Final report RO-2015-102: Electric locomotive fire at Palmerston North Terminal, 24 November 2015

Final Report

Rail inquiry RO-2015-102

Electric locomotive fire at Palmerston North Terminal
24 November 2015

Approved for publication: February 2017

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is a standing commission of inquiry and an independent Crown entity responsible for inquiring into maritime, aviation and rail accidents and incidents for New Zealand, and co-ordinating and co-operating with other accident investigation organisations overseas. The principal purpose of its inquiries is to determine the circumstances and causes of occurrences with a view to avoiding similar occurrences in the future. Its purpose is not to ascribe blame to any person or agency or to pursue (or to assist an agency to pursue) criminal, civil or regulatory action against a person or agency. The Commission carries out its purpose by informing members of the transport sector and the public, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

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Important notes

Nature of the final report

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Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1982 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

Photographs, diagrams, pictures

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Verbal probability expressions

The expressions listed in the following table are used in this report to describe the degree of probability (or likelihood) that an event happened or a condition existed in support of a hypothesis.

Terminology (Adopted from the Intergovernmental Panel on Climate Change)	Likelihood of the occurrence/outcome	Equivalent terms
Virtually certain	> 99% probability of occurrence	Almost certain
Very likely	> 90% probability	Highly likely, very probable
Likely	> 66% probability	Probable
About as likely as not	33% to 66% probability	More or less likely
Unlikely	< 33% probability	Improbable
Very unlikely	< 10% probability	Highly unlikely
Exceptionally unlikely	< 1% probability	

Source: mapsof.net

Location of accident

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Abbreviations

CCTV	closed-circuit television

Glossary

Auckland Transport	the owner of the Auckland region commuter trains
controlled network	the New Zealand rail system that is controlled by KiwiRail's National Train Control Centre
EF locomotive	a 25-kilovolt, 50-hertz alternating current electric locomotive operating on the North Island Main Trunk line between Palmerston North and Hamilton
EN 45545 & AS 7529	international best-practice standards that define the requirements to provide a minimum level of fire safety to rail rolling stock
Dunedin Rail	the operator of tourist trains from Dunedin Railway Station to Pukerangi and Middlemarch
Greater Wellington Regional Council	the owner of the Wellington region commuter trains
high-voltage cable assembly	the entire high-voltage cable, from the pantograph to the plug that terminates into the transformer housing in the transformer compartment of an EF locomotive
high-voltage plug assembly	the end of the high-voltage cable that plugs into the transformer housing inside the transformer compartment of an EF locomotive
National Rail System Standards	a set of interoperability standards for all users of the New Zealand controlled network to comply with
National Rail System Executive	the body that controls, reviews and amends the National Rail System Standards
pantograph	a device fitted to the roof of an electric locomotive that contacts the overhead line equipment to convey power to the locomotive traction system
pilot	a qualified person who ensures the safety of a train movement by guiding the driver
Transdev	the Auckland region commuter rail operator, and the Wellington region commuter rail operator from July 2016

Data summary

Vehicle particulars

Train type and number:	light locomotive EF30157
Classification:	electric locomotive
Manufacturer:	Brush, United Kingdom (See www.brush.eu)
Year of manufacture:	1988
Operator:	KiwiRail Holdings Limited
Date and time	24 November 2015 at 1830[1]
Location	Palmerston North Terminal
Persons involved	train driver
Injuries	none
Damage	fire damage within the locomotive transformer compartment

Figure 1
Electric locomotive burning at KiwiRail Palmerston North Terminal
Source: Witness mobile phone video still

[1] Times in this report are New Zealand Daylight Saving Time (Co-ordinated Universal Time +13 hours) and are expressed in the 24-hour mode.

1. Executive summary

1.1. On Tuesday 24 November 2015 at about 1830, a KiwiRail Holdings Limited (KiwiRail) light freight locomotive (EF30157) caught fire while parked at the Palmerston North rail depot.

