Government of **Western Australia**
Department of **Commerce**
Energy*Safety*

ELECTRICAL INCIDENT REPORT

BUSHFIRE
NEAR RIVER and FOLEWOOD ROADS
TOODYAY
WESTERN AUSTRALIA
29 DECEMBER 2009

15 February 2010

Report prepared by:

Energy*Safety* WA

EIS 2009-2630

Toodyay Fire Dec 2009

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1 INTRODUCTION

A bushfire occurred at approximately 12:53 hours in a paddock to the south side of River Road near the intersection of Folewood Road west of Toodyay on 29 December 2009 and burned towards Toodyay.

The Fire and Emergency Service Authority (FESA) notified Energy*Safety* on 29 December 2009 that the bushfire (FESA incident number 141266) originated in the vicinity of Western Power's T303 spur overhead single-phase high voltage 12.7 kV power line.

Energy*Safety's* A/Chief Electrical Inspector, arranged an initial site inspection with FESA and Western Power representatives on 30 December 2009. This report summarises the key outcomes of Energy*Safety's* investigation.

This investigation could not have been completed without the cooperation and assistance of FESA, Western Power and the WA Police Service.

2 SUMMARY

Energy*Safety* has been unable to determine if electricity from Western Power's distribution system caused the bushfire on 29 December 2009.

A farm manager in a neighbouring property noticed smoke in a paddock to the south side of River Road near the intersection of Folewood Road west of Toodyay on 29 December 2009 at approximately 12:53 hours. The bushfire was noticed when it was sufficiently advanced to produce a column of smoke visible at some distance above a line of trees.

The farm manager reported the bushfire through a 000 emergency call at 12:57pm.

FESA and WA Police Arson Squad fire investigators have tracked the bushfire's path back to an "area of origin"[1] but the exact "point of origin"[2] was not able to be established. The area of origin is in the vicinity of Western Power's T303 spur power line between wooden poles numbered T303-42 and T303-43. The satellite image below shows the location of these poles (prior to the bushfire) and the bushfire's area of origin.

Western Power's T303 spur overhead single-phase high voltage 12.7 kV power line crosses the paddock where the fire originated. This power line emanates from Toodyay and is protected by an automatic reclosing circuit breaker (recloser) and two sectionalisers (another type of automatic switch). The recloser (T303-1A) is designed to open and then reclose if a fault occurs on the power line. It will reclose three times and, if the fault is still present after these reclose attempts, it locks out (stays open) on the fourth operation. The sectionalisers are

[1] *Area of Origin – The room or area where a fire began (Reference: National Fire Protection Association (NFPA) 921 – Guide for Fire and Explosion Investigation – 2008 Edition).*

[2] *Point of Origin – The exact physical location where a heat source and a fuel come in contact with each other and a fire begins (NFPA 921-2001 Edition))*

designed to operate and isolate the faulty part of the power line before the recloser can lock out, thereby, maintaining electricity supply to the power line section that is not faulty.

The recloser on the T303 line detected a fault at 12:53 hours, attempted three rapid re-close operations and then locked out at 12:54 hours. The T303 spur power line was and remained de-energised from that time.

Witness statements, expert advice and on-site examination lead to the conclusion that Western Power's wooden poles T303-42 and T303-43 were standing, but burning, well after the fire front had passed. This indicates that the fire did not originate due to either pole T303-42 or T303-43 failing. Both poles eventually burnt and fell to the ground well after the fire was established.

The sectionaliser at pole T303-40 would have operated if a permanent fault had occurred at poles T303-42 and T303-43. This sectionaliser did not operate but the recloser (at the beginning of the powerline T303-1A) operated and locked out. This indicates that the fault was upstream of the sectionaliser and closer to Toodyay. The actual fault which operated the recloser could not be found due to the extensive fire damage towards, and just south, of Toodyay. A schematic diagram of the T303 spur power line is shown below. The area of origin of the bushfire was located between poles T303-42 and T303-43. The T303 spur power line commences at Toodyay (right hand side of the map).

