight poles.
Bollard	A stay pole, to which a pole (head or aerial) stay attaches, without attached circuits.
Breast Log	Log buried flat in the ground that is perpendicular to the pole to restrict pole movement.
BIG	Buried In Ground - A simple foundation for streetlight poles in which the pole base is simply planted in an excavated hole and surrounded by concrete, backfill or other foundation material.
Bush Pole	An untreated wood pole typically with sapwood removed at its base.
CMEN	Combined Multiple Earthed Neutral
Circuit	A group of one or more electrically-related wires approaching a pole from the same direction at approximately the same height.
Concrete Rebutted Pole	A wood pole with timber base (at and below ground level) replaced by a concrete butt.
CLD	Critical Load Direction - The direction of the resultant force applied by conductors attached to a pole, or the direction a pole would fall if it were to fail at the pole base.
Design Load	The calculated load imposed upon a pole under the loading conditions (calculated maximum service load) adopted by the electricity entity.
EATA	EA Technologies Australia has developed a suite of preventive maintenance documentation that has been adopted by Ergon Energy and ENERGEX as joint workings
EDO	Expulsion Drop-out Fuse
Electrical Creepage Distance	The total distance an electrical discharge would travel along an insulator to breach the insulating properties.
Factor of Safety	The ratio of assessed pole bending strength to its design bending strength
Failed Pole	A failed pole is a pole which, due to loss of strength has broken off or become incapable of standing without mechanical means of support other than permanent reinstatement. The following exclusions apply for reporting purposes: – weather more severe than design conditions allowed for at that – location e.g. lightning, severe storms and so on; – impact loads contacting poles or their attachments, e.g. vehicles, – falling trees or wind borne objects; – unforeseeable changes in ground conditions e.g. flooding

Failure	The termination of the ability of a component of the network to perform its required function.
'Flying Fox' Service	A low voltage overhead service to premises that tees off the distribution line mid-span. It comprises an insulated cable supported from the pole to the tee-off point by a steel catenary strung between the two adjacent poles.
Fully Supported Pole	– a pole in which resultant pole-top forces are countered by changed tensions in conductors or stay wires or both (other than service lines). This support ensures little or no bending moment at ground line.
GL	Ground Line
HV	High Voltage (11kV or above)
JU	Joint Use- where an ENERGEX pole supports non-ENERGEX assets such as telephony wires.
LFI	Line Fault Indicator
LL	Live Line
LV	Low voltage (240/415 volt)
Level 1	A quick, conservative, first-pass wood pole strength analysis that does not require taking detailed field measurements.
Level 1.5	A detailed wood pole strength analysis performed on poles that fail a Level 1 analysis or considered necessary for other reasons, e.g. span lengths exceeding 60m.
MSDS	Materials Safety Data Sheet
Maintenance	All work done on the network to retain it in, or restore it to, a state where it can satisfactorily perform its required functions. This includes primary maintenance activities such as inspection and condition monitoring, as well as secondary maintenance activities such as repairs, reinstatement and replacement.
Nailed or Staked wood pole	A pole with timber base (at and below ground level) reinstated by the attachment of nails/stakes in the ground beside the pole.
Non-Destructive Evaluation	An assessment in which the strength of a pole is verified by validated non-destructive techniques.
OCM	ENERGEX Overhead Construction Manual
Operator	Person/s undertaking pole inspection at worksite.
Pipe	An internal hollow running vertically within a wood pole.
Pole base	The area as measured from the standard digging depth to 2m above ground level.
Pole	An overhead line or street light support structure, excluding attachments e.g. x-arms.
Pole top	The area as measured from 2m above ground level to the top of the pole.
Pothead	Underground cable termination on pole.
PPE	Personal Protective Equipment – Gloves, eye protection, hard hat, protective clothing, respirator, gumboots etc. as required for task.
Proof Testing	An assessment in which the strength of a pole is verified by validated application of a mechanical load to simulate the design load multiplied by the factor of safety.
Reinstated Pole	A pole in which the original foundation has been supplemented or replaced by a structurally effective support system.
Reinstated steel pole	A steel pole reinforced with concrete
Rot	Internal or external fungal decay in wooden network components e.g. poles, crossarms, platforms that causes reduction in the mechanical strength
Service Provider	Company providing services specified in this SWP under a contract.

Serviceable Pole	A pole in service which, at the time of inspection and assessment, is considered capable of bearing its design load with the relevant Factor of Safety (FOS). The FOS for wood poles is equal to or greater than 2.
Structural Analysis	A structural analysis involving the calculation of the pole's strength (ability to resist an overturning moment) and comparison with forces applied by conductors and windage on the pole. The analysis may be conducted in two parts – Level 1 and Level 1.5.
Suspect	A network component that has defects of sufficient severity to call its serviceability into question. Such components require further engineering analysis and possibly remedial works. A pole that has failed the Strength Analysis, or that has defects of sufficient severity to call its serviceability into question. Such poles require further engineering analysis and possibly remedial works.
Suspect Pole	A pole in service which, at the time of inspection, is considered to require further assessment to determine whether or not it is serviceable.
Tablet	F5v mobile computer that is used by the Assessor at the worksite to record inspection, test and structural analysis and asset data.
UG	Underground
Unserviceable Pole	A pole in service which, at the time of inspection and assessment, is considered incapable of bearing its design load with the relevant Factor of Safety (FOS). The FOS for wood poles is equal to or greater than 2. The FOS for other structures as per C(b)1.
UV	Ultra-violet radiation from sun.
Vegetation	Any plant growth, either living or dead, that is located in the vicinity of overhead power lines, poles and associated components.
VPI pole	Vacuum pressure impregnated wood pole with sapwood intact and chemically treated, typically with CCA.
WH&S	Workplace Health and Safety
Works Officer	The ENERGEX officer responsible for assigning maintenance work (preventive and corrective), including receipt and assessment of field data.
Work Request	A request for maintenance lodged with the ENERGEX computer system via the tablet.
X-arm	Cross-arm

1. INTRODUCTION

1.1 Why Inspect the Overhead Network?

An electrical entity has an obligation to “inspect test and maintain the works”.

The inspection of overhead lines is carried out as preventive maintenance for the overhead network. The cost of preventative maintenance is usually minor in comparison with the costs and consequences of in-service failures.

Defective conditions can develop on the overhead network as components age or are damaged by the external environment, e.g. lightning, high winds, termites, growing vegetation. These conditions can lead to unplanned outages and conditions that are potentially hazardous.

The aim of inspection is to detect potential defects in their incipient stage so that remedial action may be taken to avert failure. It should be noted, however, that it is imperative that assessors differentiate between defects that are significant and those that are not; otherwise a proliferation of unnecessary jobs can be generated for the maintenance program.

The EATA documentation prescribes standard inspection intervals for patrols of high voltage feeders, as well as associated feeder integrity periods.

1.2 Action-Based Maintenance

ENERGEX employs action-based maintenance where practicable. Rather than simply reporting defective conditions, skilled assessors nominate what remedial action is required. This reduces the need for follow-up site visits to assess the severity of the defect or scope of remedial works. In some situations, the assessors may take direct action to repair the defect e.g. attachment of earth wire protective battens.

1.3 Crucial Role of Asset Inspectors

The success of the whole inspection and maintenance program is very much dependent upon asset inspectors.

Many defects are difficult to detect. Ground based asset inspectors are at ground level, and hence only able to examine the pole top components from below. Aerial patrols can view assets from a different aspect but are limited in the ability to examine certain defects. Live line crews are in a much better position to closely examine potential above ground defects.

Defects may be internal to the component with few external indications. The external appearance of poles, crossarms and other components can be deceptive. Some outwardly appear to be in good condition but are not. Others may have a poor appearance yet prove to be sound.

It is imperative that assessors follow the guidelines set down in this manual and those of the Lines Defect Classification Manual and develop their skills in recognising defects and scoping remedial works. Failure to detect defective conditions could result in serious accidents, widespread power outages, legal liability and damage to public image. On the other hand, failure to discriminate between defects that are critical and those that are not will result in much wasteful spending and the diversion of funds away from critical works.

1.4 Guiding Principles

In general, the following guiding principles should apply when conducting an assessment of the network including ground based feeder patrols, below ground pole inspection and live line feeder inspections:

- Understand the operational requirement and function of the asset
- Determine suitability of asset (e.g. pole, x-arm, conductor)
- Look for root cause, not just symptoms
- Report immediately any items where imminent catastrophic failure is likely
- Recommend / perform further action

1.5 Guidelines for Ground Based Feeder Patrol

A ground based patrol is conducted to provide enhanced reliability and safety performance of the electrical network. The patrol should be conducted with information of the prior network performance, including network outage data, to provide assistance in identifying typical causes of outages.

In a ground based feeder patrol, the asset inspector should consider the following key issues:

1 **Design Considerations** including:

- Pole/structure foundation type and condition
- Electrical clearances between electrical apparatus and earthed situations
- Conductor separation for span length and voltage
- Span lengths for specific constructions and conductor types
- Pole length and species
- Stays - number, direction and size

2 **Damage to Equipment** including:

- Leaning, damaged or rotting poles
- Wood X-arms with signs of rot, excessive splitting
- Steel X-arms with open ends
- Leaking or rusted transformers
- Rot/rust in support platform
- Damage to or leaking underground terminations
- Damage to air break switches
- Broken or punctured insulators, missing insulators (minimum of two insulators), bent insulators under significant tension
- Rusted or damaged clamps
- Corroded, stranded, slack or missing ground stays
- Stranding of conductors
- Stranding of earthwire or no/poor bonding to downlead

3 **Environmental impacts** including:

- Evidence of wildlife that may have potential to cause outage
- Vegetation near electrical equipment
- Sea spray from coastal areas

2. POLES

2.1 Leaning Poles

Report wood poles if:

- Pole excessively leaning, or
- Leaning to such an extent so as to have or cause secondary consequences that compromise safety or performance.

Table 2.1 shows the angle for poles for various location and pole attachments that will generate a P1 defect. Assessor should use a protractor to determine the angle of lean.

Risk Level	No plant attached	Transformer attached or Nailed
Low Risk Area	30°	20°
High Risk Area	20°	15°

Table 2.1 – Excessive Pole Lean

Secondary Consequences of Lean:

- Mains are excessively slack and evidence of conductor clashing can be seen (i.e. burn marks on conductors)
- Inadequate ground clearance
- A leaning pole and/or road with camber can contribute to motor vehicles clipping and damaging poles.

Report any poles deemed unsafe due to erosion of the surrounding soil to a significant depth.

Figure 2.1A – Acceptable Leaning pole. Check condition of pole base below ground. Note use of back-stay to stabilise pole.

Check condition of back stay anchor points.

In this situation pole is acceptable for continued use due to back stay and condition of pole base below ground.

2.2 Concrete Poles

Visually inspect the concrete poles for defects such as:

- cracking or flaking
- exposed reinforcing
- loose or missing terminal door (streetlight poles).

Report any concrete poles where:

- Significant cracking/fracturing of concrete is visible, (this is a sign of internal rust).
- Internal steel re-enforcing is visible.
- Signs of rust are present, e.g. rust is staining concrete. Unless rust stain is due to surface rust on metallic cover.

Any of the following signs are an indication of a potentially weakened pole and should be reported.

- Covers are missing.
- Metallic cover is rusting to such an extent that it can be easily dislodged, broken or punctured by a member of the public.

Figure 2.2A – Unacceptable.
Significant cracking of concrete and rust staining of concrete is evident. These conditions indicate steel re-enforcing is rusting or susceptible to rust. A potential loss of strength is quite likely.

Figure 2.2B – Unacceptable.
It can be observed that large pieces of concrete have broken off exposing steel reinforcing. This will promote rusting of the steel re-enforcing.

2.3 Steel Poles

Report any steel poles where:

- There is rust or signs of rust.
  Note: surface rust can be acceptable if it is not at the base of the pole. Pitting due to rust is unacceptable.
- The pole is damaged or has signs of damage that may weaken the structural integrity i.e. significant dents, bends, large cracks etc.
- The pole has obvious defect(s) which have the potential to weaken the pole.
- Covers are missing.
- Bolts or nuts covered with soil or corroded (above and below base plate should be assessed, if accessible)

When assessing a steel pole, consider the nature of the surrounding environment, i.e. will the environment accelerate the deterioration of the pole.

Figure 2.3A – Unacceptable.
Sandy and salt contaminated soil contributed to rust promotion below groundline and above concrete footing.

2.4 Wood Poles

Poles may become defective and/or unserviceable due to factors such as:
- fungal decay (rot)
- termite infestation
- splitting, cracking or warping of timber with age
- vehicular impact damage.

Classify wood poles as 'suspect' where there are above ground pole defects such as:
- very large splits
- termite nests
- fruiting bodies or other evidence of head rot.

Inspect the following sites closely for rot or termite infestation:
- knot holes or borer holes
- bolt holes and where fittings attach, eg crossarm brace and pole steps
- bumps or branch stubs
- where crossarms have been checked into the pole
- splits
- under earth battens.

2.4.1 Decay

Brown Rot

Brown Rot is a crusty brown growth external to the pole, shaped like a horse's hoof. This is a mature fungal fruiting body, usually associated with internal brown rot. Fruiting body indicates that the rot is at an advanced stage and is considered unacceptable.

Note: the amount of cross-sectional area of the pole affected by Brown Rot.

If possible sound and drill the pole adjacent to the fruiting body using a 10mm drill bit.

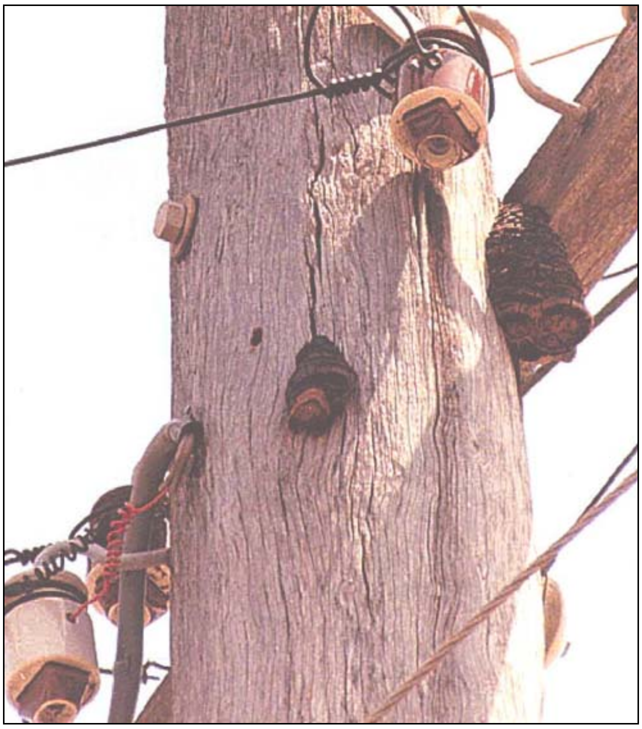
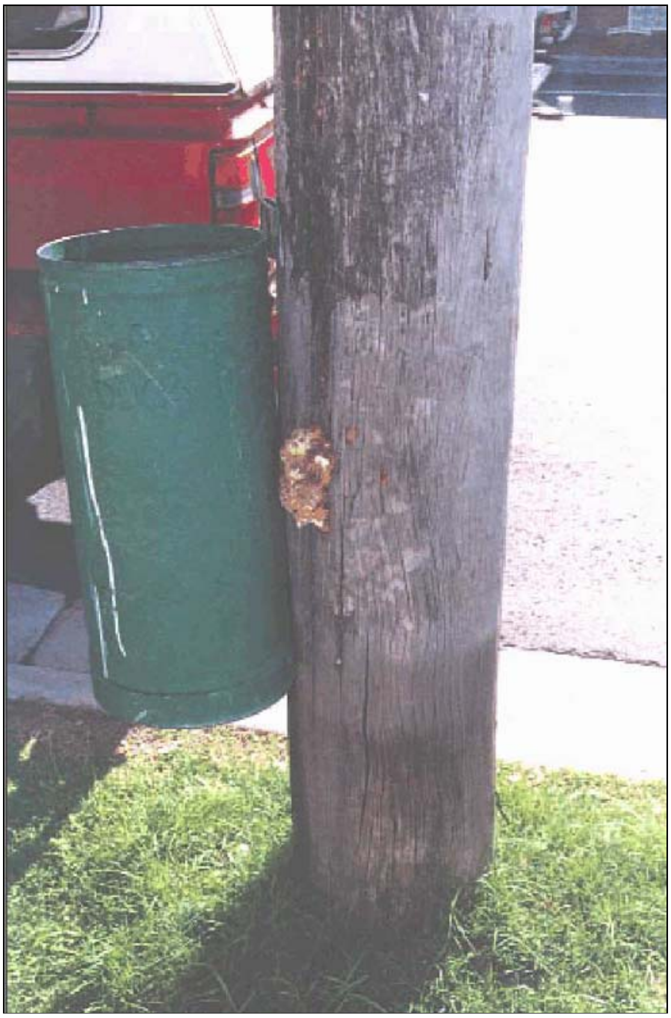


Figure 2.4.1A – Unacceptable
Internal Condition (cross section).

Figure – 2.4.1B – Unacceptable
External Indication.



Hard, crusty brown fungal growth external to the pole, growing out of pole cracks located about one metre above ground level. This is a mature fungal fruiting body, usually associated with internal brown rot.

Note: the extent of cross sectional area affected by the brown rot. An area this size will severely weaken the strength of the pole and is considered unacceptable.

As fruiting body is accessible to both ground and live line patrollers, sound and drill the pole adjacent to the fruiting body and below ground level using a 10mm drill bit.

Note: due to the internal pipe, drilling adjacent to the fruiting body may not provide a true indication of the extent of rot.

Figure 2.4.1C – Unacceptable.
External Indication.

Figure 2.4.1D – Unacceptable.
Internal Condition.

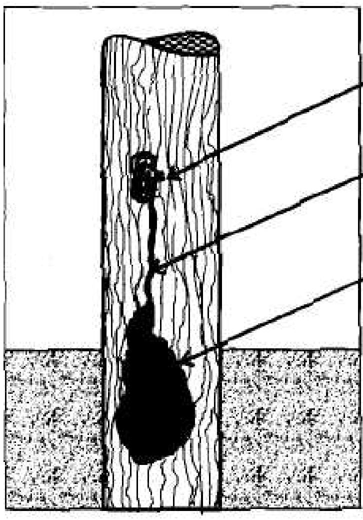


Figure 2.4.1E – Location of internal Decay.

White Rot

Figure 2.4.1F – Unacceptable
External Condition.

Figure 2.4.1G – Unacceptable
Internal Condition.

White Rot is identifiable by a white, flat growth on the pole surface and in the checks. It is located in long patches above ground.

Amount of growth indicates that rot is at an advanced stage.

Sound the pole and drill the pole adjacent to the fruiting body using a 10mm drill bit. Determine the extent of the internal rot.

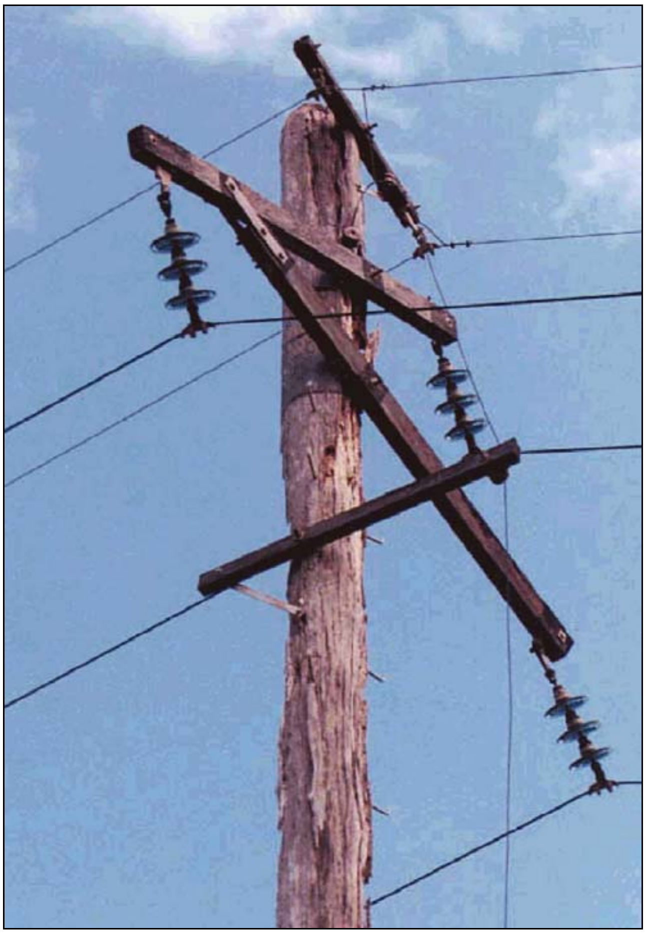


Figure 2.4.1H – Unacceptable.
External Indications.