1.2. The Fire Service attended, but the fire was not extinguished until later that evening at 2023. The locomotive's transformer compartment suffered fire damage. No-one was injured during the incident.

1.3. The Transport Accident Investigation Commission (Commission) found that the seat of the fire was located where the high-voltage cable, used to transmit power from the overhead power line to the locomotive, was connected into the transformer using a plug and socket arrangement. The socket was filled with oil to insulate the high-voltage cable plug.

1.4. The cause of the fire was attributed to a failure in the insulation of the high-voltage cable plug. A subsequent short circuit caused an explosion in the oil-filled socket and ignited the oil. The resulting fire was fed by a constant supply of oil from a 3,000-litre reservoir that could not be isolated due to the maintenance shut-off valve's close proximity to the seat of the fire.

1.5. The Commission found that:

- no fire detection and suppression system standards have been adopted across the New Zealand rail sector
- the operator of the locomotive relied on its staff to apply best judgement when dealing with fires rather than providing specific documentation and training
- from the maintenance records available it was not possible to determine if the failed cable was new or second-hand
- the 5,000-volt insulation integrity test carried out on the high-voltage cable assembly was not representative of the 25,000-volt in-service conditions.

1.6. The Commission is recommending that the Chief Executive of the NZ Transport Agency:

- ensure that in their safety cases the access provider of, and operators using, the National Rail System consider fire in rail vehicles as a risk to the safety of their operations, and must demonstrate that they have mitigated that risk as far as reasonably practicable
- when conducting safety assessments of each rail licence holder, ensure that they have identified and assessed the risk of fire in a rail vehicle. The Chief Executive should ensure that they have, as far as reasonably practicable, minimised the risk and have measures in place to deal with the outbreak of, and reactions to, fire events
- when conducting safety assessments of each rail licence holder operating on the National Rail System, ensure that systems are in place that record in detail the maintenance history of safety-critical rail vehicle parts and that any tests on replacement parts are appropriate to simulate in-service conditions.

1.7. The Commission is also recommending that the National Rail System Executive adopt or develop a New Zealand Fire Standard that incorporates, but is not limited to:

- minimising sources of fire ignition
- restricting fire propagation
- the use of fire-resistant materials
- of appropriate firefighting equipment
- ventilation systems to protect crew and passengers from harmful smoke and gases
- the installation of fixed fire protection systems

- the ability to self-rescue or relocate the train in the event of a fire in a tunnel or similar hazardous location.

1.8. A key lesson identified from this inquiry is that operators of public mass transport systems must provide their staff with guidelines, procedures and training to enable them to deal effectively with a fire, instead of relying on their best judgement.

2. Conduct of the inquiry

2.1. The incident occurred at about 1830 on Tuesday 24 November 2015. The NZ Transport Agency (the Agency) notified the Transport Accident Investigation Commission (Commission) soon after the incident occurred. The Commission opened an inquiry under section 13(1) of the Transport Accident Investigation Commission Act 1990 to determine the circumstances and causes of the incident and appointed an investigator in charge.

2.2. Commission investigators travelled to Palmerston North the next day to inspect the fire-damaged locomotive.

2.3. Commission investigators interviewed the train driver who brought the locomotive into the Palmerston North Terminal, a KiwiRail employee who witnessed the fire, a locomotive servicing assistant and a New Zealand Fire Service investigator. The Commission obtained the following records and documents for analysis:

- closed-circuit television (CCTV) recordings from on-site security cameras
- a phone video recording provided by a witness
- records of other failures and fires on locomotive power units within the KiwiRail and Auckland Transport fleet from the previous 10 years
- the locomotive's maintenance records
- fire policies, procedures and guidelines from KiwiRail, Transdev[2] and Dunedin Rail[3]
- the status of fire detection and fire suppression systems in the mainline locomotive fleet
- consultation with the manufacturer of the EF class locomotives, Brush Electric UK
- consultation with the United Kingdom's Rail Accident Investigation Branch (RAIB).