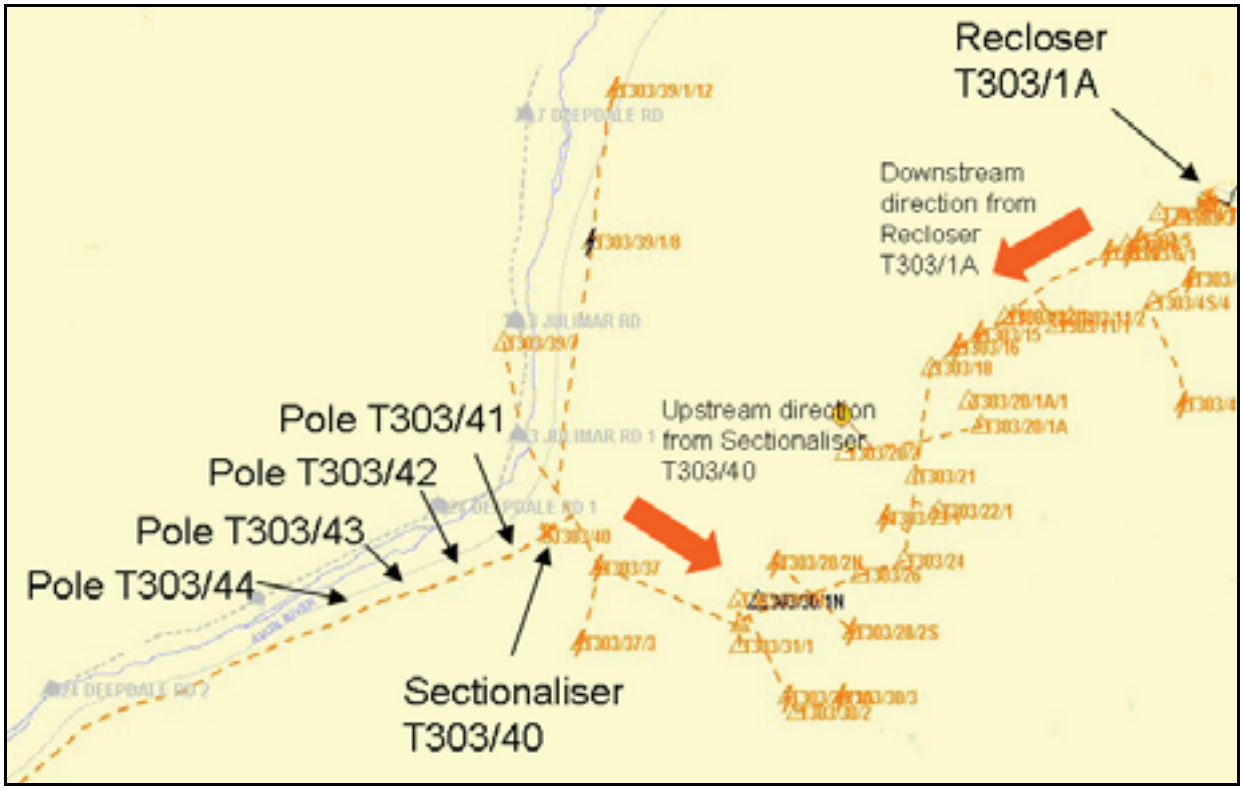
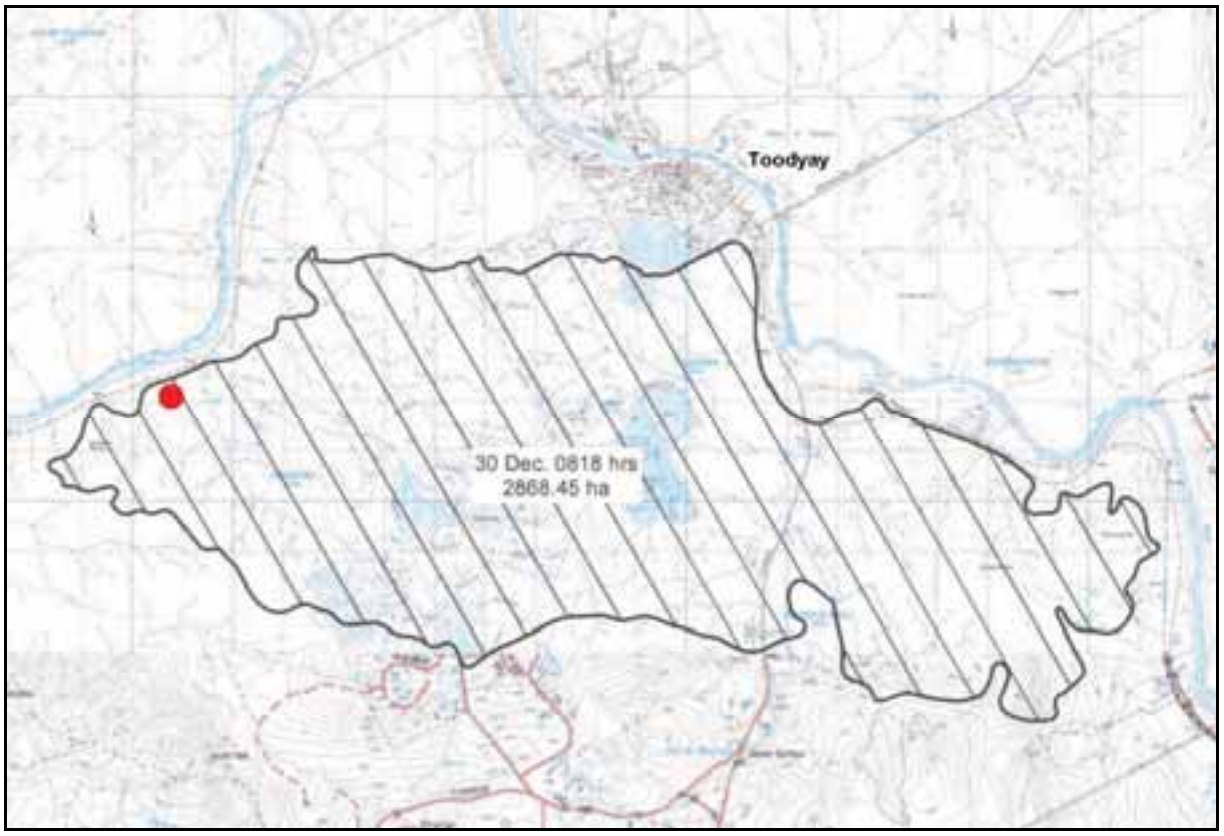