A "shaggy" external appearance is another indication of the presence of white rot.

Note: the white rot has been accelerated by water ingress due to the missing pole cap. Indications are that the rot is at an advanced stage.

This should be reported by the asset inspector (ground based or aerial patrolling) for further investigation e.g. live line evaluation.

If possible, probe, sound and drill the pole with a 10mm drill bit.

Figure 2.4.1I – Unacceptable.
Internal Condition.

Figure 2.4.1J – Unacceptable.
External Indications.

A hard, crusty brown growth with a 'velvet' surface and irregular shape can be observed external to the pole, growing out of crossarm and pole simultaneously is an indication of internal white rot.

This should be reported by the asset inspector for further investigation e.g. live line evaluation.

If live line inspection, probe, sound and drill with a 10mm drill bit the pole and crossarm adjacent to the fruiting body.

Figure 2.4.1K – Unacceptable.
Internal Condition.

Figure 2.4.1L – Unacceptable.
X-Arm Internal Condition.

2.4.2 Termites

Note the long vertical split running down the pole. This was filled with mud. This could indicate the presence of termites within the pole.

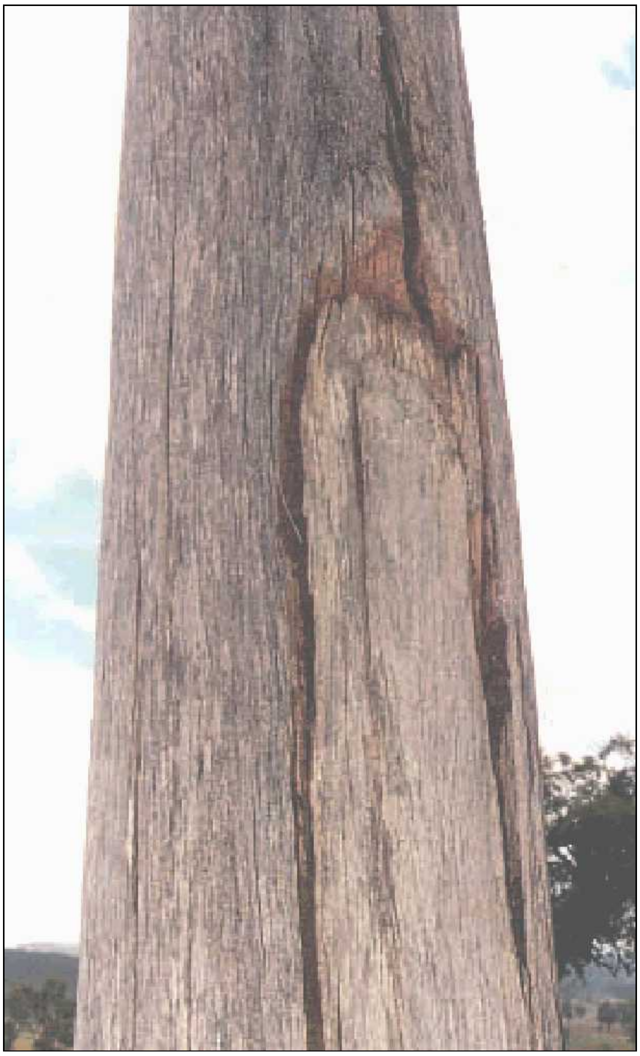
Termites fill in cracks to seal the internal chamber from the outside environment. This allows unimpeded internal destruction of the pole.

To determine the extent of internal damage, scrape out mud to see if termites are present. Sound and drill the pole with a 10mm drill bit at a number of locations around the indicated area.

Note: the amount of cross-sectional area destroyed by the termites. This would severely weaken the pole.

Figure 2.4.2A – Unacceptable.
External Indications.

Figure 2.4.2B – Unacceptable.
Internal Condition.



Mud caked checks at surface of pole, indicate termite attack. Poles are severely weakened by termites.

Confirm that the mud in the cracks is due to termites. Then sound pole and drill with 10mm drill bit at various intervals over the length of the pole (as required) to determine extent of timber loss and requirement for replacement.

Note: the amount of cross-sectional area destroyed by termites. This would have severely weakened the pole.

Figure 2.4.2C – Unacceptable.
External Condition.

Figure 2.5.2D – Unacceptable.
Internal Condition.

Figure 2.4.2E – Unacceptable.
Internal Condition.

Figure 2.4.2F – Unacceptable.
External Indications.

Earth (mud) mound with mud tracks over the entire pole length can be observed. The termite mound is at the head of the pole with associated external termite galleries

Pole raiser and crossarm could also be weakened due to termite attack.

Sound the pole and drill pole with a 10mm drill bit at various intervals over the entire pole length, raiser and crossarm.

2.4.3 Pole Caps

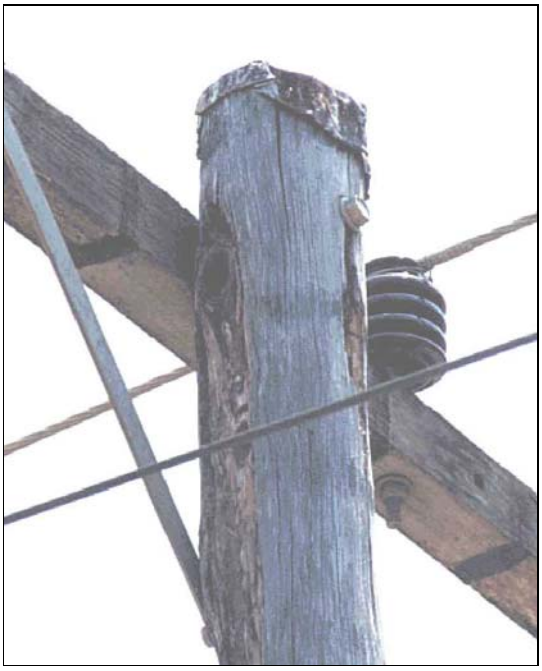
Figure 2.4.3A – Unacceptable.
Missing Pole Cap.

A missing pole cap will allow water ingress into the pole and hence speed up internal rot.
If ground or aerial patrolling, report all missing pole caps.

If live line patrolling, replace cap.

Check integrity of pole. The missing pole cap may have caused damage to the pole and if pole replacement is required.

2.4.4 Knot Holes



Knot hole and splitting associated with the king bolt. This allows ingress of moisture into the pole. This may promote the growth of fungal decay.

This should be reported by the asset inspector for further investigation e.g. live line evaluation.

If live line patrolling, sound the pole and drill the pole with a 10mm bit below knothole and adjacent to the split

Figure 2.4.4A – Unacceptable.
External Indication

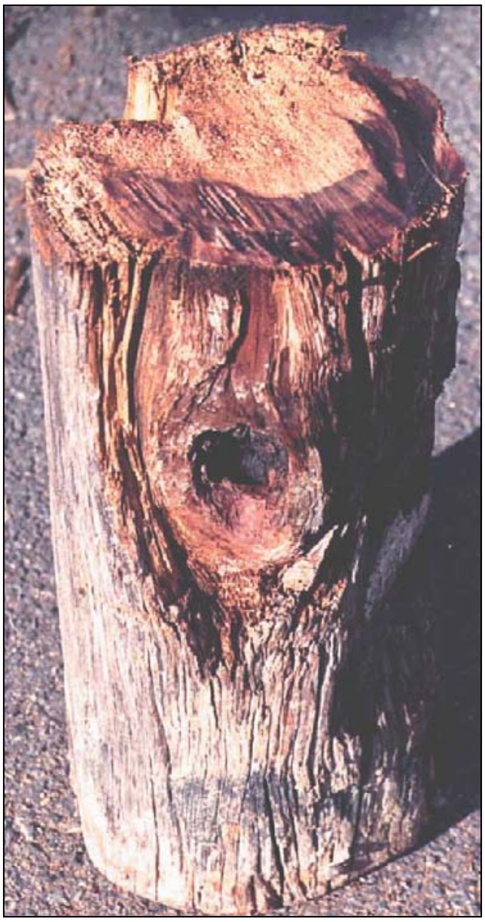


Figure 2.4.4B Unacceptable.
Internal Condition

2.4.5 Nailed or Staked Wood Poles

Defective conditions :

- cracking of poles and/or nail
- corrosion of nail
- decay around the bolts or rivets through the pole
- decay behind the nail or stakes

Figure 2.4.5A – Acceptable.
No rust or deterioration present.

2.4.6 Concrete-Rebutted Wood Poles

Defective conditions:

- Rot developing in crevices on timber above galvanized steel sleeve
- Corrosion of steel sleeve

2.5 Wood Pole Base Inspection and Strength Analysis

Pole base inspection and strength analysis requires inspection of the pole to 450mm below ground line. Strength of the pole will be determined by the tablet from the set of physical inputs.

Visual and drilling/probing inspections are used to determine the following defective conditions including:

- Internal Rot
- External Rot
- Termites
- Insufficient pole diameter
- Large cracking/splitting

Figure 2.5A – Unacceptable condition.
Reduction in pole diameter.

Figure 2.5B – Unacceptable Condition.
Reduction in pole diameter

Figure 2.5C - Unacceptable Condition.
Extensive hollow in the heart of pole.

i

Figure 2.5D – Unacceptable Condition.
Extensive splitting with rot.

Figure 2.5E – Unacceptable Condition.
Large crack through heart of pole.

Figure 2.5EF – Unacceptable Condition.
Large longitudinal crack with extensive white rot.

Figure 2.5G – Conditionally acceptable.
Large splits due to star shrinkage but no rot present. Acceptable when splits occur in the neutral axis of the pole.

Figure 2.5H – Conditionally acceptable.
External rot present. Acceptable if sound wood provides sufficient strength for the pole loading (determined by tablet) – External rot treatment required.

3. CROSSARMS

3.1 Timber X-Arm Condition Assessment – Decision Guidelines

The following chart is a guideline for assessing the condition of x-arm(s) and determining the subsequent action e.g. replacement or further detailed assessment.

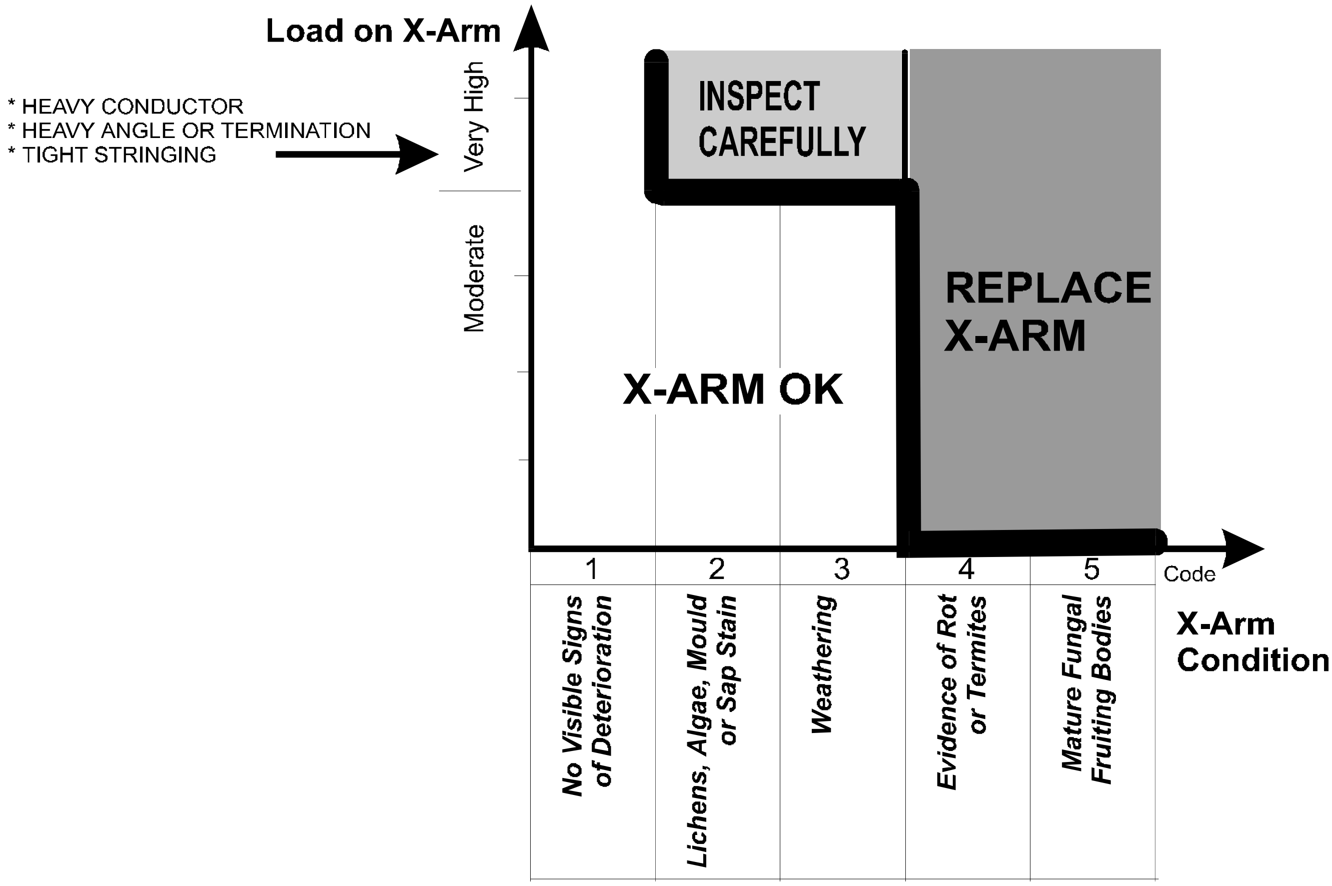


Figure 3.1A – Decision Guideline for Timber Cross Arm Condition Assessment

Evidence of rot in x-arms may be manifested by the conditions of the surrounding environment.

Things to consider are:

- Moisture content of surrounding environment
- Misshaped timber.
- Stained timber.
- Malleable timber.

3.2 Decay on X-arms

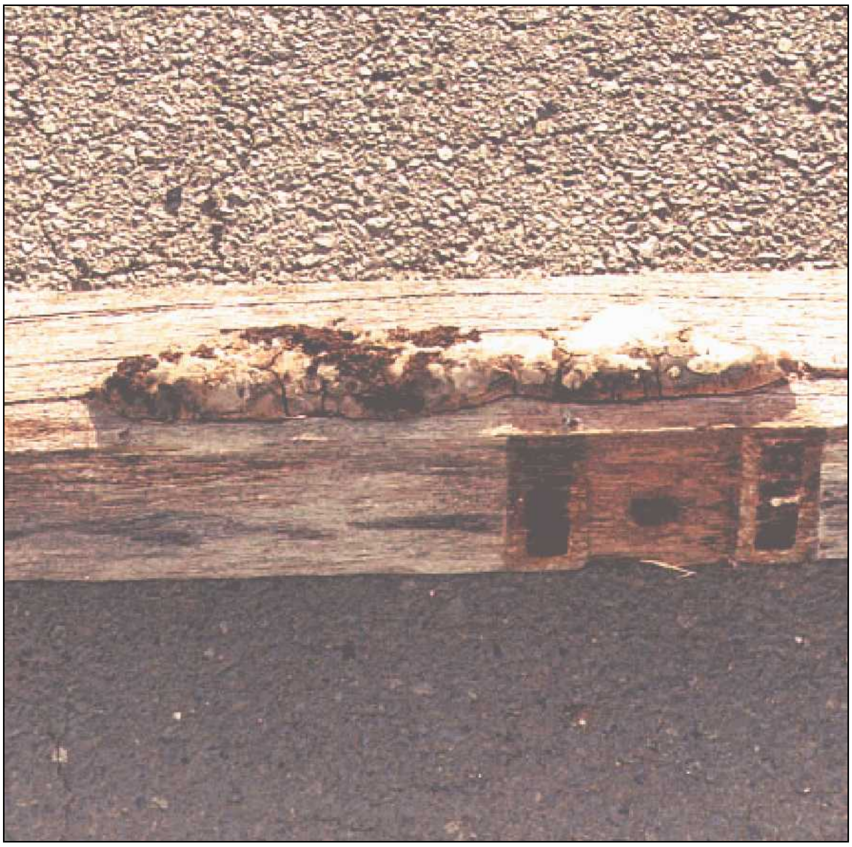


Figure 3.2A – Unacceptable.
White Rot External Indication.

A smooth or hard white growth on the outer surface of the crossarm and fine black powdery mildew growth on the surface of the crossarm can be seen.

This mature fungal fruiting body is usually associated with white rot.

This should be reported by the asset inspector (ground based or aerial patrolling) for further investigation e.g. live line evaluation.

If live line patrolling, replace x-arm.

A fruiting body present, on the timber indicates very strongly that the rot has depleted the timber and therefore the timber is no longer reliable.

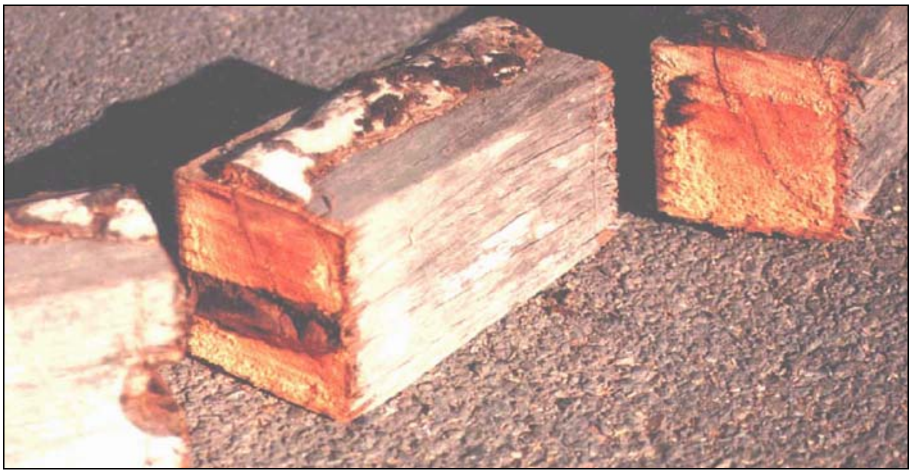


Figure 3.2B – Unacceptable.
White Rot Internal Condition.

Figure 3.2C – Unacceptable.
X-Arm Failure External Indication.

Figure 3.2D – Unacceptable.
X-Arm Failure Internal Condition.

Crusty, cream colored growth with irregular shapes external to the crossarm can be observed. The fungal fruiting body is usually associated with internal white rot.

If live line patrolling, replace x-arm.

A fruiting body present, on the timber indicates very strongly that the rot has depleted the timber and therefore the timber is no longer reliable.

This should be reported by the asset inspector (ground based or aerial patrolling) for further investigation e.g. live line evaluation.

Figure 3.2E – Unacceptable. X-arm failure due to White Rot.