2.4. On Thursday 10 December 2015 Commission investigators again inspected the locomotive. With the assistance of KiwiRail engineers and a Fire Service investigator, critical components were removed from the locomotive and transported to the Commission's secure wreckage facility in Wellington.

2.5. On Monday 14 December 2015 Commission investigators, assisted by a KiwiRail engineer, dismantled the removed high-voltage cable plug to determine the factors that contributed to its failure.

2.6. On 28 September 2016 the Commissioners considered a draft report and approved it to be sent to interested persons for consultation.

2.7. Submissions were received from four interested parties. The Commission has considered all submissions and any changes as a result of those submissions have been included in this final report.

[2] Transdev is the Auckland region commuter rail operator, and the Wellington region commuter rail operator from July 2016.
[3] Dunedin Rail is the operator of tourist trains from Dunedin Railway Station to Pukerangi and Middlemarch.

3. Factual information

3.1. Narrative – timeline of the event

3.1.1. On Tuesday 24 November 2015 at about 1800, a southbound freight train consisting of a single electric locomotive and 12 wagons stopped near the tower in the KiwiRail Palmerston North Terminal (see Figure 2).

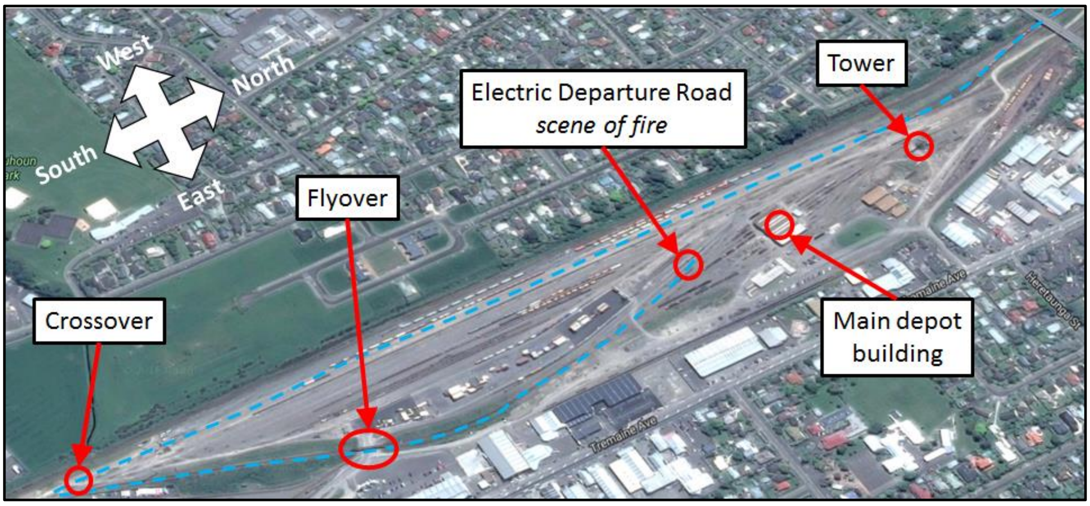

Figure 2
Palmerston North Terminal aerial view

3.1.2. The train driver was relieved by a local depot driver before six wagons were detached. The train was then moved beyond the 'crossover' (see Figure 2) where the locomotive was detached from the remaining wagons. The depot driver, assisted by a pilot[4], drove the locomotive over the 'flyover' before it was parked on the electric departure road (see Figure 2) in preparation for a northbound service.

3.1.3. The pilot alighted from the 'north end' locomotive cab and walked towards the main depot building. The depot driver secured the locomotive by turning the lights off and applying the brakes.

3.1.4. At 1837 CCTV footage confirmed that a puff of smoke emanated from the locomotive transformer[5] compartment.

3.1.5. At 1838 the depot driver alighted from the 'south end' locomotive cab and walked along the eastern side of the locomotive towards the main depot building (see Figure 2). As he did so flames shot out of the side grille of the transformer compartment (see Figure 3).