Diagram of T303 Spur Power Line Supplied by Western Power

Recent marks of metal melting (arcing) were found on the steel active and earth return conductors 14 metres from pole T303-43 towards pole T303-42 in the vicinity of the origin of the fire. These marks indicate that a short circuit occurred between the conductors. Field tests confirmed that it is possible for the conductors to be brought together within 14 metres of a pole but significant force is required. In Energy*Safety's* opinion, such wind generated clashing so close to a pole, given the force shown to be required, is very improbable. Energy*Safety's* investigation was not able to establish how or when this short circuit occurred and if it contributed to the cause of the fire.

3 ORIGIN OF THE BUSHFIRE

FESA and WA Police fire investigators established that the bushfire's "area of origin" was located on the ground in a paddock south of River Road and west of Folewood Road approximately seven kilometres west of Toodyay. The map below shows the fire area. The bushfire's area of origin is marked with a red circle and the hatched area indicates the full extent of the bushfire.



Map Supplied by FESA

An inspection of the bushfire's area of origin indicated that a large area of paddock of recently harvested barley crop had burned out adjacent to the Western Power 12.7 kV overhead power line T303 spur. The bushfire had continued in an easterly direction, which is consistent with being driven forward from the area of ignition by wind coming from a west north westerly direction. While pole numbers T303-42 and T303-43 were located within the nominated area of origin, FESA and WA Police were unable to pin-point the exact point of origin where a heat source and fuel came into contact with each other and started the fire.