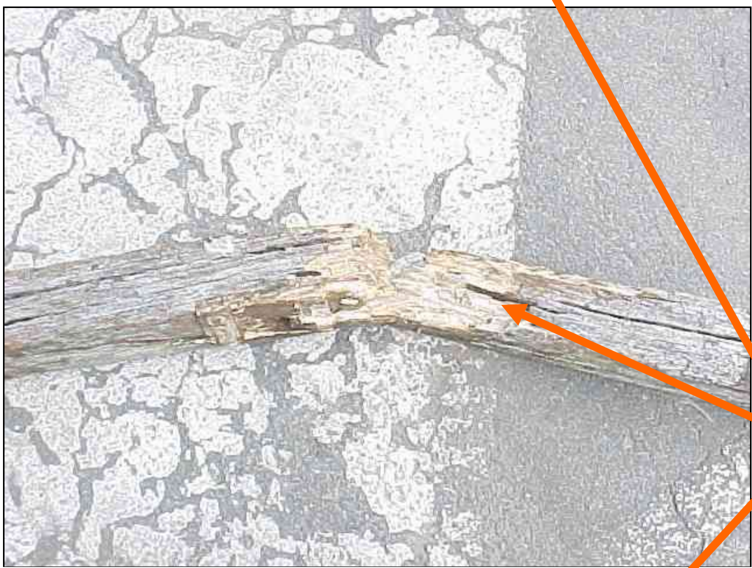


Figure 3.2F – Unacceptable.
X-arm failure.

Examples of white rot.

Report all cases of white rot. Rot can occur without a fungal body. A fungal body is just an indication of rot.

When looking for rot note different colours in the wood. For example, all three of these photos show white stripes along the timber – a tell tale sign of white rot.

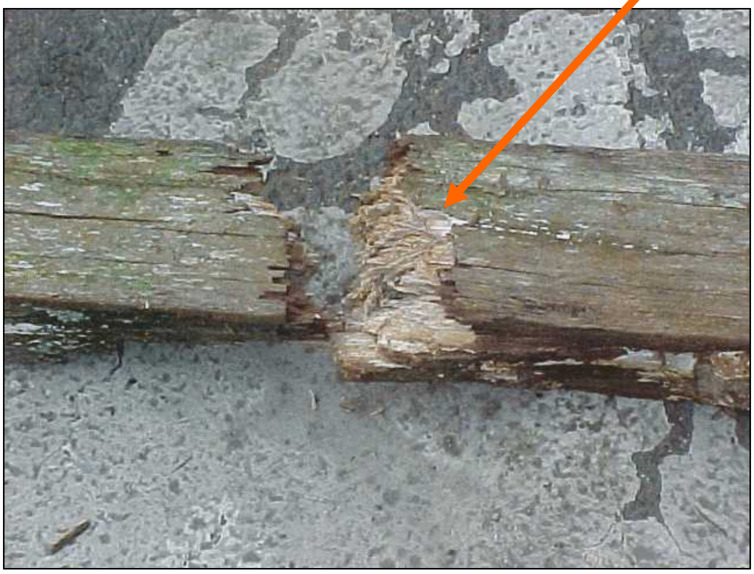


Figure 3.2G – Unacceptable.
X-arm failure due to White Rot.

Figure 3.2H – Unacceptable.
Shackle loose due to White Rot.
Note: the light coming through the hole, and the buckling of the X-arm.

Figure 3.2J – Unacceptable.
Loose shackle due to white rot.

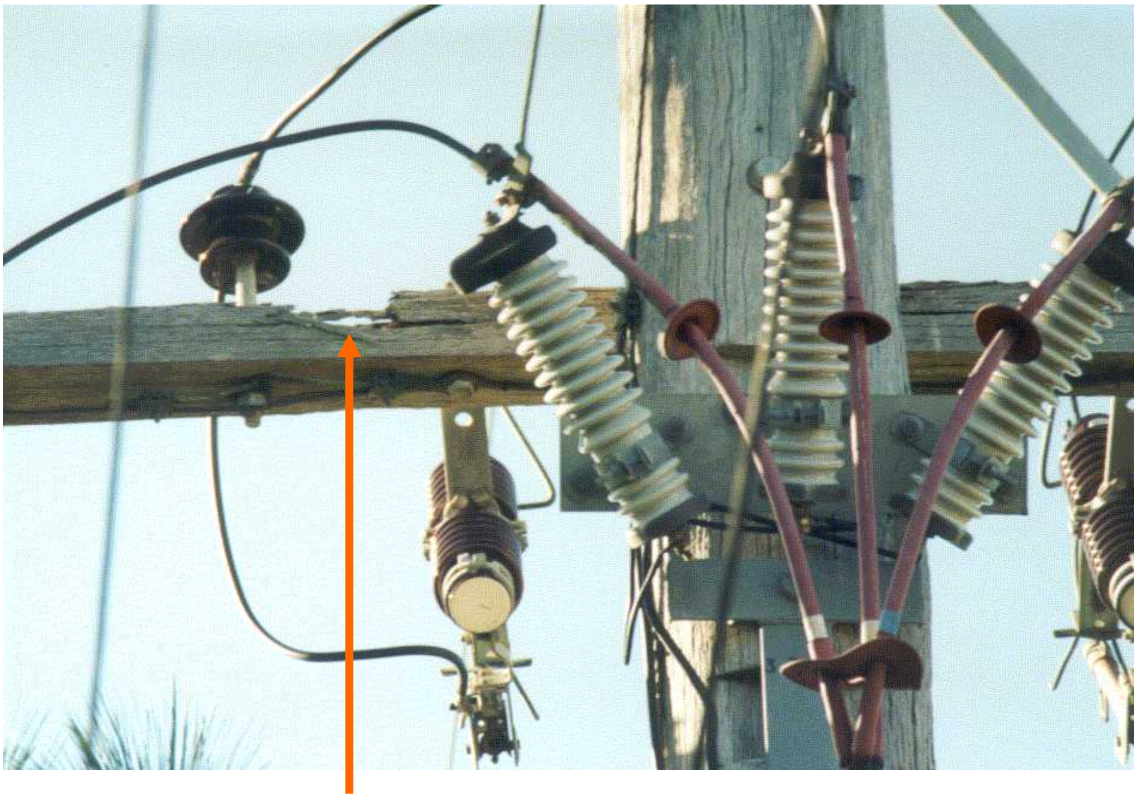


Figure 3.2K – Unacceptable.
Rotten X-arm. Failure imminent.

At least 1/3 of the x-sectional area has been lost due to rot. Note also the large crack running along x-arm.

3.3 Splitting of X-arms

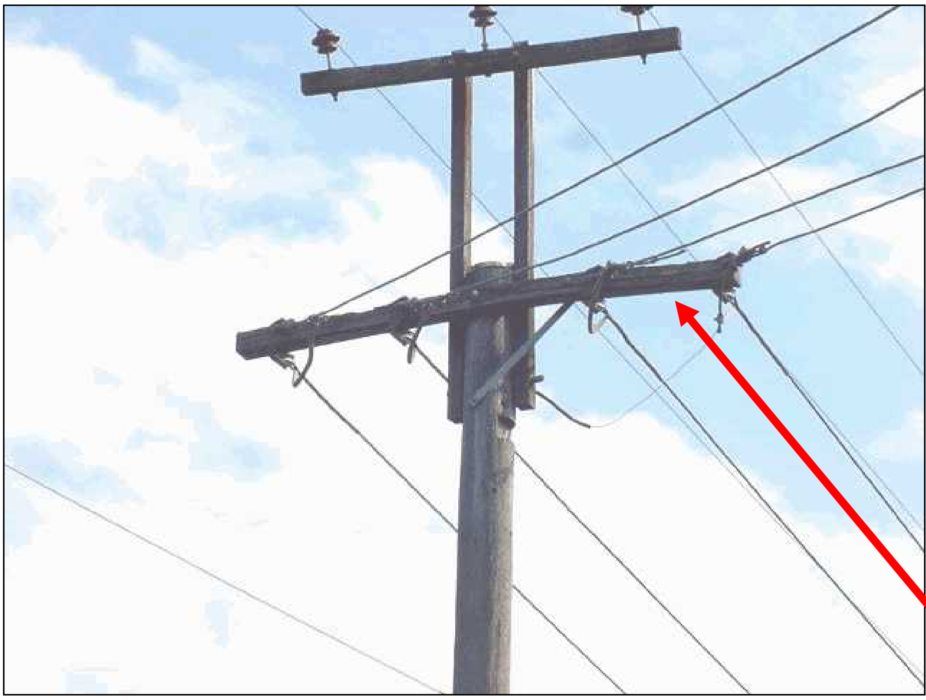


Figure 3.3A – Unacceptable.
Split in X-arm.

Long split in x-arm, causing x-arm to bend. A split as large as this affects the structural integrity of the x-arm and is therefore unacceptable.

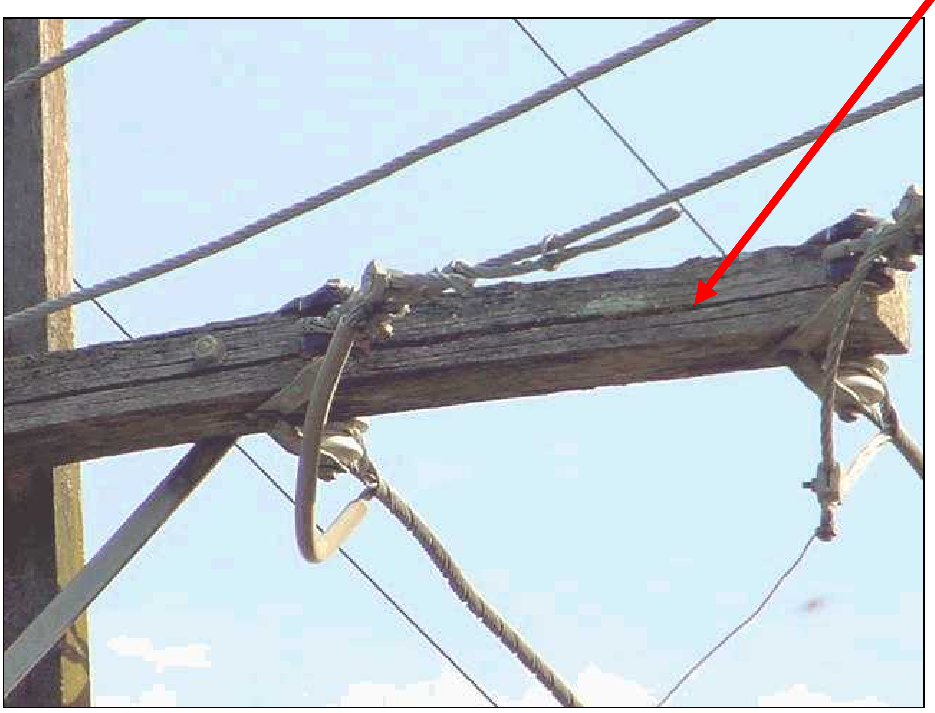


Figure 3.3B – Unacceptable.
Split in X-arm.

Figure 3.3C – Unacceptable.
A large split at the end of the x-arm is unacceptable as the bolt holding the insulator can move and potentially disengage from the x-arm.

3.4 Holes in X-Arms

Figure 3.4A – Acceptable.
Hole in X-Arm.

Hole is inside support bracket and appears to be 'natural' i.e. not a product of rot.

When inspecting holes in x-arms consider the following:

- Length and stringing tensions of span, (a short, slack span will require less strength from the x-arm).
- If the hole appears to be due to natural causes such as dislodged knots.

Amount of cross sectional area taken from the timber. The resultant decrease in strength is directly proportional to the cross-sectional area.

When considering holes in x-arm report if:

- Signs of rot exist
- Fungal bodies exist.
- Hole is on the outside of the support bracket.
- No support bracket exists.

Figure 3.4B – Acceptable.
Hole in X-Arm

Hole is inside support bracket and appears to be 'natural' i.e. not a product of rot.

3.5 Weathered X-arms

Figure 3.5A – Acceptable.
Weathered x-arm may not mean it is unservicable. If no rot is found and it is still structurally sound, the x-arm is acceptable for continued service

Figure 3.5B – Acceptable
Weathered x-arm. No rot found, still structurally sound. Acceptable for continued service.

Note: although Lichen is visible on x-arm, when x-arm was checked by live line team no rot was found.

Figure 3.5C – Acceptable
Weathered X-Arm.

Lichen is visible, however timber has no rot and is therefore acceptable.

Note leaning insulator. No burn marks are visible, x-arm is wood, insulator is mechanically and electrically acceptable, thus leaning insulator is acceptable for continued service.

Figure 3.5D – Acceptable.
Weathered X-arm.

Lichen is visible, however timber does not appear to have been adversely affected and is therefore acceptable.

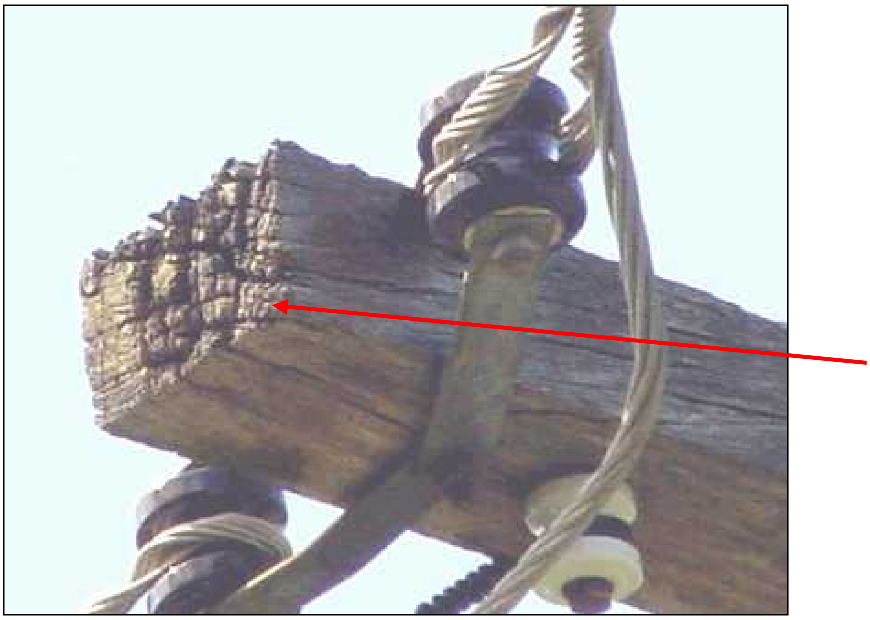


Figure 3.5E – Acceptable.
Weathered X-arm.

Evidence of end splitting occurring. Splitting has not affected structural or electrical integrity of x-arm. X-arm acceptable for continued service.

3.6 Other X-arm Defects

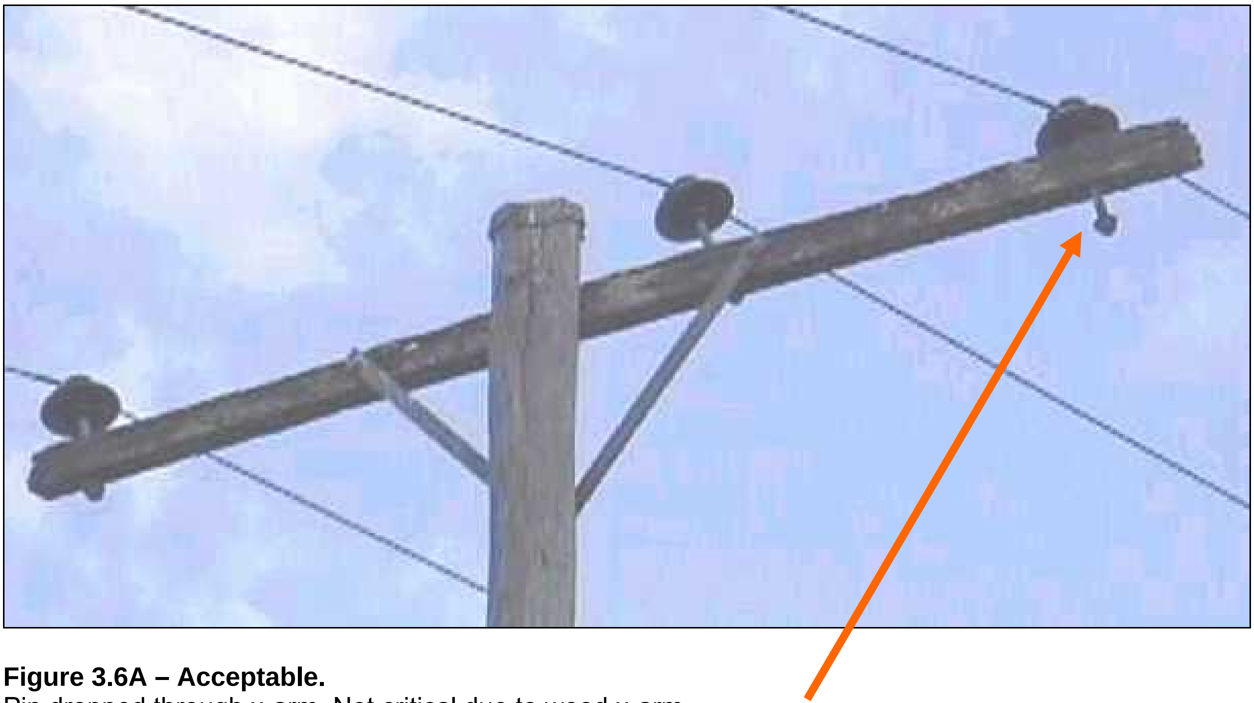


Figure 3.6A – Acceptable.
Pin dropped through x-arm. Not critical due to wood x-arm.
Check X-arm very carefully for signs of rot. If rot present report.

Figure 3.6B – Acceptable.
Insulator leaning. Not critical due to wood x-arm.

4. POLE MOUNTED PLANT

4.1 Transformers

Report pole mounted transformers if:

- Dripping oil (i.e. active leak). A good indication of an active leak is dead grass/vegetation below transformer.
- Surface pitting badly due to rust. Oil may weep through walls if surface pitting bad enough
- No oil in sight glass (if visible)
- Timber platform rotting
- Steel platform rusting, so as to affect its structural strength. Surface rust is acceptable.

No action if:

- Oil leak from roof. A leak from the roof of a transformer is likely to be due to expansion of the oil.
- Oil smear. An oil smear could have occurred during installation
- Oil leak from sight glass. An oil leak from sight glass is acceptable, visually inspect sight glass for oil level.
- Surface rust. Surface rust unlikely to cause transformer to fail

Note: an active oil leak is identified by its shiny appearance. An inactive or dormant oil leak has a relatively dull appearance.

Figure 4.1A – Acceptable.
Surface rust on transformer. Unlikely to result in transformer failing.

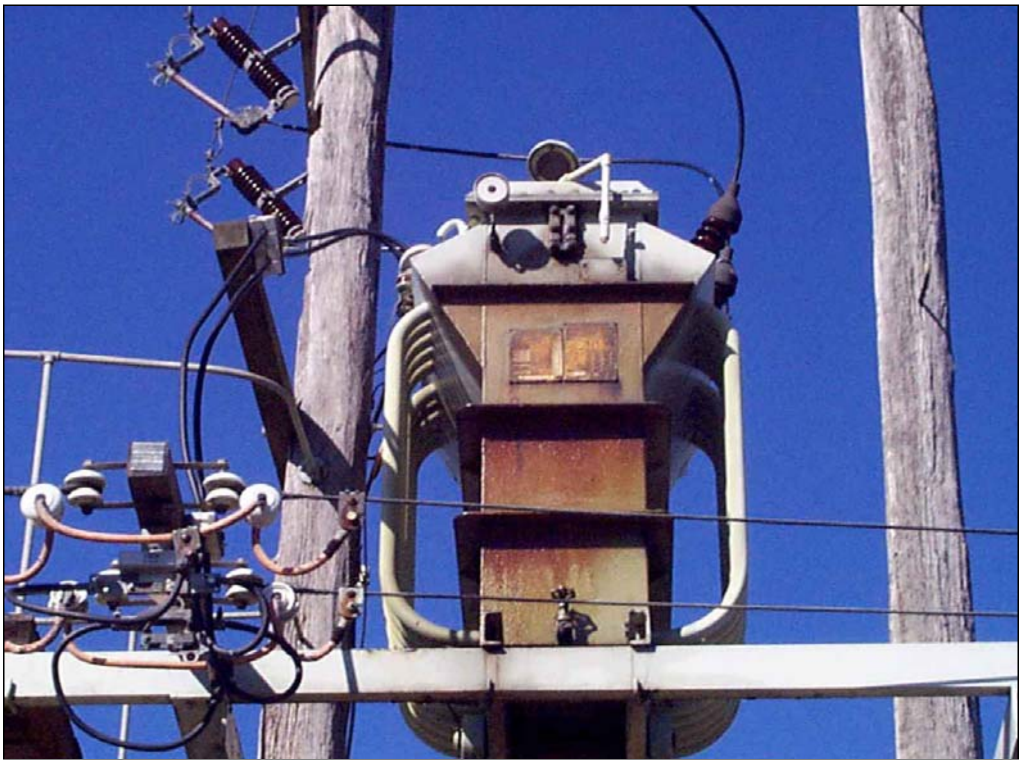


Figure 4.1B – Acceptable.
Surface rust on Transformer.