3.1.6. At 1843 a KiwiRail maintenance engineer observed the fire and entered the south end cab to drop the pantograph[6] and disconnect the locomotive from the overhead power line.

3.1.7. At 1848 an emergency call was made to the Fire Service requesting its attendance at the fire. The Palmerston North Fire Service arrived at the scene at 1852.

3.1.8. To help the Fire Service determine the most effective way to extinguish the fire, KiwiRail used the internal layout of an electric locomotive parked nearby for familiarisation.

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[4] A pilot is a qualified person who ensures the safety of a train movement by guiding the driver.
[5] The electric locomotive transformer takes the high 25-kilovolt input voltage and reduces it to a lower voltage for the locomotive traction motors to use.
[6] A pantograph is a device fitted to the roof of an electric locomotive that contacts the overhead line equipment to convey power to the locomotive traction system.

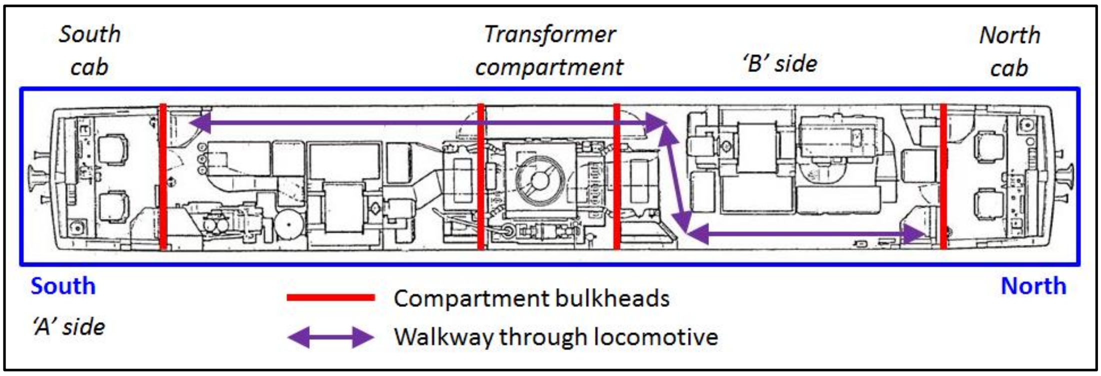

Figure 3
Layout of an electric locomotive (see Appendix 1 for more detail)

3.1.9. At about 1905 KiwiRail overhead traction maintenance staff confirmed to the Fire Service that the overhead power line was isolated and earthed.

3.1.10. At 1906 the Fire Service attempted to extinguish the fire by applying water to the outside of the locomotive, aiming the water through the vents on the eastern side of the transformer compartment. The water had no effect on extinguishing the fire.

3.1.11. At 1923 the Fire Service applied foam to both external sides of the locomotive transformer compartment in an attempt to smother the fire. The foam had a minimal effect on extinguishing the fire.

3.1.12. In response, firefighters equipped with breathing apparatus entered the internal walkway of the locomotive (see Figure 3) and applied foam directly to the source of the fire inside the transformer compartment.

3.1.13. The fire was declared extinguished at 2023.

3.1.14. Both the interior and the exterior of the transformer compartment were damaged by the fire (see Figure 4). The fire was contained within the transformer compartment and the locomotive is considered repairable by KiwiRail.

Figure 4
Fire damage to the exterior and interior of the transformer compartment

3.2. The power supply to the locomotive

3.2.1. Power is transferred from the overhead power line to the locomotive through the pantograph and down into the transformer compartment by a high-voltage cable assembly. The cable terminates in the transformer housing using a plug and socket arrangement. The socket is an oil-filled reservoir.

3.2.2. The high-voltage cable has a conductive core that is surrounded by insulation, an earth mesh screen, and an outer rubber sheath (see Figure 5).