4 INVESTIGATION ANALYSIS

4.1 Scene at the Area of Origin of the Bushfire

The fire scene's area of origin was extensively disturbed by Fire Service and Western Power vehicles and personnel while undertaking fire suppression and damage assessment activities. The burned butts of the two poles located within the area of origin were removed by Western Power. Energy*Safety* seized the lengths of marked conductor and, later, the sawn butt sections of interest (after testing) from the two poles involved. Energy*Safety* carried out its own independent investigation of these items of evidence.

4.2 T303 Spur Power Line Specifications

The Western Power T303 spur overhead 12.7 kV power line was constructed in approximately 1976 and extends from Toodyay to the south west of Toodyay.

The high voltage 12.7kV T303 spur power line consists of steel conductors supported on insulators and wooden poles.

The T303 spur power line specifications in the vicinity of the origin of the bushfire are:

- Phase conductor (x1): 3/12 SC/GZ (galvanised steel)
- Underslung earth return conductor: 3/12 SC/GZ (galvanised steel)
- Pole material: Wood (Jarrah untreated)
- Pole lengths (#42 and #43): 11 metres
- Pole height above ground: Approximately 9.3 metres
- Span length (poles #42 to #43): 255 metres
- Conductor spacing at supports 1.2 metres
- Direction of power line: East-West orientation

4.3 T303 Spur Power Line Electrical Protection

The T303 spur power line is protected at its origin by an automatic recloser set to operate at 16 amperes. The recloser is set to lock out after four consecutive trip operations. The recloser's 16 ampere operating current is appropriate to protect the steel conductor.

T303 spur is divided into three sections with a sectionaliser at pole T303-40 and at pole T303-67. The sectionaliser at pole T303-40 is set to operate after three consecutive faults of 20 amperes or more. The sectionaliser at pole T303-67 is set to operate at 20 amperes and after two consecutive faults. The sectionaliser at pole T303-40 did not operate at the time of the bushfire. It was tested later by Western Power in the presence of Energy*Safety* and found to function correctly.

4.4 Consideration and Analysis of the Arc Marks on the Conductors

The investigation identified arc marks (melting of the steel) on the active and earth return conductors 9 metres and 14 metres out from Pole T303-43 towards pole T303-42. The arc marks at 14 metres were recent. The marks 9 metres from the pole were old.

Arc Marks at 14 Metres. Photograph Taken by Energy*Safety*

Arc Marks at 9 Metres. Photograph Taken by Energy*Safety*

The arc marks were analysed and found to be consistent with either the conductors clashing or some conductive object causing a short circuit between the two conductors. It has not been possible to determine the cause of these marks. The marks 14 metres from pole T303-43 were made recently because their surface had not begun to rust or corrode (the arc melting had removed the protective galvanising).

When live bare high voltage active and earth return conductors come together an arc develops across the air gap between them or at the point of actual contact. In both cases a significant amount of electric energy passes between the two conductors and considerable heating is produced in the metal at the point where the arc is formed or contact is made. This heat causes melting of the conductor metal, with possible welding of the conductors and the formation of very hot, molten metal globules falling to the ground that may ignite a fire. Such molten droplets have caused several fires in Western Australia and in other states after falling onto dry combustible vegetation on the ground.

Clashing of the active and earth return conductors between poles T303-42 and T303-43 was simulated by a field tests applying an upward force of 420 Newtons (corresponding to a weight of 42 kilograms) 14 metres from a pole on a span comparable to the span between poles T303-42 and T303-43. This test indicated that it is possible for the underslung earth return conductor to contact the 12.7kV active conductor by applying mechanical force. This did not explain how the 200mm horizontal offset between the active and earth return conductors (due to the insulator mountings) could be bridged. Also clashing of conductors, so close to a pole, is unusual and very improbable. Such clashes typically occur near mid-span.