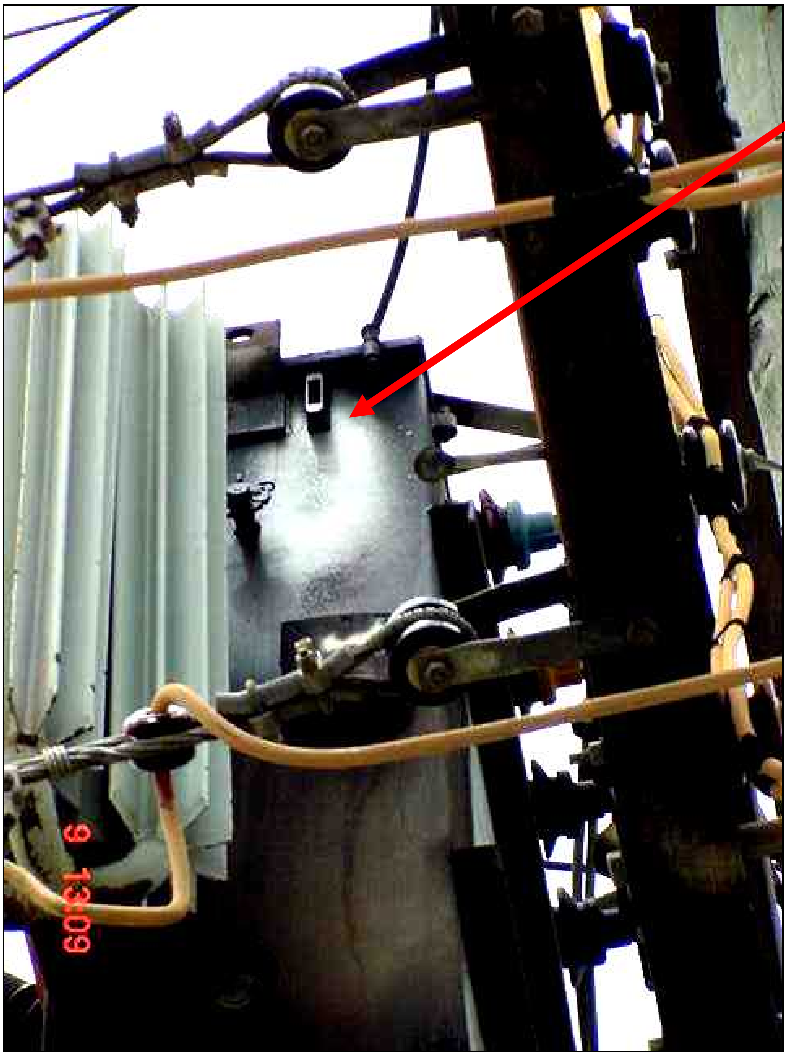


Figure 4.1C - Unacceptable
Active oil leak from sight glass.

Note: the shiny appearance of the leak.

Figure 4.1D – Acceptable.
Old / Inactive oil leak from lid of transformer.

Note: the dull appearance of the leak.

4.2 Underground Terminations

Report U/G terminations if:

- Leaking is occurring.
- Insulating tubes are bulging.
- Splitting or cracking has occurred.
- Wildlife is living on or in very close vicinity to U/G termination.
- Insulators are burnt or have unacceptable deficiencies.

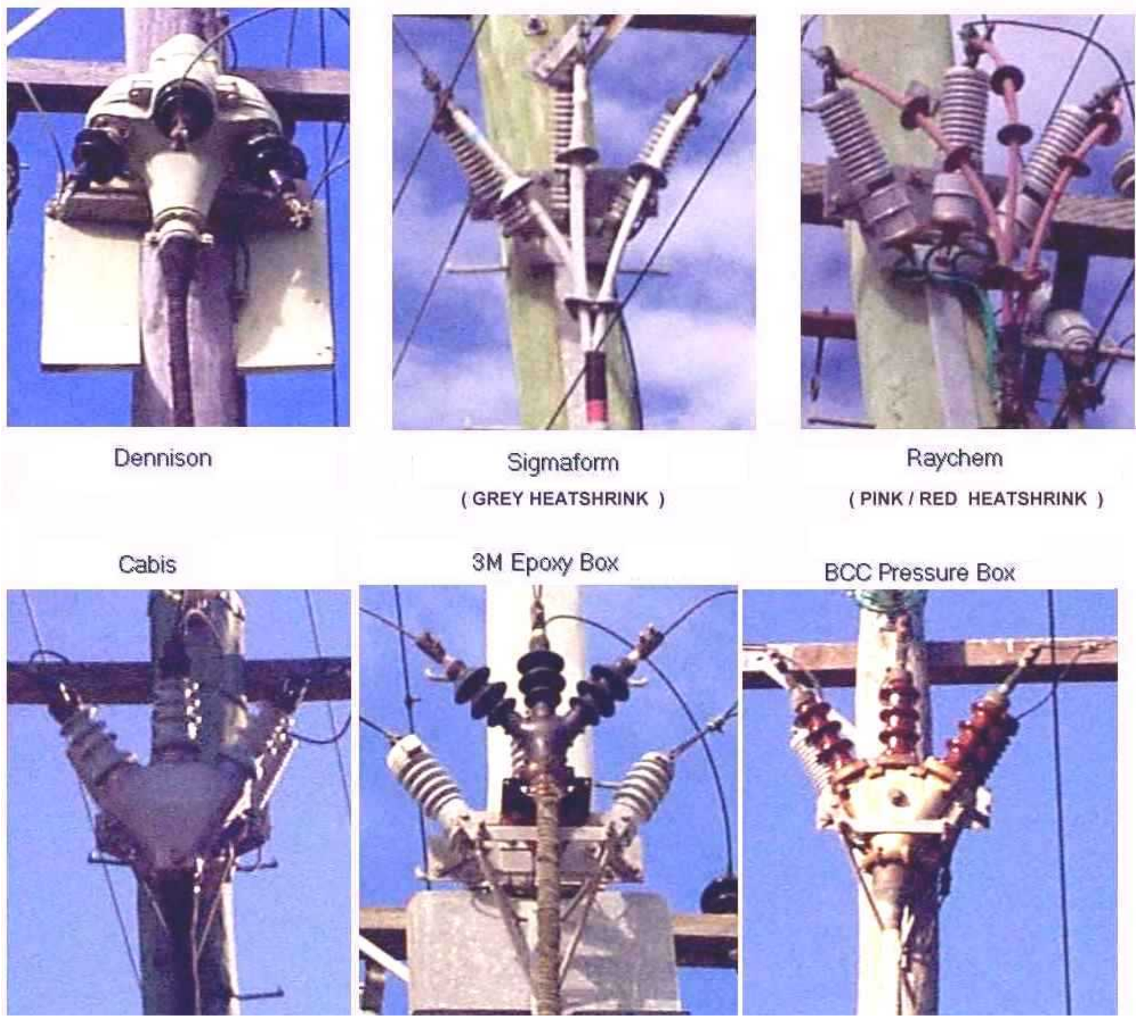


Fig 4.2A – 11kV U/G Terminations for identification purposes.

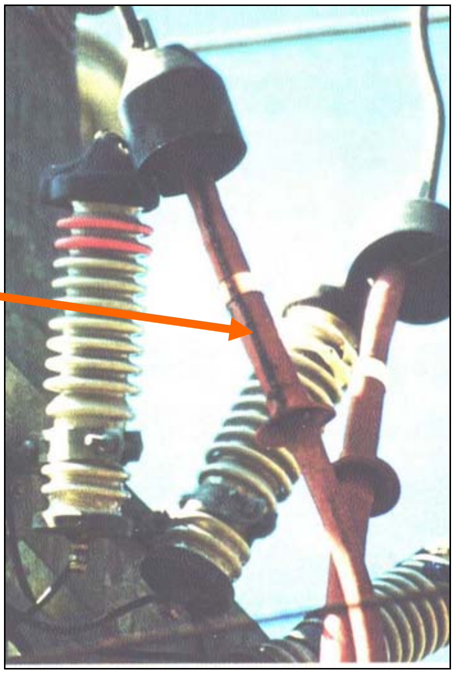


Fig 4.2B – Unacceptable.
Compound leaking from top of insulating 'tubes' on Raychem pothead.

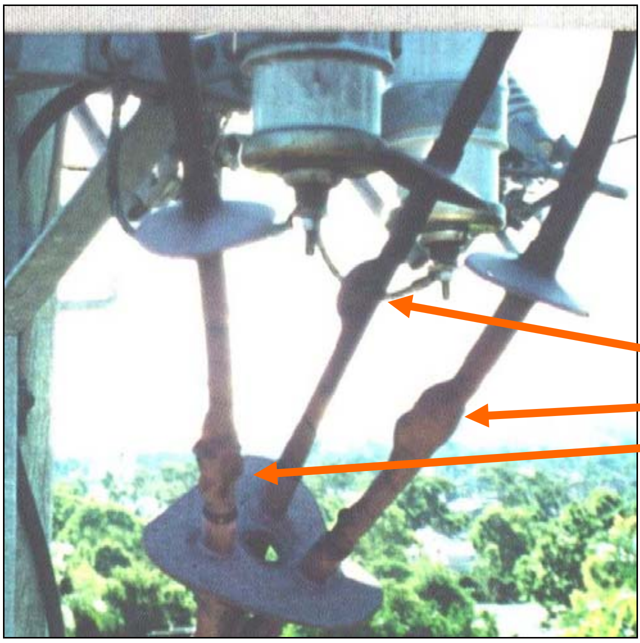


Fig 4.2C – Unacceptable.
Insulating 'tubes' on Raychem pothead bulging due to internal electrical discharge.

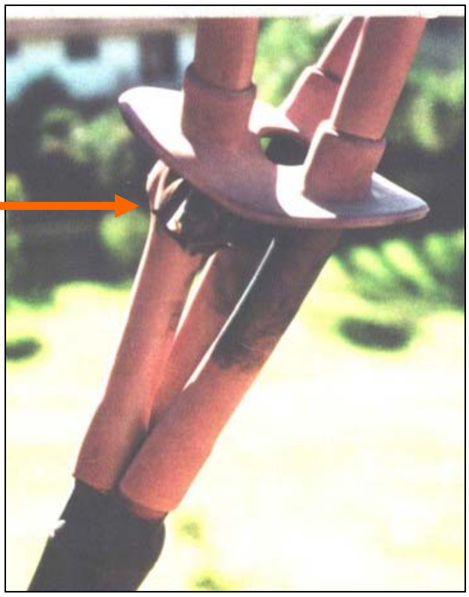
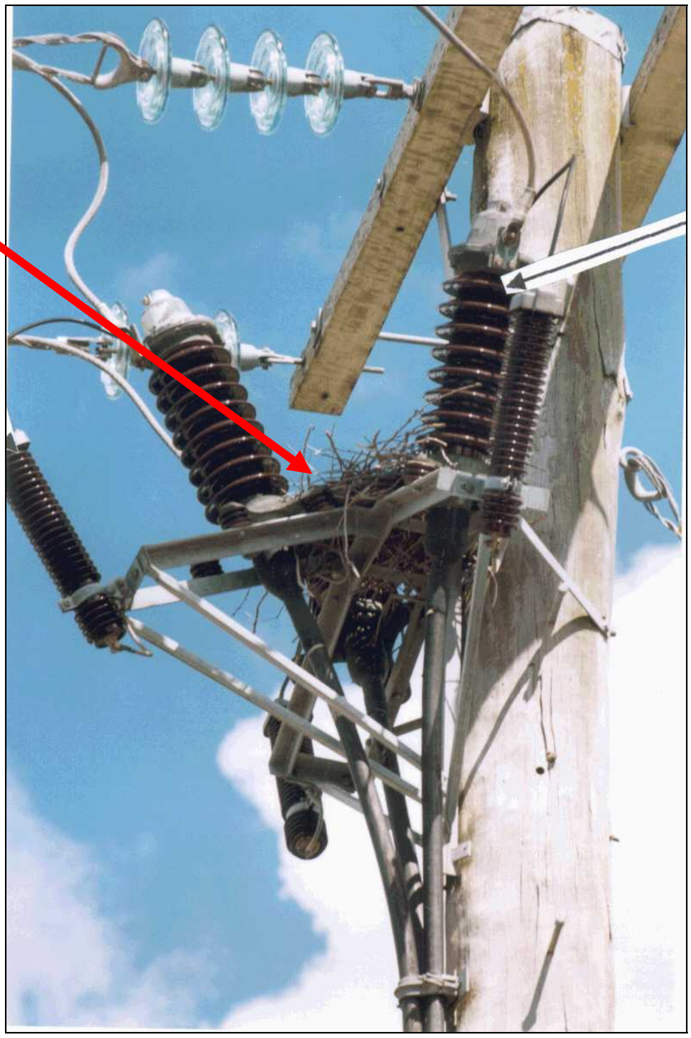


Fig 4.2D – Unacceptable.
Split below sheds on Raychem pothead.

Fig 4.2E –Unacceptable.
Birds nest on U/G termination.
Potential cause of faults.



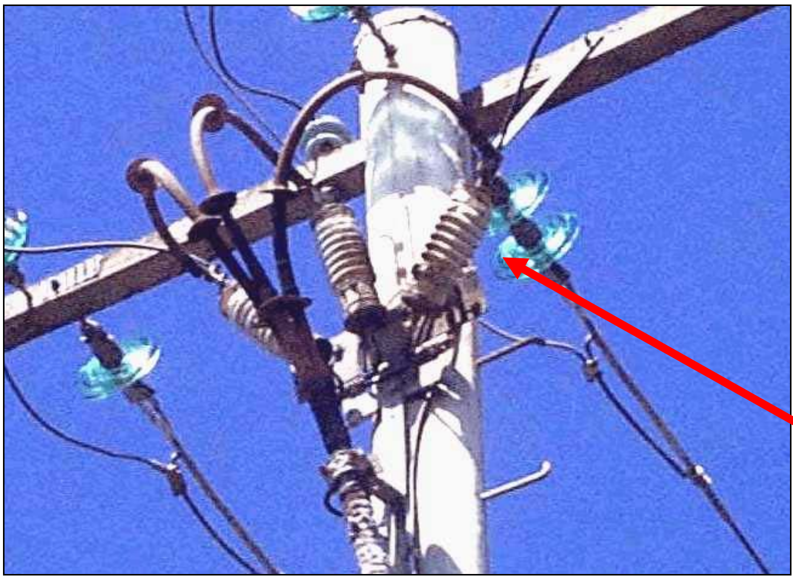


Figure 4.2F Unacceptable.
Burnt insulators.

4.3 Air Break Switches

Report an ABS if:

- Insulators are broken/cracked such as to significantly decrease the electrical creepage distance.
- Burn marks are evident on insulators.
- Fingers are missing.
- Arcing is occurring around contact points.
- Arcing horns are welded closed on an open ABS.
- Earthing on downrods is missing or degraded to such an extent that it is compromised.
- X-arm is deteriorated to such an extent that it is no longer reliable, i.e. very significant rust on steel x-arm, or wood x-arm has significant rot etc.

Figure 4.3A – Acceptable.
Unitised type ABS, for identification purposes.

Figure 4.3B – Acceptable.
Side Swinger type ABS, for identification purposes.

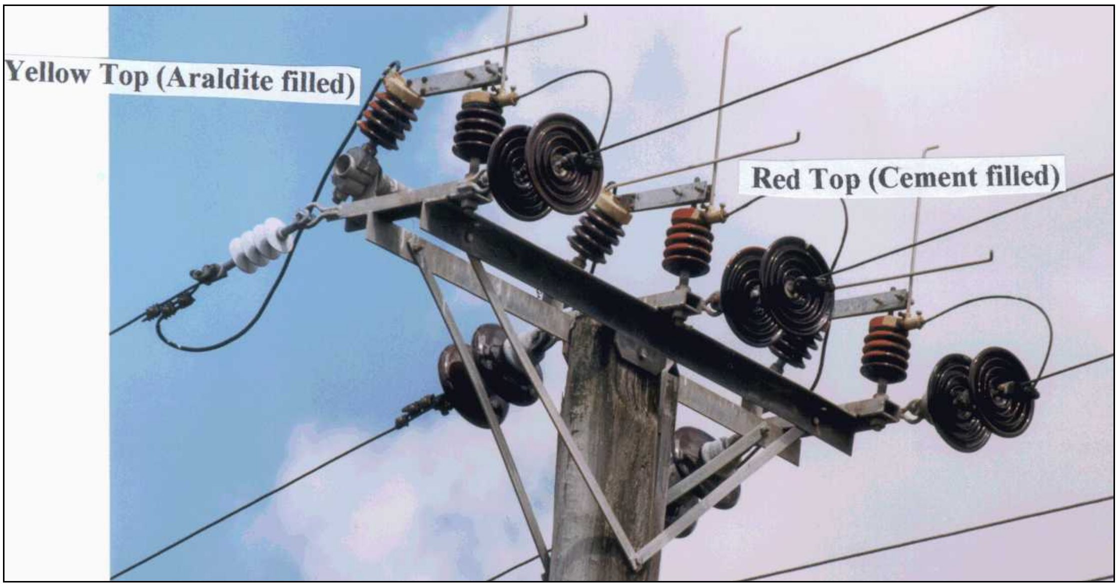


Figure 4.3C – Acceptable
Chopper type ABS, for identification purposes.

5. HARDWARE

5.1 Insulators

When assessing insulator quality, report:

- Any insulator that has lost more than 25% of it's electrical creepage distance.
- That has significant cracks and chips penetrating through the glazing.
- Noticeable tracking on surface of insulator

Cracks and chips that penetrate through the glazing will allow ingress of moisture into the porcelain, over time this will greatly reduce the insulators insulating qualities.

Figure 5.1A – Unacceptable.
Cracked insulator on ABS. Unacceptable due to length and severity of crack.

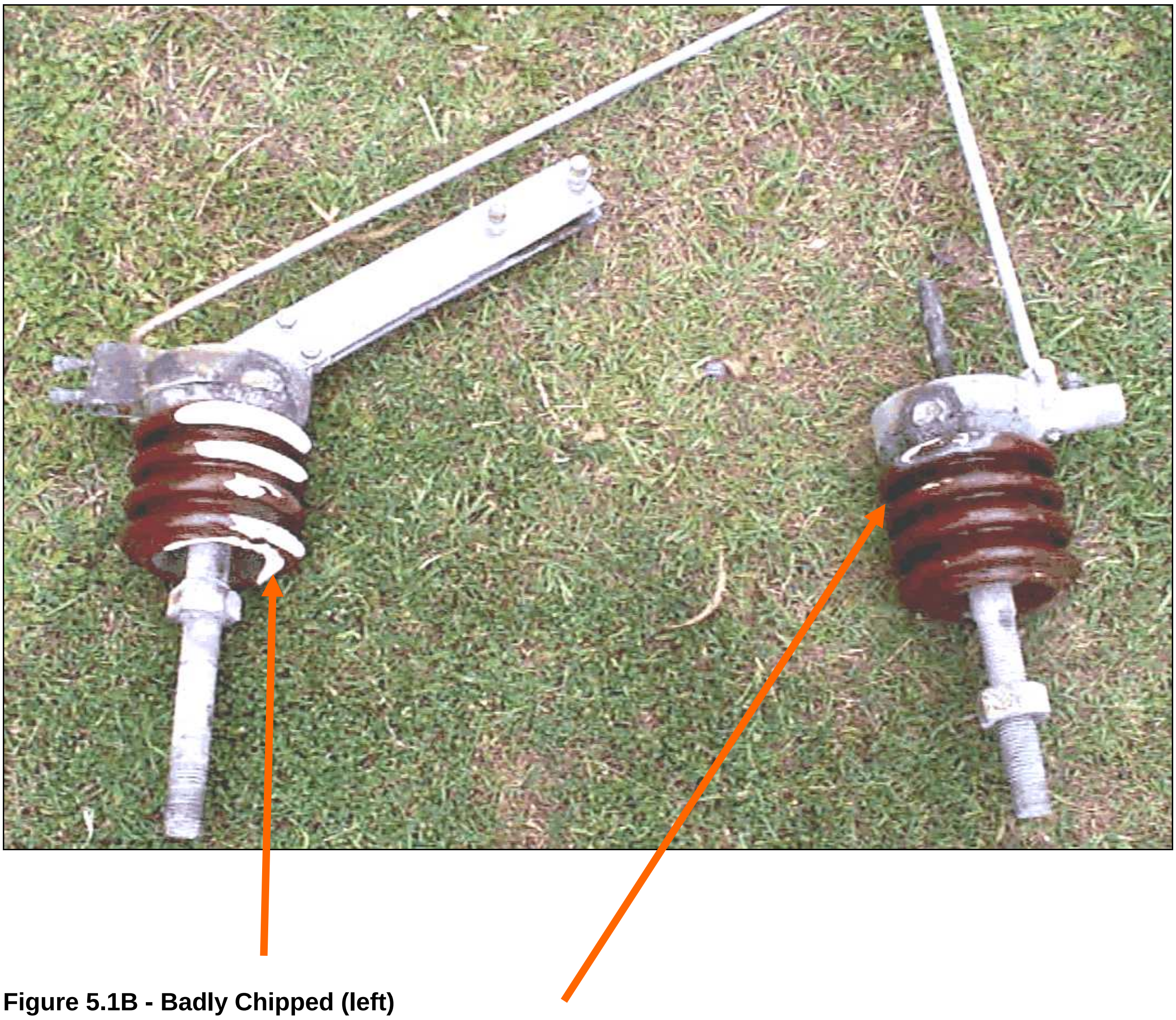


Figure 5.1B - Badly Chipped (left)
Unacceptable and burnt Insulator Acceptable (right).

Chipped insulator is unacceptable due to severity of chipping. Only one shed is affected on the burnt insulator and hence burnt insulator is acceptable.

5.2 Clamps

Report clamps if the electrical and/or structural integrity of the insulator is unacceptable e.g.

- Clamp visually loose
- Burn marks are visible
- Corrosion is present.

Figure 5.2A – Unacceptable.
Burnt out split bolt clamp.
Note how clamp has burnt through allowing mains or bridging to fall.

Figure 5.2.B – Damage to Conductor from Loose Split Bolt Clamp.

5.3 Wildlife Proofing

Wildlife proofing should be fitted on pole mounted distribution transformers, pole top underground cable terminations and vertical shackles. Partial or non-standard wildlife proofing should be upgraded, wherever practicable, to the present standard.

Tubing and shroud fitted to droppers and surge arresters if mounted on steel cross arms on a concrete pole

Tubing fitted to droppers. Leave bare 700mm from top of fuse.

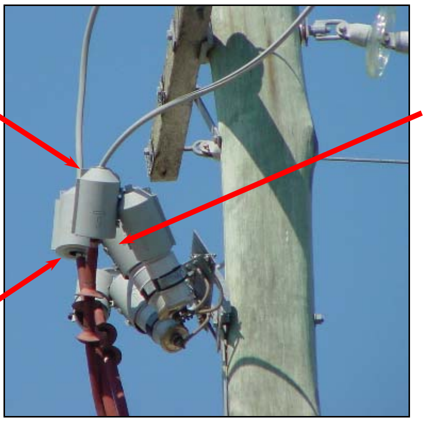
Fargo GS-560 shroud (stock code 17270). Clipped under top shed of bushing

On new installations only Vinidex tubing is fitted to LV droppers and mains for approx, 2m either side of transformer.

Figure 5.3A – Acceptable
Wildlife proofing for distribution transformer.

Where 10mm tube is used, fit tube into shroud entry.

Two shrouds per phase



Lightning arrester bar goes between shrouds through cut out . No tape required anywhere on this termination (unless large tube is used)

Figure 5.3B – Acceptable
Wildlife proofing of Raychem Heatshrink or 3M Coldshrink.

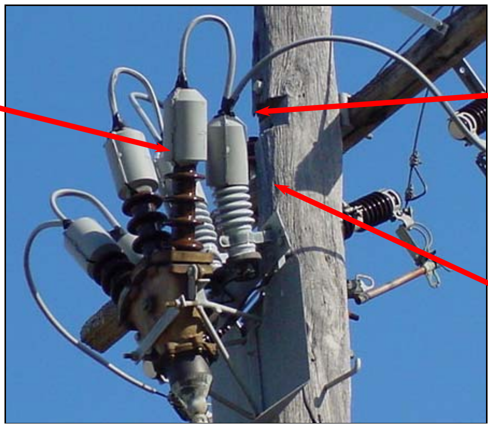


Figure 5.3C Acceptable
Wildlife proofing of porcelain U/G termination.

5.4 Ground Stays

Visually inspect ground stays for defects such as :

- corrosion
- frayed or broken strands
- missing or damaged stay guards
- insufficient tension (slack) on the ground stay.

6. CONDUCTORS

Questions to consider when inspecting conductors are:

- Are mains close to coastal spray?
- Are mains in an area of high industrial pollution?
- Are dissimilar metals present?
- Is moisture abundant?
- If rust is present, is rust surface rust?
- If not surface rust how much rust is present?
  note: As a rough guide, when corrosion has reduced the outer cross-sectional area by more than 20% the conductor needs to be replaced, as most of the strength of these conductors comes from the outer layers.
- Has the conductor expanded in volume?
  note: Corrosion products – rust, etc tend to have a much greater volume than the original metal, leading to expansion of the conductor.
- Are the conductors subject to mechanical fatigue?
- Are burn marks evident on the conductor?
- Are the conductors showing signs of stranding? (especially smaller cables such as 7/.080 and 7/.104)

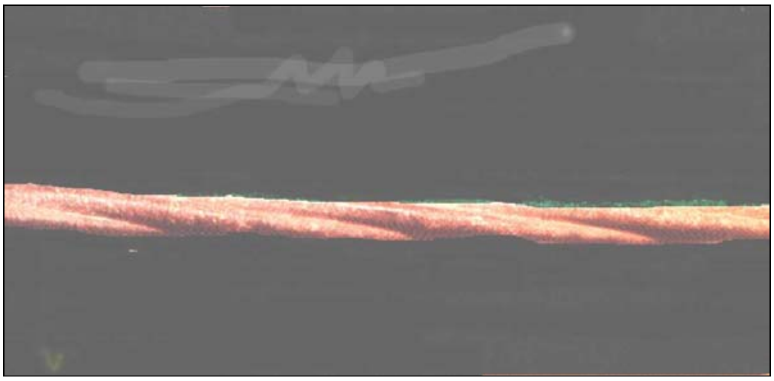


Figure 6.A – Acceptable.
Superficial rust on galvanized steel conductor.

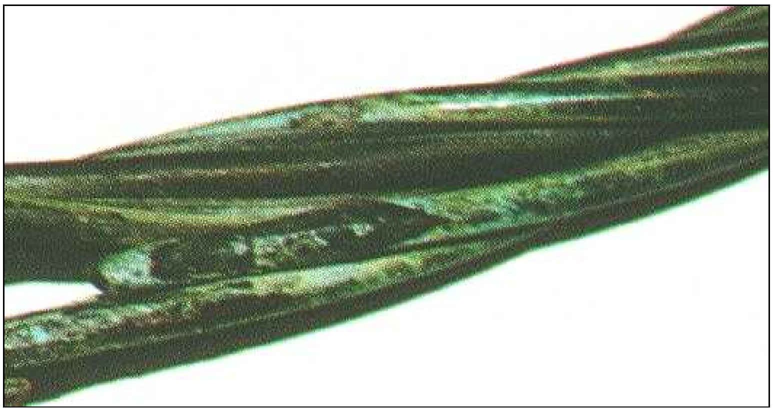


Figure 6.B – Acceptable.
Greenish-black oxide layer on copper conductor.

Figure 6.C – Unacceptable.
Advanced rusting of galvanized steel conductor.

Figure 6.D – Unacceptable.
Severe rusting of galvanized steel conductor under helical splice.

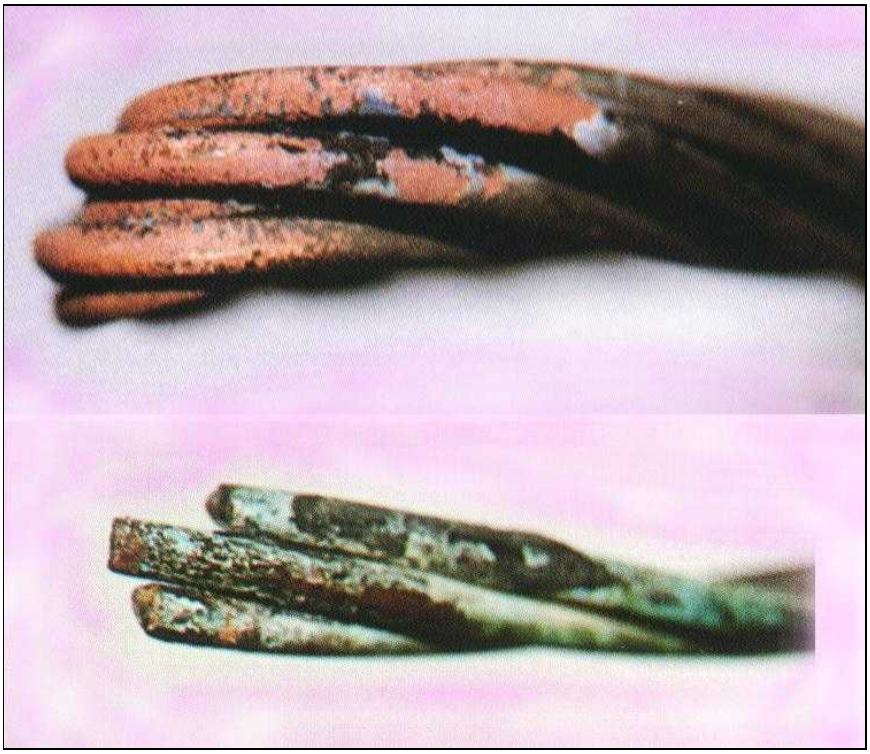


Figure 6.E – Unacceptable.
Advanced corrosion of copper conductor.

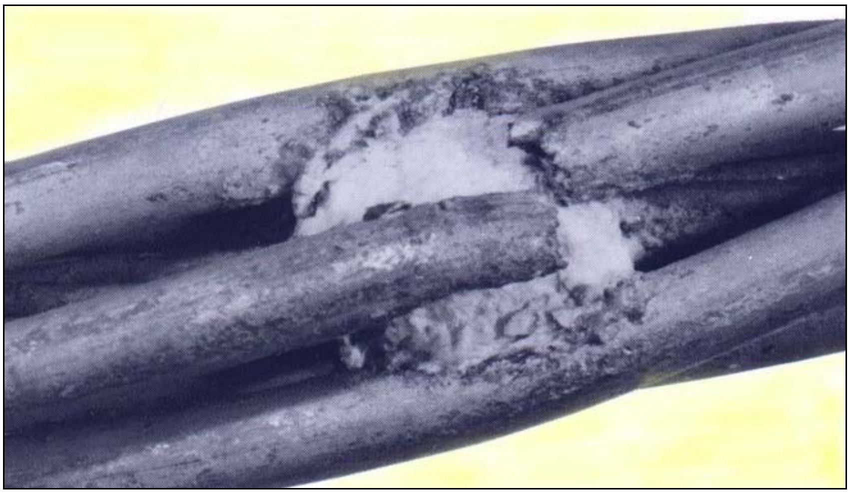


Figure 6.F – Unacceptable.
Advanced corrosion of ACSR conductor.

7. VEGETATION

7.1 Vegetation Requirements

Vegetation clearance specifics and associated requirements are detailed in the Mains Asset Maintenance Policy (MAMP).

Particular note should be made regarding the identification of:

- Inappropriate tree species and
- Trees with structural defects.

7.2 Guidelines for Vegetation Management

In accordance with the Mains Asset Maintenance Policy, vegetation should be identified for trimming/removal in potentially hazardous situations i.e. where it is likely to impact on the performance and/or safe operation of the power lines.

When conducting an assessment of the vegetation in an area consideration should be made regarding existing vegetation management agreements with other parties, including Memorandums of Understanding, wayleave and easement requirements.

Questions to consider when assessing vegetation are:

- Is vegetation climbable and, if climbed by person, may result in personal contact with mains?
- Is the vegetation within the clearance zone?
- Evidence the vegetation has or may cause conductor clashing?
- Could vegetation impede access to pole or plant?
- Are branches likely to interfere with conductors, insulators, pole mounted plant etc?
- Is the vegetation of weak structure or have dead branches likely to fall onto mains?
- Are there dead trees of sufficient size nearby likely to fall on the mains?
- Is the vegetation of a species likely to shed large branches?
- Does vegetation allow wildlife to circumvent wildlife proofing?
- Is the vegetation identified for clearing/trimming considered rare/threatened species?
- Is the vegetation an inappropriate tree species?

7.3 Examples of Unacceptable Vegetation

Figure 7.3A – Unacceptable.
Report, as Palm growing directly under mains.

Figure 7.3B – Unacceptable.
Report as trees are climbable to within touch distance of mains. Trees well into clearance zone.

Figure 7.3C – Unacceptable.
Trees allow wildlife to circumvent wildlife proofing.

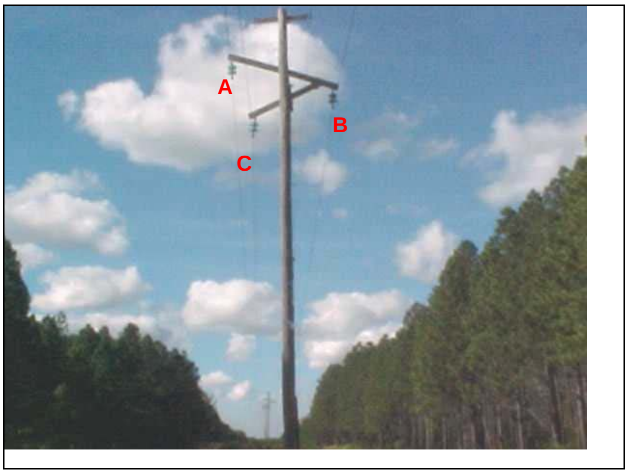
Figure 7.3D – Unacceptable.
Vegetation through LV and just touching 11kV - well within clearance zone.

8. DESIGN CONSIDERATIONS

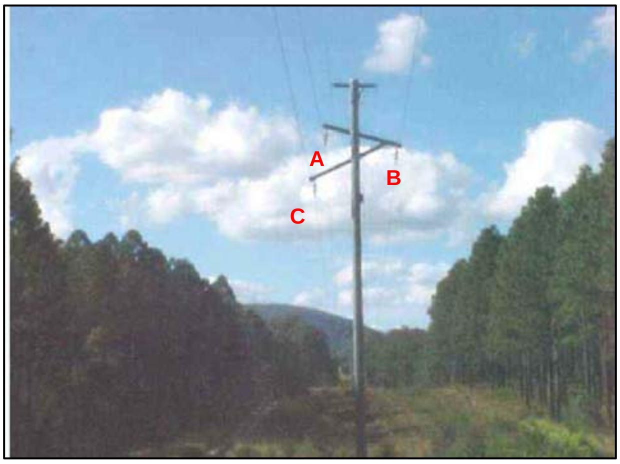
Some overhead network constructions may cause unnecessary outages, resulting from conductor clashing, or compromise minimum electrical clearances.

Report the following:

- Long, slack spans where conductor clashing is noted
- Underslung suspensions (with two phases on one side) where conductor clashing is noted
- Pin constructions with spans greater than 130 m
- Suspension constructions with spans greater than 100 m remote from a substation or 80m near a substation
- Transition from the old to new 33kV wishbone constructions (Figure 8.1A)
- Transitions from 33kV vertical delta to flat constructions (Figure 8.1B)
- Where statutory , phase to phase or phase to earth clearances are compromised (Figure 8.1C)



Old 33kV Wishbone Construction



New 33kV Wishbone Construction

Figure 8.1A – Transition from old to new 33kV wishbone constructions
May compromise the minimum electrical clearances – Phases A and C crossed.

Figure 8.1B – Transition from 33kV vertical delta to flat construction
May compromise minimum electrical clearances

Figure 8.1C – 33kV electrical clearances between steel crossarm and conductor
May be compromised by birds. Bird proofing required (Vertical Shackle).

APPENDIX A – NON DESTRUCTIVE TIMBER CONDITIONS

Lichens, algae and moulds are commonly found growing on external surfaces of x-arms and poles, often in shady gullies and mountainous areas with high rainfall.

These growths do not attack or weaken timber structures. However these are an indication of the frequent wetting of the surface, and may be an indicator that good conditions exist for fungal growth.

A1 Lichens

These may consist of leathery encrustations or may be embedded in the timber. Colour is usually grey-green, although they may also be orange-brown or black.

Various types are:
- crustose – crust-like flat appearance on surface
- fruticose – shrubby appearance, standing up or hanging down
- foliose – spreading leaf-like appearance.

A2 Algae

Algae will grow on virtually any substrate, including ironwork, if moisture levels are adequate and there is insufficient illumination.

Algae appears green, reddish-brown or black. It consists of powdery deposits or filaments which appear slimy when wet.

A3 Moulds

Mould growths occur on any substrate where adequate nutrients are available, either from the substrate itself or in the form of accumulated dirt or dust.

Mould appears as spots or patches which spread to form a furry layer on the surface of the substrate. Colour is usually black, green, grey or brown.

A4 Sap Stain

Sap stain varies in colour – blue and grey to black.

It does not have any appreciable effect on timber strength, although it may reduce shock resistance.

While stained timber does not decay significantly faster than sound timber, conditions which favour the development of sap stain also favour decay, so sap stained timber should always be carefully examined for other indications of rot.

A5 Weathering

Loss of moisture occurs as timber ages, particularly on surfaces exposed to the sun and at end-grain. This leads to shrinkage and cracking.

The repeated wetting and drying of timber exposed to the weather causes it to alternately swell and shrink. This process causes cracks and splits to develop. Provided the splits are not severe, the timber is not significantly weakened. However the cracks may provide a lodging place for fungal spores.

Figure A1 - Weathering

Figure A2 - Mould
Grey, Green, Brown or Black in Color

Figure A3 - Lichens
Green, Grey, Black or Orange in Color

Figure A4 – Algae
Green, Brown or Black in Color

APPENDIX B – DESTRUCTIVE TIMBER CONDITIONS

B1 Stages of Decay

There are various stages in the process of decay. In the earliest stages, the wood appears to be hard and firm, the only evidence of attack, if any, being a slight to marked colour change from the normal. This is known as the "incipient" or "initial" stage. In some cases, there is no indication of incipient decay, hyphae extending for 1/2 metre or more longitudinally in advance of the visible evidence of rot. Such a hidden stage can only be detected by a microscope or by cultural work. Incipient decay is dangerous as it can be easily overlooked and in some forms, particularly brown rot, the wood is seriously weakened in the incipient stage and should not be used where strength is required.

After the incipient stage has passed, the wood becomes more and more noticeably affected until it is finally completely changed in appearance and structure, with the continuity of the wood tissues destroyed. This is known as the "Advanced" stage, in which generally the strength of wood is so reduced it can be crumbled between the fingers or easily broken. It is often common to see in one piece of timber a gradation from advanced to incipient decay to sound wood.