The arc marks are therefore more likely to have been caused by a conductive object, such as fencing wire or vegetation, bridging between the active and return conductors. Energy*Safety* therefore conducted a thorough ground search using a metal detector around the area under and adjacent to the point under the position where the arc marks occurred. Short lengths of wire were found but these were well outside the area underneath the arc marks. The wire found was also too short to reach across the 1.2 metre space between the conductors and would not explain the two arc marks on the active conductor. If such an event happened it would be an act of vandalism and not the responsibility of Western Power. Western Power was not able to offer a reason as to how the arc marks were caused. The cause of the arc marks could not be determined nor could it be determined if they contributed to the cause of the bushfire.

4.5 Operation of the T303 Spur Automatic Recloser

The T303 spur power line emanates from Toodyay and is protected by an automatic reclosing circuit breaker (recloser) and two sectionalisers. The recloser is designed to open and then reclose if a fault occurs on the power line. The recloser protecting the T303 spur power line is set to operate four times and, if the fault persists it locks out (stays open). The sectionalisers are designed to operate and isolate the faulty part of the power line before the recloser can lock out, thereby maintaining an electricity supply to the section of the power line that is not faulty.

The fire was reported through a 000 emergency call at 12:57 hours. The automatic recloser located at the origin of the T303 power line detected a fault at 12:53 hours, attempted three rapid re-close operations and locked out at 12:54 hours. The power line was and remained de-energised from that time. The bushfire was noticed first at approximately 12:53 hours when it was sufficiently advanced to produce a column of smoke visible at some distance above a line of trees. A minute later the power line was de-energised. The recloser detected a fault at very close to the same time the fire was first noticed.

The fault pattern detected by the recloser is not consistent with conductor clashing. Such a clash would have caused the recloser to open briefly and then re-close (and stayed closed) to restore supply, which it would likely have done, since clashes are brief and fleeting. The actual pattern corresponds to a permanent, rather than fleeting, short circuit, which most likely occurred upstream from the area where the fire started. The section of T303 spur upstream of the area of origin was extensively burned and no evidence remained to indicate the location or cause of such a short circuit.

The sectionaliser at pole T303-40 would have operated if a permanent fault had occurred at poles T303-42 and T303-43. This sectionaliser did not operate, instead, the recloser operated

and locked out. The sectionaliser was tested and found to be operating correctly at 20 amperes. This indicates that the fault was upstream of the sectionaliser and closer to Toodyay. The T303–40 sectionaliser also would not have operated from a clashing of conductors as it requires three consecutive faults to lock open.

4.6 Western Power's Report

Western Power provided a report which was considered as part of Energy*Safety's* independent investigation. Western Power concluded that "it is most unlikely that an electrical discharge from this section of line (if there was any, which is unlikely) could have been caused by agents or factors within the control of Western Power on 29 December 2009".

4.7 Condition of Poles T303-42 and T303-43 Prior to the Bushfire

Examination of evidence from two independent witnesses immediately after the bushfire was noticed confirmed that poles T303-42 and T303-43 did not fail prior to the commencement of the bushfire. This was also confirmed by later examination of the poles and fire scene by a scientist from the Forrest Products Commission.

Investigation concluded that Pole T303-42 eventually burnt through near the ground and then fell towards the ground. The fire consumed all except for the top of the pole.

Pole T303-42. Photograph taken by FESA on 29 December 2009

Pole T303-43 was also burning near the ground and then fell to the ground and continued to burn until it was completely consumed. Marks on the ground confirm that the earth return conductor then broke at Pole T303-43 and pulled away from the pole (after it was consumed by the fire).