Fungus requires oxygen, moisture and a substrate to feed upon. It tends to be ‘light-shy’, developing inside the timber. The internal timber condition is usually far worse than it appears externally.

There are numerous types of rot only the most common classes affecting poles and cross-arms are discussed.

B2 General Macroscopic Characteristics of Decay

The appearance of fungal decay depends not only on the species of fungus and kind of timber concerned, but also on the stage of attack that has been reached. The incipient stage of any particular kind of rot is often entirely different to the more advanced stages, the latter being readily apparent to the unaided eye.

The indications of fungal decay include some or all of the following characteristics:

i) Colour Changes

Decay in wood is almost invariably accompanied by a change in colour; it may become bleached in the case of a white rot or darkened in the case of a brown rot. It should be remembered, however, that colour changes may be absent in the incipient stage of some decays. In timber in use, the first sign of decay may be a dark brownish spotting or streaking, or flecks of lighter colour depending on the species of fungus and type of wood involved. Certain fungi that cause white rots may form narrow black lines, called zone lines, which may outline the badly decayed areas.

ii) Softening

On testing an area of incipient decay with a knife, it will usually be found that the texture of the wood has been softened and that it is impossible to prise up a long splinter as the fibres break off quickly over the top of the knife owing to their loss of toughness, that is, they have become brash. Even slight incipient decay greatly reduces the strength of wood.

iii) Change of Density

Decayed wood is less dense than sound wood owing to destruction of the wood substance by the fungus. Wood in a very advanced stage of rot may be extremely light and yet retain its outward form. Excessive lightness is a good indication that the wood is in an advanced stage of decay but in practice, this test is often unreliable as the wood may be light owing to the nature of its growth (eg very rapidly grown softwood may be much below the average density for the species).

iv) Change in Odour

Wood affected to any appreciable extent by fungal decay may have a "mushroomy" smell, but the presence of such an odour, although generally indicative of damp conditions which favour the development of moulds, does not necessarily mean that there is any actual decay present. However, a clean, fresh resinous smell is a fairly good indication, especially in softwoods, that the wood is sound.

v) Shrinkage

Decayed wood shrinks more on drying than sound wood does, and this difference is more obvious in brown rots than it is in white rots at the same stage of decay.

B3 The Chemistry of Decay

Decay fungi decompose wood by secreting enzymes and acids which, in the presence of moisture, dissolve cellulose, lignin and other constituents of wood. These are absorbed and used as nutrients by the fungus.

Decomposition of wood by fungi is of two main types which have been described as brown and white rots respectively. In brown rot, the cellulose and related constituents are attacked while lignin is left in a more or less unchanged condition, in white rot, the lignin may be preferentially utilised or all the components of the wood are decomposed.

Decay Type	Nutrient Source	Appearance of Decayed Timber
Brown	Polyoses (cellulose)	Reddish brown to dark brown blotches or streaks, cross-cracking, softening, powdery mud-like residue. **Common at pole base.**
White	Lignin & Polyoses	Bleached appearance, flecks and blotches whiter or darker than the natural colour, softening, black or darkish zone lines, pulpy or fibrous residue. **Common in x-arms, pole head and pole base.**
Soft	Polyoses	Darkening, cracking, surface softening, mostly found in timber with high moisture content, wet patches, surface cracking. **Common around insulator pins in x-arm and outside of VPI pole bases.**

B4 Brown Rot

Brown rot fungi utilise cellulose and the related constituents of the cell wall and leave lignin in a more or less unchanged condition, hence wood attacked by these fungi takes on a brown colour. Because the "stiffening agent", lignin is left virtually untouched the form of the original cell wall is preserved. Microscopically, the cell wall is not appreciably thinned until a very late stage of decay when nearly all the cellulose framework has been removed. Another microscopic feature of the cell wall resulting from attack by brown rot fungi is the presence of bore holes.

In the incipient stage, brown rot is characterised by dark brown blotches or streaks. In the advance stage of decay, affected wood is brownish. Invariably, shrinkage cracks are associated with brown rot, badly decayed wood breaking up into cube-shaped fragments, hence the term "brown cubical rot".

Individual fragments may be easily crumbled between the fingers. The strength of wood may be seriously reduced by brown rot, even in its incipient stage. Quite often, individual cubes may be separated by mycelial matting.

B5 White Rot

White rot fungi may preferentially utilise the lignin within cell walls or perhaps more commonly may break down all the components of wood. Because of this, wood affected by white rot fungi is generally of a bleached appearance. Two microscopic characteristics of cells attacked by white rot fungi are the presence of bore holes through the walls, and a general thinning of the cell wall, particularly when decay is more advanced.

In the incipient stage, wood may contain flecks or blotches which are whiter or darker than its natural colour, depending on the type of wood and the species of fungus attacking it.

There are basically two types of white rot in the advanced stage, but in both affected wood is whitish in colour. The first is the fibrous, stringy white rot. When dry, the wood is punky and friable and is reduced to a state where it is easily crumbled between the fingers. Black or darkish zone lines are often found associated with this type of rot and, as contrasted to brown rots, the wood very rarely contains shrinkage cracks.

The fungus tends to be ‘light-shy’ and gives little evidence of its presence on the exterior surfaces of the infected timber.

The second type of white rot is the white pocket rot, so called because, in the advanced stage, affected timber contains pockets of white rot which are separated by areas of hardwood. Quite frequently, wood containing white pocket rot may be subsequently attacked by brown rot fungi which break down the areas of hardwood separating the individual pockets of white rot.

B6 Soft Rot

Because soft rot fungi use only the cellulose of cell walls of infected wood, wood affected by soft rot fungi is generally darkish. Conifer (softwood) wood is generally more resistant to soft rot decay probably because of the higher lignin content of its cell walls.

In contrast to the other types of decay, the rate of deterioration by soft rot is directly correlated with the amount of nitrogen and therefore it is more active in wood which is in contact with soil or with water containing nutrients in solution. Several soft rot fungi not only tolerate very high moisture contents but actually cause more rapid decay in timber containing 100% moisture content. They survive long periods in fairly dry wood and revive quickly on re-wetting.

Soft rot fungi are resistant to wood preservatives, particularly those based on fluorides and chromates and are more tolerant of copper levels that are sufficient to prevent attack by white and brown rot fungi. Some soft rot fungi are also more resistant to heartwood extractives and can survive slightly alkaline conditions and thrive at higher temperatures than other decay organisms can tolerate.

Contrary to white and brown rots, which may occur internally within a piece of timber, soft rots are usually found in the exposed superficial layers of wood. The most common situations in which soft rots are found are:

1 crossarm fixing points, i.e. insulator pins; and
2 on the ground and below ground level on surfaces of poles, even in CCA-treated poles.

Attack by soft rot fungi differs microscopically in a major way from that of white and brown rot fungi in that, instead of fungal hyphae decomposing cell walls by passing through them they extend in a general longitudinal direction within the secondary wall so that, in cross section, attacked cells display roughly circular cavities in the secondary wall. As with the brown rots, cells subjected to soft rot attack retain their shape and walls do not appreciably thin until almost all the cellulose is utilised.

In the advanced stage, wood affected by soft rot is very soft and cheesy when wet. When dry, the wood is very brittle and develops shrinkage cracks similar to wood affected by brown rot.

B7 Mature Fungal Fruiting Bodies

Fungal fruiting bodies, of which mushrooms and toadstools are best known, are the reproductive structures of decay fungi. Fruiting bodies are the structures in which spores are made and dispersed. Fruiting bodies can take many forms.

The presence of fruiting bodies usually indicates that the timber resource is becoming depleted or unstable for fungal growth, and the fungus is ‘moving on’ to colonise a new substrate.

If the timber substrate is depleted or unstable for fungal growth, then, in order for the genes of the fungus to survive, it must reproduce and disperse to colonise a fresh substrate. In order to do this in an isolated unit of timber such as a crossarm, it must produce spores.

Therefore the appearance of a fruiting body on a crossarm or pole is a strong indication that the timber can no longer support the growth of the fungus and that decay is extensive.

The fruiting body may appear some distance from the centre of fungal decay.

Fruiting bodies vary in appearance. Some common types have the following appearance:

- crusty brown growth
- white flat growth
- crusty brown growth with velvet surface and irregular shapes
- smooth or hard white growth with black powdery mildewy segments
- rusty cream growth with irregular shapes
- orange semicircular or tongue-like growth.

These growths often emanate from cracks or splits in the timber.

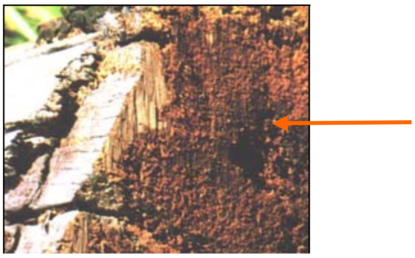


Figure B1 - Brown Rot
consumes polyoses

Incipient Stage:	Dark brown blotches or streaks
Advanced Stage:	Powdery mud-like appearance, cross-cracking on surface

Common at pole base.

Figure B2 - White Rot
consumes lignin & polyoses

Incipient Stage:	Whitish flecks, light or dark blotches, colour change observable over length of timber.

Figure B3 - Advanced Stage
Bleached, pulpy appearance, dark zone lines shrinkage cracks, fibrous residue.
Common in cross-arms and pole heads, also in pole bases.

Figure B4 - Soft Rot
consumes polyoses
Darker than surrounding timber, with surface cracking.
Found where moisture levels are high.
Common around insulator holes in cross-arms and exterior of VPI pole bases.

Figure - B5 Mature Fruiting body
Velvety Surface, Irregular Shape

Figure B6 - Mature Fruiting Body
Orange or Rusty-Cream Growth

Figure B7 - Mature Fruiting Body
Creamy-White Growth

Figure B8 - Mature Fruiting Bodies
Crusty Brown Growths

Figure B9 - Mature Fruiting Body
Flat White Crust

Look Carefully in All Cracks and Holes for Fruiting Bodies!

APPENDIX C – CORROSION

This appendix has been included to provide background knowledge and guidance on corrosion.

C1 Factors Causing Corrosion

Corrosion is an electrochemical process in which metals oxidise. For corrosion to occur, the following elements are usually present:

Oxygen – from the air

Moisture – rain, dew or condensation. Corrosion in accelerated in pockets where moisture may accumulate, e.g. on top of insulators, beneath insulator skirts, between conductor strands or under sleeves.

Electrical potential difference – due to dissimilar metals (possibly connectors or ties) or leakage currents

Salts – due to coastal spray, industrial pollution, dust accumulation, water washing salts from one metal down over another.

C2 Galvanised Steel

In the galvanising process, steel is dipped in molten zinc. The protective coating of zinc corrodes sacrificially, i.e. instead of the steel, and at a much slower rate. However, once the zinc layer is exhausted, corrosion progresses rapidly.

As the zinc layer corrodes, it produces a whitish-grey oxide layer. Once this layer is exhausted and the zinc-steel alloy layer is exposed, a light-coloured superficial rust will form on the surface.

Once the alloy layer has corroded away, dark red/brown rust will form, leading to pitting of the surface.

Apart from corrosion over time, the protective zinc layer on a conductor may be damaged due to lightning, flashover, conductor clashing or abrasion with the insulator, armour rods or ties.

C3 Copper

Copper soon discolours in the weather, assuming a greenish-black appearance.

When severely corroded, a thick, brittle green/black crust develops and rough reddish-pink metal may be exposed wherever the crust flakes away. This can cause conductor strands to become cracked and very brittle.

C4 Aluminium

When exposed to the air, aluminium develops a dull greyish-white oxide layer. It is self-passifying, protecting the aluminium from further oxidation. However, should the aluminium come into contact with certain other metals, or salts washed from these metals, the aluminium will corrode rapidly.

Where aluminium is abraded, it may leave a black wear mark on the surface, e.g. on a porcelain insulator.

C5 ACSR Conductor

When the zinc coating of the galvanised steel strand has corroded away or suffered mechanical damage, the electrochemical reaction between the bare steel and the aluminium will cause corrosion of the aluminium. Due to the large volume of aluminium oxide produced, ACSR conductor will tend to swell.

C6 Corrosion Product

Corrosion product – rust, verdigris, aluminium oxide – tends to have a much greater volume than the original metal. Therefore corrosion may lead to swelling, resulting in cracking of components such as porcelain or timber crossarm around an insulator stem.

C7 How much Corrosion can be Tolerated?

The amount of corrosion that can be tolerated depends upon how critical the component is and what the consequences of failure will be.

As a *rough* guide, it is recommended that conductors or other structural components be replaced when corrosion has reduced their cross-section by 10 – 20%, since much of the strength of these components is derived from their outer layers.

Components that are subject to mechanical fatigue, e.g. due to wind forces/vibration, are particularly susceptible to weakening by corrosion.

APPENDIX D - CHARACTERISTICS OF WOOD

D1 Tree Growth

There are three main parts to the tree-roots, trunk and crown, each with a particular function.

The Root System

The extensively branched root system provides a firm anchorage against forces exerted on the above-ground parts by storms or strong winds and, at the same time, supplies essential water and mineral salts which it extracts from the soil.

The Trunk

The trunk, in which timber users are primarily interested, conducts water and mineral salts to, and manufactured food materials from, the crown, stores food and provides the rigidity necessary to keep the crown above competing vegetation. The components of the trunk as taken progressively from the outer circumference to the centre of the tree in a radial direction are:

1. The **outer bark** is a corky layer of dead tissue whose chief function is to protect the tree against external damage and to reduce loss of water by evaporation. It is provided with breathing pores (lenticels) to aid gaseous exchange (oxygen intake and disposal of carbon dioxide to the atmosphere).

2. The comparatively soft, moist **inner bark** is the tissue through which food manufactured in the leaves is conducted down to the branches, trunk and roots.

3. Next comes a thin layer of cells called the **cambium**. This zone is invisible to the naked eye and is responsible for all growth in trunk thickness. It builds wood cells on the inside and bark cells on the outside. Any increase in diameter or length in a tree is due to the addition of new wood cells, not elongation of individual cells. Thus, a cell laid down at a particular time always maintains the same height above ground level and distance away from the pith. The same applies to any article embedded in a tree, such as nails, fence rails or fencing wire. Outward growth continues in layers beyond it. In ringbarking, it is the cutting of this cambium which causes the tree to die (see Figures D1 and D2).

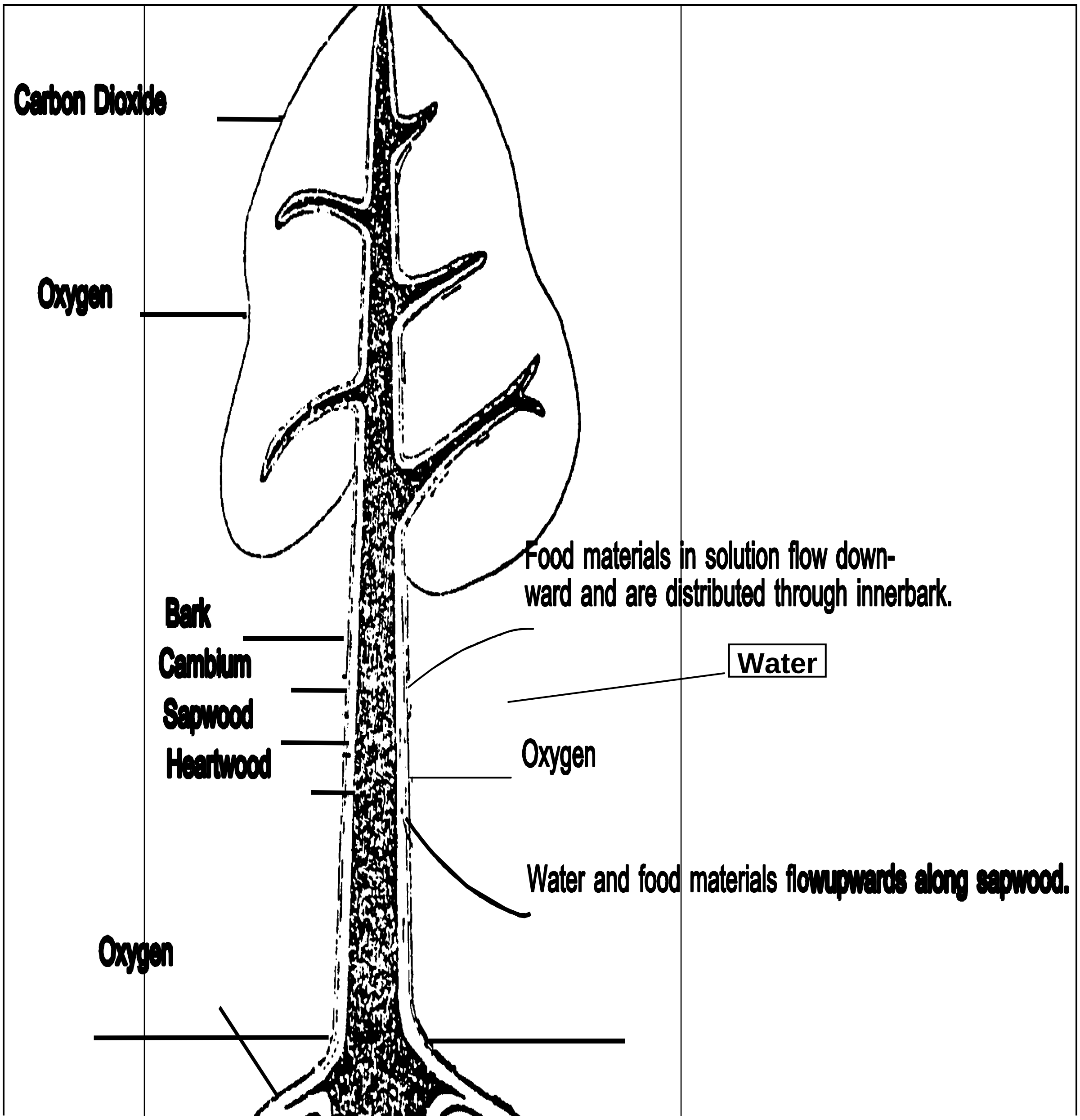


Figure D1 – Tree Biology showing Flow of Water, Oxygen and Food

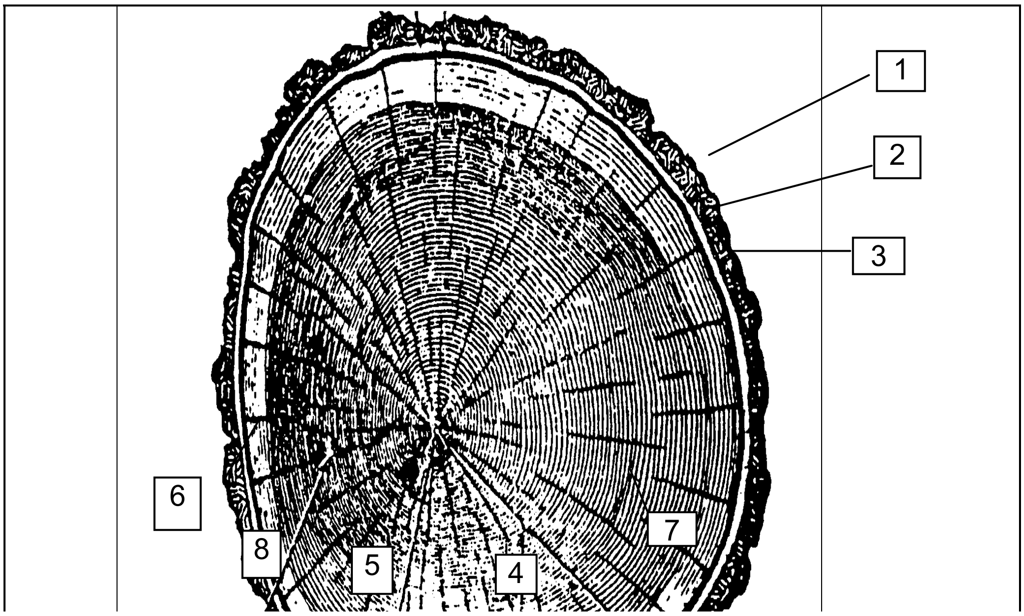


Figure D2 – Key Component Layers for a Tree

1. Outer bark 2. Inner bark 3. Cambium layer 4. Wood rays
5. Pith 6. Truewood 7. Sapwood 8. Heartwood

4. Immediately under the cambium is the **sapwood** zone, composed of living cells whose function is to conduct water and mineral salt solutions from the roots to the leaves. This zone varies greatly in width from species to species and even within a species. While the sapwood may often be no more than 1 inch thick on trees such as the Ironbarks, some rain forest species consistently produce trees of up to 1 metre diameter which are practically all sapwood, with only a few inches of truewood around the pith. White Cheesewood (*Alstonia scholaris*) is an excellent example of this extreme. Sapwood is usually lighter in colour than the truewood and the two layers may be well defined but this is not always so. In species such as Silver Ash and Hoop Pine, which have pale coloured truewood, the slight difference in sapwood colour is practically indistinguishable. Others, like the Tulip Oaks (*Argyrodendron Spp*.), which have very wide sapwood zones and brownish to red truewood, may have a pale coloured outer band or readily distinguishable sapwood but inside this there is usually a much wider layer of so-called "intermediate sapwood" apparently identical with the truewood and usually inseparable from it. It does, however, contain living cells and is, therefore, sapwood.

5 **Truewood** is derived from sapwood by blockage of the conducting channels and conversion of stored food materials into tannins, resins and other substances. It is these changes which make truewood more durable than sapwood. The truewood zone is the inner portion of the tree between the pith and the sapwood. Its component cells are dead and its main function is in providing rigidity for the trunk and support for the crown.

6 **Heartwood**, a term often substituted for truewood, is, strictly, the earliest formed truewood and the term is often used to denote the innermost central core around the pith. It is often low in density, brittle and faulty. Specification of the term "free from heart and sap" means that the merchantable truewood between sapwood and heartwood is required.

7 The **Pith** is the central soft core, usually no more than □ an inch in diameter, around which wood is first formed in the earliest stage of growth.

The Crown

The crown's main function is to manufacture food materials. Carbon dioxide (absorbed by the leaves from the atmosphere), oxygen (taken in through pores on leaves, twigs, branches, trunk and roots) and water (conducted from the roots) are, through the process of photosynthesis, changed in the green leaf into complex food materials (sugars, starch, etc.) for transmission to growth tissues.

D2 Wood Structure

Like all other living organisms, wood is composed of individual units known as **cells**. These cells are either long pliable tubes or brick-shaped, and each one is intended to act in either:

1. conduction of water and food materials;
2. food storage; or
3. provision of mechanical strength. Some cells perform more than one of these functions at the same time.

The wall of the woody cell is formed principally of cellulose (45%), non-cellulosic polysaccharides or hemicelluloses (15%-30%), lignin (20%-30%) and a variable amount of incorporated water.

The lignin is strongly bonded to the cellulose and thus confers stability on the network. It is the resin-like adhesive substance bonding the framework of individual cells and cementing cell to cell. Tannins, resins, gums and other substances are often included in the cell cavities but, although important in

their effect on durability and other properties, are not present in any great proportionate quantity.

A group of similar cells with the same function is called a tissue.

D3 Formation of Growth Rings

The rate of growth of a tree is subject to fluctuation, mainly associated with seasonal changes. This is particularly noticeable in the colder climates of Europe and parts of North America where the growth rate is fastest in Spring, resulting in the formation of a concentric layer of wood cells which are large and frequently thin walled. This zone is known as "springwood" or "earlywood" and consists of relatively more conductive tissue than strengthening tissue.

In summer, the cells become smaller and thicker walled in the next layer formed. This zone, which is composed predominantly of strengthening tissue, is usually referred to as "summerwood" or "latewood". The terms "earlywood" and "latewood" should be used instead of "springwood" and "summerwood".

A layer of lighter coloured "earlywood", and a layer of darker coloured, denser "latewood", together form a "growth ring". These growth rings vary considerably in width, even within the same tree. The line between earlywood and latewood is not always well defined. In some cases the transition is quite gradual.

Density

As will be realised from the previous comments on wood anatomy, the weight of the wood produced by different species varies considerably in accordance with variations in cell wall thickness, lumen or cell cavity size, types of structural elements predominating etc.

D4 The Presence of Water in Wood

Under ordinary conditions all wood contains some water. Freshly cut plantation-grown conifers may consist of something like one part of water to one part of wood substance.

Green off-saw timber from hardwood saplings may have a moisture content of about 100% while the moisture content of mature hardwoods (eg brush box and ironbark) may be in the region of 60%.

When freshly cut timber is used in service it will gradually lose the bulk of its moisture until the moisture content reaches a level similar to the moisture level of the surrounding atmosphere. This loss of moisture is referred to as seasoning, and it is often desirable to season timber before using it for certain purposes.

Poles and crossarms are not as a rule preseasoned, however, during their in-service periods of seasoning, degrading in the form of splits and checks can occur as a result of the inevitable phenomenon of shrinkage.

D5 The Effect of Moisture on the Properties and Uses of Wood

The amount of moisture present materially affects the following properties and uses of wood and this influences its suitability for different purposes.

Weight

Handling costs and freight charges are much greater for a given volume of green timber than for the

same volume of dry timber because the weight of the former may be more than twice the weight of the latter.

Strength

Except for shock-resisting ability and resistance to shear, dry wood is as a rule considerably stronger than green wood.

Durability

Wood having a moisture content of less than about 20% will not decay. Likewise, wood which is completely submerged in water so that air is excluded will not rot. A certain amount of both water and air are necessary in order that fungal activity may take place.

Painting

To obtain the best results when applying paint to wood, the wood should be dry, first because an oil paint will not penetrate green wood satisfactorily, and second because the paint will crinkle as the wood dries.

Gluing

Here again it is essential that timber should have a suitable moisture content in order that the glue may be absorbed into its surface and as little shrinkage or swelling takes place in the glued joints as possible. Otherwise, these joints may open up.

Transmission of Heat and Electricity

Dry wood is a good insulator, whereas water is a fairly good conductor. Consequently, the drier the wood, the higher its resistance to the flow of both heat and electricity. The effects of the presence of varying amounts of water on the electrical conductivity of wood is the basis upon which the functioning of the well-known electrical moisture meter depends.

Absorption of Liquids

Most preservative treatments of wood are more easily affected when the wood is seasoned to a suitable extent, because the presence of excess water retards the penetration of the preservative liquid.

D6 Drying Processes and Pole Defects

Drying Stresses

Timber will lose moisture more quickly at the end grain than it will across the grain. So, timber at either ends of a pole or crossarm will shrink before the adjacent timber that is sheltered from the effects of rapid end drying. As this timber shrinks, its continuity with the adjacent timber, which has not started to shrink, will form stresses which can only be relieved by the formation of small checks or spits along the grain. The checks themselves help to promote end drying and so they will extend on a receding front as end drying and shrinkage occur. The size and seriousness of this checking will depend to a large extent on the species. If it is considered necessary to restrict end drying there are a number of wax or bituminous coatings available that reduce the rate of end drying to a rate comparable with that of transverse drying.

Growth Stresses

Growth stresses can produce serious splits in the ends of poles and these occur because the outer portion of a tree trunk is often in longitudinal tension while the inner section is in compression. Growth stresses are usually most severe in certain quickly grown young eucalypts, and when the constricting tops are cut off such stems the ends will split and the pieces bend in the same way that a piece of celery will split and bend when cut. The bending is merely in response to the relief of the stresses previously mentioned. Splitting can be prevented by embedding "C" irons or gang-nail plates in the exposed ends. A protective cap would achieve the same result as well as restricting end drying.

Face checking with large sections of timber such as poles and crossarms develops as the timber seasons but it can also be a continuing process as the material is subjected to weathering.

Weathering

When a pole, which has undergone the seasoning or drying process, is exposed to severe wet weather, the outer layers will absorb moisture and will tend to swell. With the outer layers tight, swelling will be prevented and so compression set will occur in this zone. Compression set means that on redrying, shrinkage will be greater than would have normally occurred and this results in the reopening of the original drying checks. Repeated wetting and drying over the life of a pole enlarges these checks providing possible access for fungal infection.

Twisting

Twisting of poles is a form of degrade which can occur during drying. It is most unlikely that large hardwood poles would twist as they season, however, twisting has been recorded with smaller softwood poles (eg cypress pine or pinus species) when used for telephone poles. Such twisting is related to an unusually high level of spiral structure within individual cell walls.

Seasoning

The question of whether poles should be seasoned is dependent largely on whether they are to be given a preservative treatment prior to being put into service or will be used untreated.

In general, records have indicated that where untreated poles (species of high durability) are used, the service life is not increased by seasoning (NB no advantage is gained by preliminary seasoning). However, for nondurable species, where the preservative treatment of sapwood is necessary, a seasoning period is essential. The necessity is twofold, first to remove sufficient moisture from the sapwood so that good penetration of the preservative will result; and, second, to ensure that the seasoning checks which normally develop in poles will appear prior to the application of the preservative treatment rather than subsequently. When checks develop before treatment is given, all surfaces will be coated with preservative, but if they appear after the treatment has been given, untreated wood will be exposed to possible fungal infection.

Irrespective of whether poles are to be held temporarily in storage, or seasoned prior to treatment with preservatives, systematic stacking is essential. Decay will rapidly develop, particularly in sapwood, where conditions are favourable (as at the base of solid piles) and once fungus has gained an entry into a pole, growth will continue after the pole has gone into service, thus resulting in a shorter service life.

For this reason, and also to reduce the possibility of attack by insects and to assist the drying process, all poles should be barked as soon as possible after felling. Desirable practice is to stack poles on foundations, which may be of concrete, steel or sound timber. These should be at least 12

inches high and be kept clear of weeds and rubbish so that efficient air circulation can result. A pig-sty formation (ie alternate layers, each consisting of 30 or more poles, being so laid that the poles in them lie at right angles) has proved very satisfactory and convenient. For further stability, alternate poles in any one layer should be "end-for-ended" (ie the taper in alternate poles should run in opposite directions). Where rapid drying is required, pole lengths are kept parallel in all layers, the layers being separated by three or four small diameter sound timbers (ie four to six inches diameter) used as stacking strips.

D7 Fungal Deterioration of Timber

Fungal Stains

Before proceeding with a discussion on staining caused by fungi, it is important that you should be able to distinguish stains resulting from incipient decay and those arising from attack by stain-causing fungi and moulds. The indications of incipient decay and fungal stains are shown in Table D1.

Incipient Decay	Stains Caused by Moulds
Not always confined to sapwood, though often more severe in sapwood	Mostly confined to sapwood, sometimes entirely superficial
Usually in form of blotches and streaks	Often generally distributed, frequently in medullary rays. Stained area often wedge shaped in cross-section
Colour: In sapwoods usually dark or reddish brown In hardwoods either whitish or dark brown blotches or steaks	Colour: Blue-grey, green or blackish, occasionally pink, yellow, or orange
Narrow black or dark coloured zone lines may be present	Sharply defined zone lines never present
Fibre weakened and break off short when tested with a knife	No appreciable weakening of fibres when tested with a knife

Table D1 - Incipient Decay and Fungal Stains

D8 The Effect of Stains on Wood Properties

Effect on Mechanical Strength

Numerous workers have investigated the effect of sap stain, in particular, on the mechanical properties of timber. The results of this work reach agreement in that sap stain has no significant effect on the compressive and bending strengths when compared to clear wood but does appreciably affect timber's resistance to suddenly applied shocks when the strain is heavy.

In timber used for ordinary constructional work, blue stain need not be regarded as a serious defect. Since it has no serious effect on compressive or bending strengths, its presence is not significant in timber used for building purposes and it is only in structures such as the modern-day fast run-about where sudden and severe stresses are likely to occur that rejection of timber on account of stain is justifiable on mechanical grounds; even for such purposes, the use of timber containing slight sap stain should be permitted and only the heavily stained timber rejected. From a purely decorative view point, any staining may be objectionable.

Effect on Moisture Loss and Uptake

The rate of drying of stained softwood is almost the same as that of unstained and, more importantly, there is no appreciable difference in the equilibrium moisture contents which stained and clear wood attain. However, blue stained wood absorbs water more readily than does unstained timber.

Effect on Decay Resistance

Results of work undertaken on this aspect of stains generally show that the rate of decay of stained wood may be slightly greater, but not to any significant extent, than that of clear wood. The presence of staining associated with incipient decay may be overlooked if other stains or moulds are present. While stained wood does not decay significantly faster than sound wood, conditions which favour the development of sap stain also favour decay, so stained wood should always be carefully examined for other indications of rot.

D9 Fungal Decay (General)

Stages of Decay

There are various stages in the process of decay. In the earliest stages, the wood appears to be hard and firm, the only evidence of attack, if any, being a slight to marked colour change from the normal. This is known as the "incipient" or "initial" stage. In some cases, there is no indication of incipient decay, hyphae extending for ½ metre or more longitudinally in advance of the visible evidence of rot. Such a hidden stage can only be detected by a microscope or by cultural work. Incipient decay is dangerous as it can be easily overlooked and in some forms, particularly brown rot, the wood is seriously weakened in the incipient stage and should not be used where strength is required.

After the incipient stage has passed, the wood becomes more and more noticeably affected until it is finally completely changed in appearance and structure, with the continuity of the wood tissues destroyed. This is known as the "Advanced" stage, in which generally the strength of wood is so reduced it can be crumbled between the fingers or easily broken. It is often common to see in one piece of timber a gradation from advanced to incipient decay to sound wood.

General Macroscopic Characteristics of Decay

The appearance of fungal decay depends not only on the species of fungus and kind of timber concerned, but also on the stage of attack that has been reached. The incipient stage of any particular kind of rot is often entirely different to the more advanced stages, the latter being readily apparent to the unaided eye.

The indications of fungal decay include some or all of the following characteristics:

Colour Changes

Decay in wood is almost invariably accompanied by a change in colour; it may become bleached in the case of a white rot or darkened in the case of a brown rot. It should be remembered, however, that colour changes may be absent in the incipient stage of some decays. In timber in use, the first sign of decay may be a dark brownish spotting or streaking, or flecks of lighter colour depending on the species of fungus and type of wood involved. Certain fungi which cause white rots may form narrow black lines, called zone lines, which may outline the badly decayed areas.

Softening

On testing an area of incipient decay with a knife, it will usually be found that the texture of the wood has been softened and that it is impossible to prise up a long splinter as the fibres break off quickly over the top of the knife owing to their loss of toughness, that is, they have become brash. Even slight incipient decay greatly reduces the strength of wood.

Change of Density

Decayed wood is less dense than sound wood owing to destruction of the wood substance by the fungus. Wood in a very advanced stage of rot may be extremely light and yet retain its outward form. Excessive lightness is a good indication that the wood is in an advanced stage of decay but in practice, this test is often unreliable as the wood may be light owing to the nature of its growth (eg very rapidly grown softwood may be much below the average density for the species).

Change in Odour

Wood affected to any appreciable extent by fungal decay may have a "mushroomy" smell, but the presence of such an odour, although generally indicative of damp conditions which favour the development of moulds, does not necessarily mean that there is any actual decay present. However, a clean, fresh resinous smell is a fairly good indication, especially in softwoods, that the wood is sound.

Shrinkage

Decayed wood shrinks more on drying than sound wood does, and this difference is more obvious in brown rots than it is in white rots at the same stage of decay. Shrinkage cracks are often very obvious in the form of decay known as "dry rot".

The Chemistry of Decay

Decay fungi decompose wood by secreting enzymes and acids which, in the presence of moisture, dissolve cellulose, lignin and other constituents of wood. These are absorbed and used as nutrients by the fungus.

Decomposition of wood by fungi is of two main types which have been described as brown rots and white rots respectively. In the brown rot, the cellulose and related constituents are attacked while lignin is left in a more or less unchanged condition, in a white rot, the lignin may be preferentially utilised or all the components of the wood are decomposed.

D10 Specific Types of Fungal Decay

Brown Rot

Brown rot fungi utilise cellulose and the related constituents of the cell wall and leave lignin in a more or less unchanged condition, hence wood attacked by these fungi takes on a brown colour. Because the "stiffening agent" lignin is left virtually untouched the form of the original cell wall is preserved. Microscopically, the cell wall is not appreciably thinned until a very late stage of decay when nearly all the cellulose framework has been removed. Another microscopic feature of the cell wall resulting from attack by brown rot fungi is the presence of bore holes.

In the incipient stage, brown rot is characterised by dark brown blotches or streaks. In the advance stage of decay, affected wood is brownish. Invariably, shrinkage cracks are associated with brown rot, badly decayed wood breaking up into cube-shaped fragments hence the term "brown cubical rot".

Individual fragments may be easily crumbled between the fingers. The strength of wood may be seriously reduced by brown rot, even in its incipient stage. Quite often, individual cubes may be separated by mycelial matting.

White Rot

White rot fungi may preferentially utilise the lignin within cell walls or perhaps more commonly may break down all the components of wood. Because of this, wood affected by white rot fungi is generally of a bleached appearance. Two microscopic characteristics of cells attacked by white rot fungi are the presence of bore holes through the walls, and a general thinning of the cell wall, particularly when decay is more advanced.

In the incipient stage, wood may contain flecks or blotches which are whiter or darker than its natural colour, depending on the type of wood and the species of fungus attacking it.

There are basically two types of white rot in the advanced stage, but in both affected wood is whitish in colour. The first is the fibrous, stringy white rot. When dry, the wood is punky and friable and is reduced to a state where it is easily crumbled between the fingers. Black or darkish zone lines are often found associated with this type of rot and, as contrasted to brown rots, the wood very rarely contains shrinkage cracks.

The second type of white rot is the white pocket rot, so called because, in the advanced stage, affected timber contains pockets of white rot which are separated by areas of hardwood. Quite frequently, wood containing white pocket rot may be subsequently attacked by brown rot fungi which break down the areas of hardwood separating the individual pockets of white rot.

Dry Rot

Although basically this type of rot is a brown rot, it is included separately because this term is quite frequently, and in Queensland always, used erroneously to describe decay in certain situations. In Australia, dry rot is the decay caused by only one species of fungus *Merulius lacrymans* and has been found to occur, to date, only in Melbourne.

Dry rot attacks both softwoods and hardwoods and is virtually confined to structural timbers in buildings. Dry rot has been recorded as causing tremendous damage in the United States and Europe.

Dry rot is a form of brown cubical rot, with cracks developing in infected wood as soon as it begins to dry out, resulting in the formation of rectangular or cubical fragments. In an advanced stage of rot, the wood crumbles readily into a dry powder, thus giving rise to the popular name of "dry rot".

Usually there is a considerable development of mycelium on the surface of infected wood. Under very moist conditions, this may take the form of mycelial mats that may also occupy cracks appearing in the wood. Usually the fungus responsible for dry rot develops rhizomes which enable the fungus to transport water very long distances (in some cases from the ground to even the third floor of a building). Under favourable conditions, the dry rot fungus can bring about very rapid decomposition of wood and it spreads rapidly by means of its superficial growth. Under poorly ventilated conditions where high humidity prevails dry rot fungi grows most actively.

Soft Rot

Because soft rot fungi use only the cellulose of cell walls of infected wood, wood affected by soft rot fungi is generally darkish. Conifer (softwood) wood is generally more resistant to soft rot decay probably because of the higher lignin content of its cell walls.

In contrast to the other types of decay, the rate of deterioration by soft rot is directly correlated with the amount of nitrogen and therefore it is more active in wood which is in contact with soil or with water containing nutrients in solution. Several soft rot fungi not only tolerate very high moisture contents but actually cause more rapid decay in timber containing 100% moisture content. They survive long periods in fairly dry wood and revive quickly on rewetting.

Soft rot fungi are resistant to wood preservatives particularly those based on fluorides and chromates and are more tolerant of copper levels that are sufficient to prevent attack by white and brown rot fungi. Some soft rot fungi are also more resistant to heartwood extractives and can survive slightly alkaline conditions and thrive at higher temperatures than other decay organisms can tolerate.

Contrary to white and brown rots, which may occur internally within a piece of timber, soft rots are usually found in the exposed superficial layers of wood. The most common situations in which soft rots are found are:

1. in the cooling towers; and
2. on the ground and below ground level surfaces of poles, posts, etc.