Remains of Pole T303-43. Photograph taken by FESA on 29 December 2009

Remains of Pole T303-43. Photograph taken by Energy*Safety* on 30 December 2009

Broken earth return conductor near pole T303-43 (between poles T303-42 and T303-43). Photograph taken by Energy*Safety* on 30 December 2009

Broken earth return conductor near pole T303-43 (between poles T303-43 and T303-44). Photograph taken by Energy*Safety* on 30 December 2009

4.8 Possible Causes of Fire Ignition from a High Voltage Power Line

The potential sources of ignition from the T303 spur power line in the relevant area are:

- A pole top fire.
- A pole falling over causing:
    - The live active and earth return conductors to clash, producing molten metal droplets falling to the ground and igniting stubble in the paddock, or
    - The live active conductor to contact the ground, igniting the stubble.
- The active and earth return conductors clashing through wind-generated forces while the poles are standing, causing molten metal to drop to the ground.
- Farm machinery or vehicles making contact with the active conductor, pushing the under-slung earth return conductor up into the active conductor above it or bringing some form of metal attachment on the machinery or vehicle into simultaneous contact with both the active and earth return conductors, again producing hot metal droplets.
- Wind-blown debris, either catching fire upon contacting the power lines and igniting stubble when falling to the ground or in vaporising, releasing hot metal droplets which fall to the ground.
- Vandalism – a person throwing conductive objects over the power line.

Each of these potential causes were considered as detailed below.

4.8.1 Pole Top Fire

Pole T303-42 was still burning on the ground after the fire but the top of the pole was not damaged. Pole T303-43 burned from the top and bottom, but both sections of burning are likely to have been initiated by the ground fire after the pole had fallen. The low humidity on 29 December 2009 also makes pole top fires very improbable.

4.8.2 Poles Falling Over

Both poles T303-42 and T303-43 were untreated jarrah, in-line, intermediate single-phase rural distribution poles with no transverse support. They were not reinforced (staked) at the ground line. The insulators (dated 1976) and return conductor fixings to the poles indicate they were installed in the mid-1970s and are approximately 35 years old.

Australian Standards 1720.2 and 2209 specify a service life of 15 to 25 years for untreated jarrah poles below the ground line and 15 to 40 years above the ground line. Thus, the two poles in question were at least ten years older than the service life generally considered as safe for untreated poles below ground.

The poles were consumed by the fire in the safety-critical zone at the ground line where wood poles normally fail. It is not possible to determine whether or not these poles had the necessary strength to withstand the forces acting on them while in service without this evidence.

The statement made by the witness who first reported the fire indicates that pole T303-42 was standing when he drove along River Road at about 13:00 hours on 29 December 2009, by which time the bushfire was well established.

A second witness's statement indicates that pole T303-43 remained standing at approximately 14:30 hours when he completed his patrol of the western edge of the fire and crossed under the power line to leave the paddock. He noticed that pole T303-42 was either lying on the ground or near to the ground and he was forced to divert his vehicle when attempting to cross under the power line after encountering low conductors at windscreen height. This indicates that Pole T303-42 had fallen over but the conductors were still intact as the active and earth return conductors were connected to the tops of poles T303-41 and T303-43 respectively on either side.

Therefore, evidence that both poles were burnt and then fell to the ground some time after the bushfire had commenced indicates that pole strength is not a factor.

The area of origin was disturbed by FESA and Police during fire scene investigation activities, as well as by necessary measures taken by Western Power. The butts of poles T303-42 and T303-43 were removed by Western Power and taken to its Northam Depot for safe keeping. Under Regulation 38 of the *Electricity (Supply Standards and System Safety) Regulations 2001* Western Power was obliged to ensure that the site remained as undisturbed as practicable, consistent with the need to restore electricity supply and avoid further risks to life and property. A written protocol, headed "Incident Evidence Retention" (DMS#:3892762v3) sets out Western Power's undertaking to preserve evidence to enable any investigation deemed appropriate.

Top of pole butt T303-42

Top of pole Butt T303-43

Western Power, after removing the pole butts from the ground engaged the Forest Products Commission to examine the cut sample cross sectional slices from the two butts.

Energy*Safety* inspectors viewed and photographed the burned pole butt sections before they were subjected to destructive testing. The conductors strung between poles T303-42 and T303-43 were seized by Energy*Safety* and sent to a specialist laboratory for metallurgical examination.