Attack by soft rot fungi differs microscopically in a major way from that of white and brown rot fungi in that, instead of fungal hyphae decomposing cell walls by passing through them they extend in a general longitudinal direction within the secondary wall so that, in cross section, attacked cells display roughly circular cavities in the secondary wall. As with the brown rots, cells subjected to soft rot attack retain their shape and walls do not appreciably thin until almost all the cellulose is utilised.

In the advanced stage, wood affected by soft rot is very soft and cheesy when wet. When dry, the wood is very brittle and develops shrinkage cracks similar to wood affected by brown rot.

D11 Insect Damage to Timber

Insect Damage to Poles

Attack by insects is by no means the only way in which poles may be damaged. It is proposed at this point to look into the various groups of insects which cause damage before poles enter service and after they are in service (whether treated with preservatives or not) and also to examine how this damage may occur. It is accepted that the general practice today is to utilise poles treated with preservative and the subject of insects attacking poles is discussed with this in mind.

Tree Damage

Some insects damage a tree in such a way that it may not be visible until the tree is felled (e.g. termites) or more importantly, until the pole has been in service some time (e.g. cossid wood moths and ambrosia beetle damage).

Each of these groups of insects attack standing trees and affect the heartwood region. The large tunnels made by cossids are obvious sites for rot or decay development but since the growing portion of the tree is unaffected all external signs of the damage are soon hidden by the callous tissue produced by the tree. In some cases these moths tend to attack small trees (up to 15 cm diameter at breast height) which allows the tree several seasons of growth before any form of utilisation would be contemplated. Unless decay has developed to the extent that it is visible at a cut end of the log, an attacked tree could go into service and be an unrecognisably structurally weak pole. Preservation treatment would almost certainly arrest any extension of decay but would not correct the weakness already there (see Figure D3).

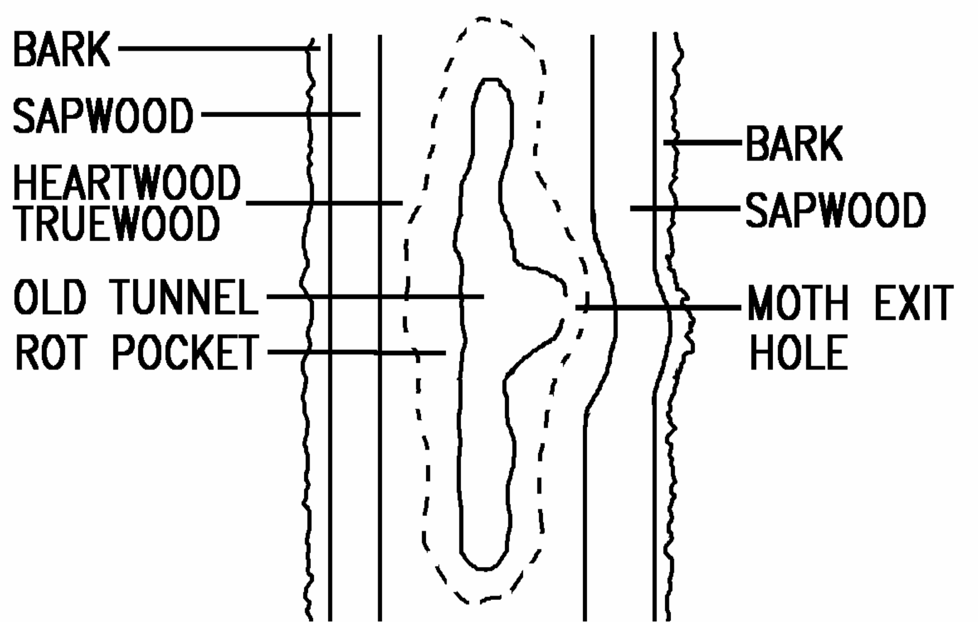


Figure D3 - Cossid wood moth damage to a tree some years after attack

Insects such as the bullseye borer (a longhorn beetle), ambrosia beetles and the wood moths belonging to the families Xylorictidae and Hepialidae, could cause this type of damage also.

In the past when poles were 'desapped' prior to being installed, damage of this type would frequently have caused the rejection of such poles as the callous tissue over a sound would generally be seen during such work. With the advent of pressure treatment this is no longer done and poses a risk that, fortunately, is small!

Pole Damage

In general only two groups of insects will be encountered infesting or attempting to infest poles in service.

The first group (auger beetles or bostrychids) are of incidental importance with one possible exception, while the second group (termites) are of great importance and a serious threat to all poles.

Auger Beetles

Auger beetles are sapwood feeders that under normal conditions attack freshly felled logs. The adult female excavates a gallery in the sapwood and deposits eggs along it often constructing special egg chambers for the purpose (see Figure D4).

The larvae penetrate directly into and tunnel in the sapwood to obtain their carbohydrate diet. The larval galleries may be several centimetres long and the larvae can continue to tunnel in sawn timber until they emerge as adults.

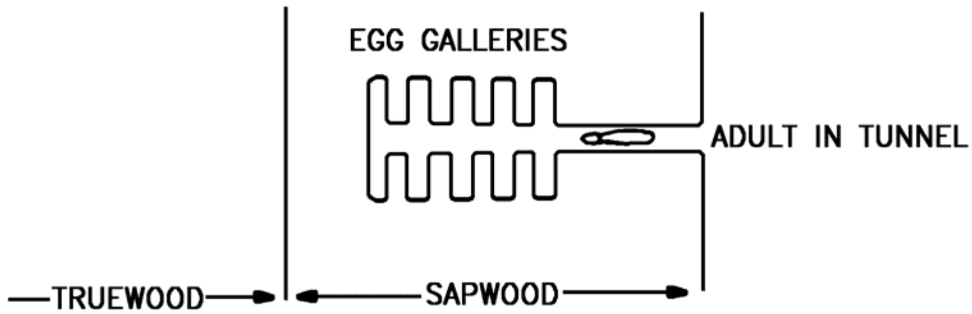


Figure D4 - Cross-section of a typical auger beetle gallery

Unfortunately, the adults are also stimulated to attack freshly sawn timber or rewet timber. Within this latter category freshly treated poles are occasionally confused with natural egg-laying sites by the beetles, and one will be alarmed by the outpourings of coarse frass from a stack of treated poles or a new pole in service.

The beetles apparently consume little or none of the wood tissues when tunneling as holes up to 2.5 cm may result from this activity. The important point is that no larval infestation can occur since the larvae must feed on the treated wood tissue which is lethal to them.

Mesoxylion clyindricus is the most commonly encountered auger beetle.

There is perhaps a remote chance that an adult may inadvertently tunnel into the heartwood and

provide access for decay fungi or possibly termites, but it is a very remote possibility. Auger beetle infestations may therefore be considered of nuisance value only.

Termites

Brief mention of termites and their importance in forestry has already been made. Of the 300-odd species found in Australia only a few are of economic importance. In Queensland, there are 10 species of subterranean (soil-dwelling) termites that commonly attack timber-in-service. The two most serious pest species are *Mastotermes darwiniens* and *Coptotermes acinaciformis*. The former has a relatively restricted distribution in northern Australia while the latter may be found anywhere along the coast including the Torres Strait Islands and as far west as Cunnamulla.

There is a separate group of termites called drywood termites that infest timber by flight rather than from underground nests. These species are not common in poles; their importance as pests ranks much lower than subterranean termites.

It should be realised that preservative pressure treatment does not always prevent subterranean termite infestation and some ways in which infestation can occur will be considered.

We will now consider in some detail the biology, structure and behaviour of a termite colony in order to emphasise the nature of the insect and why the risk is so high.

Biology

The termites which concern you are all soil-dwelling forms and all are social insects, living in colonies of many millions of individuals in some cases. Each colony contains workers, soldiers, juvenile forms and at least one part of reproductives known as the king and queen. At certain times each year winged forms or alates will be present. The workers constitute the great mass of individuals and are wingless, sterile and blind. The soldiers are also wingless, sterile and blind but have strongly chitinised and darkened heads. They also possess a pair of strong mandibles or a prominent snout and are particularly important in the identification of species as well as in the defence of the colony. The king alters little during his lifetime while the queen frequently develops into a grotesque egg-laying machine capable of producing in excess of 2000 eggs per day. Such a queen is known as a **physogastric queen**. In some termite species supplementary reproductives or **neotenics** are produced should the original queen die or if her reproductive capacity decreases. In other species neotenics may in fact be first-form queens that is, the original source of eggs in a colony (see Figure D5).

Figure D5 - Castes of Termites. A: alate B: worker C: soldier D: mandibulate soldier E: nasute soldier

The foundation of new termite colonies is a spectacular event the so-called swarming or colonising flight in which thousands of young reproductives fly off in search of mates and a place in which to commence breeding. These individuals possess functional eyes and have much darker bodies than their fellows. Initially a king and queen do all the work of building a new colony, however, after the first progeny emerge they are relieved of all duties but reproduction. It has been estimated that it would take 20 to 25 years for a colony of *Eutermes exitiosus* to reach maturity and a colony of *Eutermes triodiae* was thought to be over 150 years old when it died. This latter species does not produce neotenics which indicates that the original queen must have lived for this exceedingly long period.

Subterranean termites derive two great benefits from their adoption of a cryptic existence walled off in a world of their own:

1. protection; and
2. control over their environment (within limits).

The nest or **nursery** is so designed that the temperature gradient between the central portion and the periphery combine to build and maintain the high humidity required it always exceeds 90%. A certain amount of heat regulation is also possible and in cooler months the workers congregate in the nursery to increase the temperature through their own metabolism and body heat.

The diet of termites is primarily cellulose and other essential nutrients are acquired from the food source or provided by symbiotic micro-organisms. Cannibalism also occurs and is probably associated with the removal of superfluous individuals and possibly also for protein (organic nitrogen) conservation.

Behaviour

Because of their cryptic habit termites as individuals are rarely seen. The mound-type nests of many species are such a common feature of the landscape that they are almost taken for granted. It is curious to note that *Mastotermes*, and *Coptotermes acinaciformis* south of 25° S Latitude (Bundaberg) do not produce mound-type nests. Mastotermes nests have been found below ground level in posts, stumps, tree trunks etc, while *Coptotermes* builds mounds in northern Australia and nest above ground level in stumps or the trunks of dead or living trees south of 25 ° Latitude.

The first visual evidence of subterranean termites is usually provided by the familiar mud-covered galleries over the surface of attacked material. These fragile covered ways permit the termites to work in complete seclusion and go about their destructive ways. It is very difficult to isolate the nest of a termite colony attacking a pole or any other structure, and it is largely for this reason that some means of preventing attack, rather than destroying termites, is countenanced. Entry could, and usually is, made below ground level, so that no visible sign of infestation may occur until the pole collapses.

When dealing with treated poles entry must be gained by the insect bridging the treated zone. This most commonly occurs through people's own folly in providing such bridges, for it is a well-known fact that if any weakness in a barrier occurs, the termites will find it. The most common example of such a bridge is to place a piece of untreated material on a pole to protect a wire running from an overhead cable to the base of the pole. This usually abuts against an untreated crossarm bolted to the pole, and could lead to the attack of both the crossarm and the pole - the bolt hole providing the point of entry in the latter case.

NOTE:	Be exceedingly cautious when it becomes necessary to make any addition to a pole which will contact the ground.

More recently termites have been located in association with soft-rot fungi. It is known that soft-rot decay causes a depletion in the CCA content of affected material and in at least one instance, termites have gained entry through such a zone and destroyed a pole. Therefore while inspecting poles for soft-rot decay the possibility of termite attack at the same point must not be overlooked. In these circumstances symptoms of termite attack may not be very obvious but one would expect to find small numbers of individuals on the surface of the pole at the point of entry, and by removing the decayed wood evidence of mud galleries would be expected.

D12 Effect of Decay on Strength

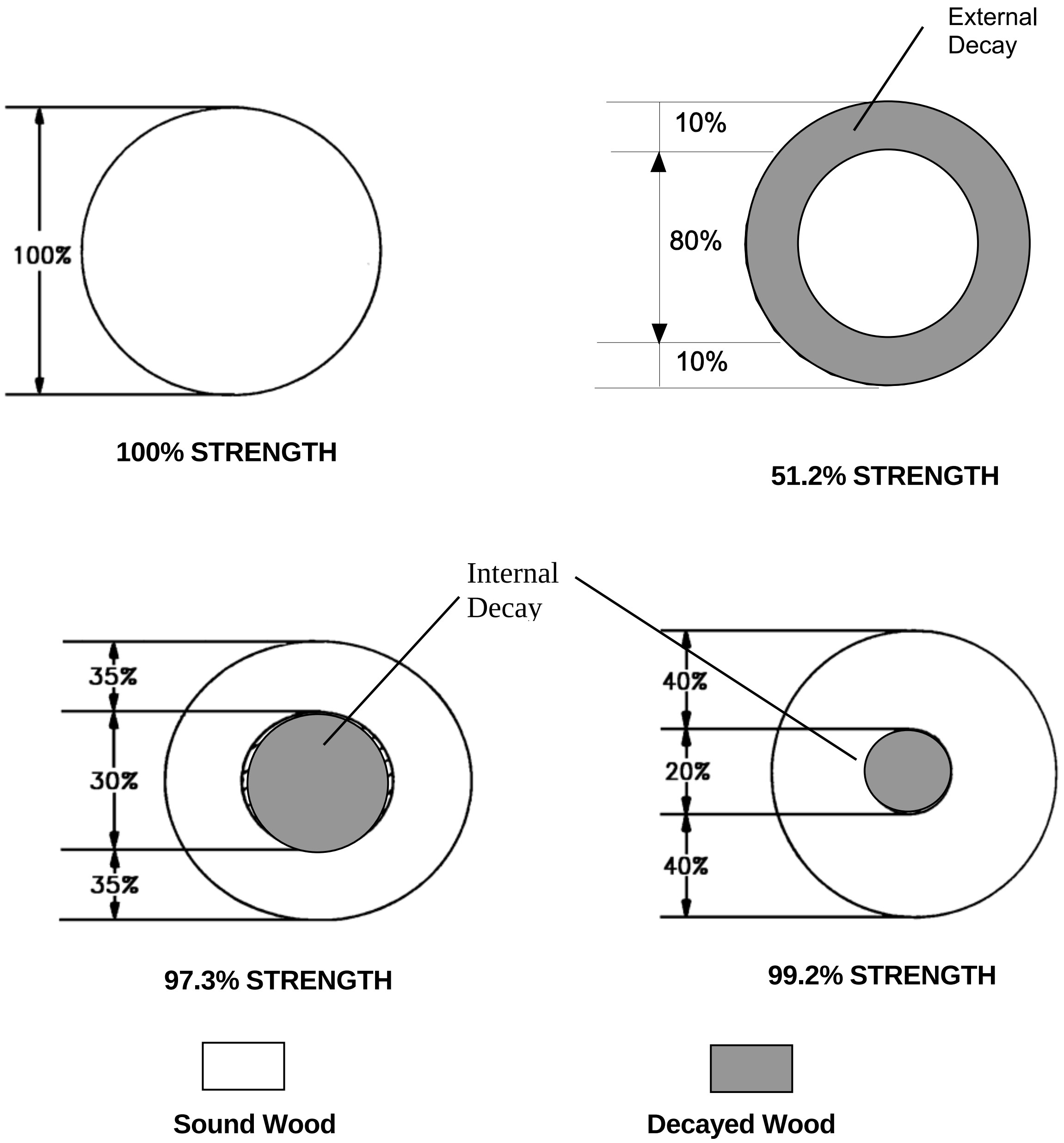


Figure D6 – Effect of Internal and External Decay on Pole Strength

Note that a solid exterior contributes more strength than a solid interior.
External decay reduces pole strength far more than internal decay.

D13 Natural Defects in Wood Poles

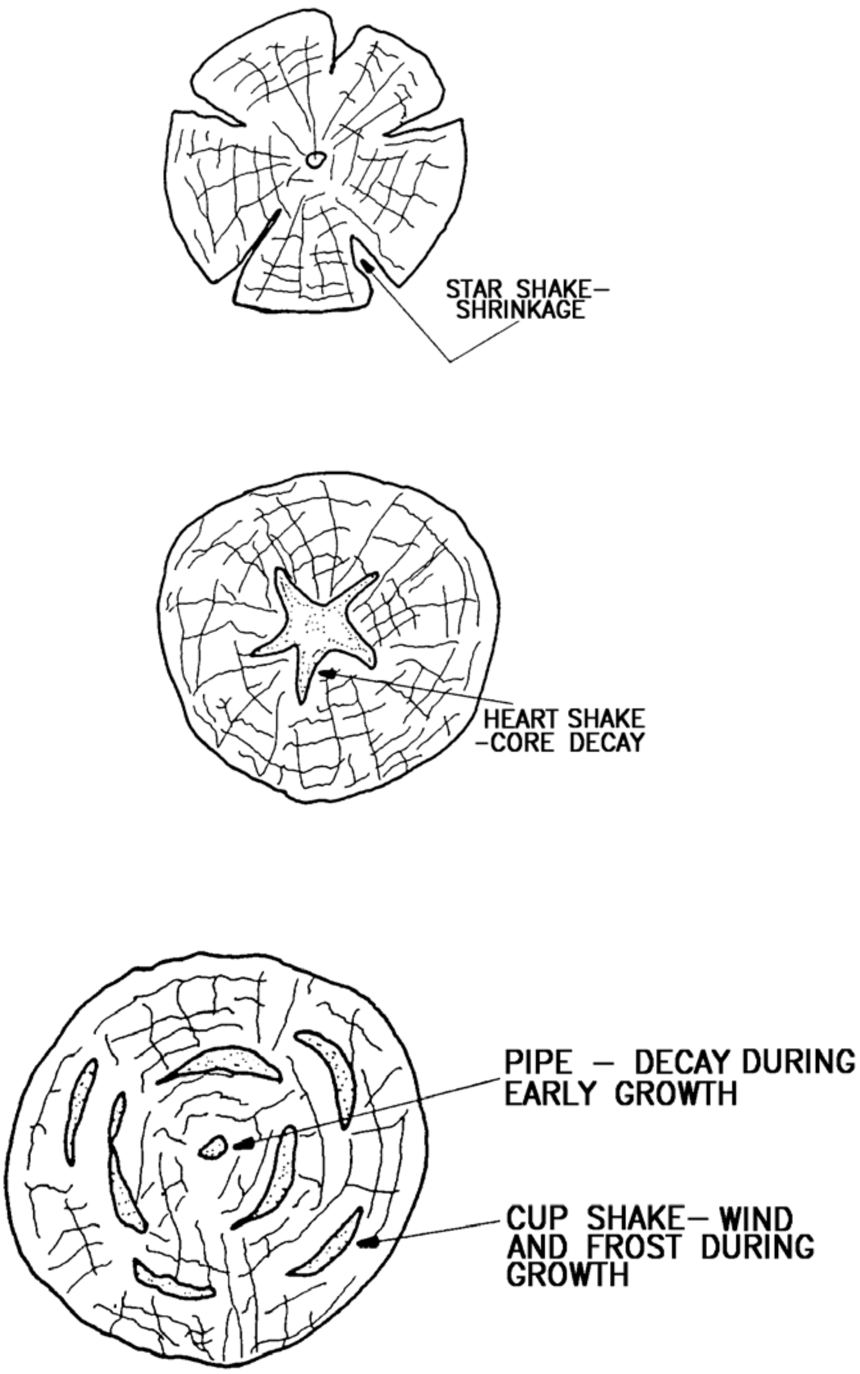


Figure D7 – Natural Defects in Wood Poles

Amendment Record

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12 April 2012
Version 3

- Removal of Appendix E – Algorithm for Strength Assessment

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14 October 2003
Version 2

- Theory from Pole Inspection Handbook incorporated into Body and Appendices of document.
- Incorporation of 33kV Ground Feeder Patrol criteria / photos including addition of Section 8.0
- Design Considerations.
- Minor text amendments.

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27 February 2003
Version 1

Manual overhauled as creation of a BMS document.