In the wood scientist's opinion, poles T303-42 and T303-43 did not fall down, but were burned through at the ground line and immediately above by the fire and then fell over when there was no longer sufficient unburned wood to support them. The scientist's report finds that these poles were set alight by the bushfire after it was ignited by some other source. Energy*Safety* agrees with this opinion.

While the scientist assessed the good and rotten wood in the pole butts, he relied on the section sawn from the poles below the ground line for his testing. Nearly all poles failing structurally do so at the ground line. The wood of both poles at the ground line was burned, preventing any reliable assessment of the structural strength of either pole before the fire.

4.8.3 Short Circuit Between the Conductors

Melted arc marks were found on the active and earth return conductors approximately 14 metres east of pole T303-43. These were surrounded by lighter marks over approximately 700 mm.

Conductor clashing has occurred in other power lines but the underlying reason in such cases usually is attributed to a non-complying design, attachment failure, inadequate maintenance, dissimilar metals in active and earth return conductors or a combination of these, which caused sufficient conductor sag to facilitate clashing.

The failure of the earth return conductor at pole T303-43 could not have caused the arc marks as the earth return conductor broke some time after the bushfire commenced and after the recloser had locked out, de-energising the T303 power line.

Measurements performed by Energy*Safety* and Western Power on 28 January 2010 were intended to verify that power line T303 spur had been constructed to comply with ESAA C(b) 1-1974 (the relevant standard applicable at the time of construction). Undisturbed spans downstream from the fire area were used for the purpose, as they were judged to be similar in all material respects to the sections involved in the fire. The conductor tensions, sags and conductor attachments were found to comply with the relevant standard.

A special test was carried out to ascertain the force required to lift the under-slung earth return conductor sufficiently for it to make contact with the high voltage active conductor strung above it, at a point 14 metres from the pole. The force required was found to be 420 Newtons, corresponding to a weight of 42 kilograms. This force is significant and Energy*Safety* believes it is a very improbable that wind action on the relatively small cross sectional area of the earth return conductor could have caused oscillations sufficiently violent to lift the conductor up into contact with its active counterpart at a point so close to the pole.

The metallurgist engaged by Energy*Safety*, reported that the main arc marks were recent because they had not yet started to rust or corrode. Recloser T303-1A had not tripped on a fault, such as conductor clashing, in the period from March 2009 to 28 December 2009. The sectionaliser on pole T303-40 also did not operate on or prior to the 29 December 2009.

Recloser T303-1A, set to open at a current flow exceeding 16 Amperes, first operated at 12:53:38 hours, attempted four operations and finally locked out at 12:54:07 hours. The recorded fault currents were in excess of 50 amperes. This recloser operation pattern is consistent with a permanent short circuit somewhere along the power line downstream of the recloser. The T303-40 sectionaliser is located downstream from the recloser and up-stream from the bushfire's area of origin. Three consecutive faults where the current exceeded 20 Amperes would have caused the sectionaliser to open. It did not operate. This indicates the fault must have been located between poles T303-1 and T303-40, which embraces a length of power line outside the bushfire's area of origin, and which was extensively burned as the fire front passed, leaving no useable evidence. Sectionaliser T303-40 was tested following the fire and found to be operating correctly.

The farmer, in charge of the land where the fire originated, confirmed that harvesting of the paddock was completed on 23 December 2009 and there was no farming activity in the paddock since then. All farming work, including harvesting, is done by the members of his family. Contractors are not used. On the basis of his assurance and inspection of his farm machinery Energy*Safety* has concluded that farm machinery is not responsible for forcing the two conductors into contact with each other.

Because the T303 spur power line was de-energised before or very soon after the fire started, there would not have been sufficient time for the fire to develop enough heat and smoke to cause a flash-over due to ionised gases.

4.8.4 Wind-blown Debris

The paddock is cleared of trees and other sources of flying debris that could short the power lines and provide a source of ignition. The nearest trees are too far away and lower in the valley to be a likely source of such debris.

4.8.5 Vandalism

The Police Arson Squad was unable to find any evidence of criminal activity which could have caused the fire ignition.

4.9 Weather Conditions

The weather recorded by the Bureau of meteorology at Northam on the 29 December 2009 was:

- 09:00 hours: 36.6 ℃, wind NNE at 9 km/h, RH 21%.
- 15:00 hours: 40.9 ℃, wind WNW at 44 km/h, RH 12%.
- Minimum Temperature 26.1 ℃ with a maximum temperature of 45.4 ℃.
- The fire hazard warning issued was “Catastrophic”.

4.10 Other Sources of Ignition - Eliminated

No lightning was recorded on the day. Harvesting and vehicle movement on the property was reported to have been finished on 23 December 2009. No vehicle movements or persons were observed near the area immediately before the fire was noticed.

5 SEQUENCE OF EVENTS

From the witness interviews, scientific analysis and logical evaluation of the available evidence the following sequence of events is probable:

- The recloser on the T303 power line detected a fault at 12:53 hours, attempted three rapid re-close operations and then locked out at 12:54 hours. The T303 power line was and remained de-energised from that time.
- At, or some time before, 12:53 hours a bushfire originated in the paddock to the south of River Road and west of Folewood Road Toodyay in the area encompassing Western Power's poles T303-42 and T303-43.
- A farm manager noticed smoke from the fire at approximately 12:53 hours from his home on the rise directly across the Avon River to the north of the paddock where the fire started. The witness did not have a clear view of the paddock and power line and saw the smoke over the trees along the river in the foreground. The farm manager indicated that fire started between poles T303-42 and T303-43.
- The farm manager then called 000 at 12:57 hours which alerted FESA of the bushfire.
- The fire extended to and almost burnt down pole T303-41 to the east, but did not extend to and burn pole T303-44 to the west.
- Another witness from a farm to the south-east of the origin of the fire noticed smoke and called 000 at 13:05 hours.
- Pole T303-41 was substantially burnt at the ground line, but remained standing, supported by the power lines and stay wire.
- Pole T303-42 burned through at the ground line, fell and was almost consumed by fire after falling, apart from the top metre or so. The pole butt was burnt on the top where it was exposed to the fire. The rest of the butt below the ground was not burnt.
- Pole T303-43 burned through at the ground line, fell and was completely consumed by fire. Again, its butt was burnt on the top, but not below the ground.
- After pole T303-43 burnt through near the ground line and fell to the ground the earth return conductor that was attached to it broke.

6 CONCLUSION

Energy*Safety's* investigation concluded that:

- The bushfire on 29 December 2009 to the west of Toodyay started in the paddock south of River Road and west of Folewood Road in the cleared area through which Western Power's T303 single-phase 12.7 kV rural distribution power line passes.

- The smoke from the bushfire was first observed and reported to FESA at 12:57 which fixes the bushfire's ignition a short time before.

- The exact point of origin within the area of origin of the bushfire has not been determined and is now unlikely to be determined. The best estimate of the point of origin is towards the eastern end of the span between poles T303-42 and T303-43, given the direction and strength of the wind at the time (40 kph from the WNW).

- A pole-top fire did not cause the ignition.

- Neither pole T303-42 nor T303-43 fell over and caused the fire ignition from live conductors clashing or coming into contact with the ground. The available evidence confirms that the poles were standing when the fire started and continued to stand for some time after the fire front had passed.

- Western Power's line protection (recloser) operated and locked out on 29 December 2009 at 12:54 hours. It did not record a trip operation between March 2009 and prior to this event on 29 December 2009.

- The sectionaliser at pole T303-40 did not operate indicating that the fault which caused the recloser (at T3030-1A) to lock out was between the sectionaliser and recloser (i.e. upstream of the area of origin of the bushfire). This fault was not found and could not be determined due to the damage from the bushfire.

- There is clear evidence of arcing between the conductors in the span between poles T303-42 and T303-43. The reason for and timing of the arcing or whether this caused the ignition of the fire could not be determined.