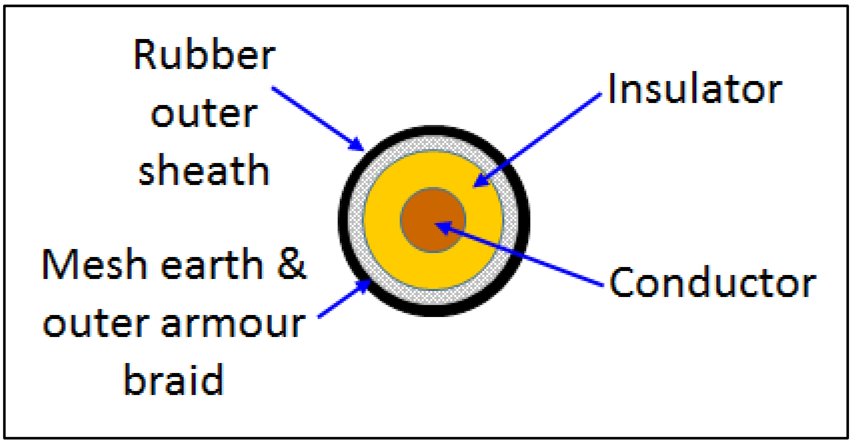

Figure 5
Cross-section of high-voltage cable

3.2.3. The high-voltage cable assembly is manufactured and delivered as a complete unit, ready to install. The cable plug is bolted to the transformer socket and the space between them is filled with insulating transformer oil (see Figure 6).

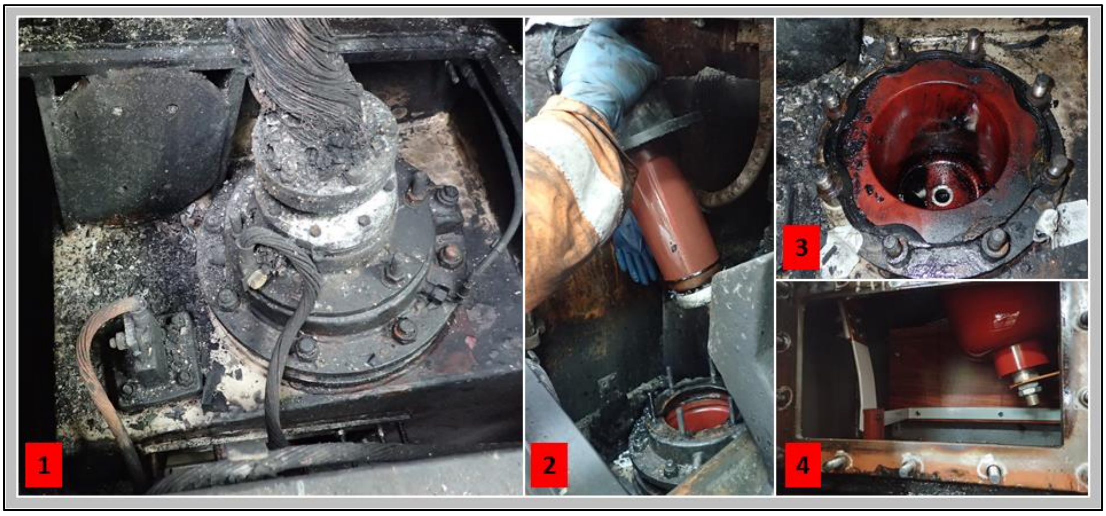

Figure 6
The high-voltage cable assembly – post fire

Picture 1 – the cable and plug bolted on to the transformer housing
Picture 2 – the plug being lifted clear of the oil-filled socket in the transformer housing
Picture 3 – the socket in the transformer housing with the oil drained
Picture 4 – the socket inside the transformer housing, viewed from the side access hatch

3.3. The importance of high-voltage cable insulation

3.3.1. The quality of the insulation between the 25-kilovolt[7] conductors and earthed metal parts is essential for providing continuous power to the transformer and for electrical safety. Under normal operating conditions the insulation is under constant electrical stress. If the insulation is weakened at any point this could lead to failure and in turn an electrical short to earth.

3.3.2. A short to earth will result in a high temperature being generated. An increase in temperature increases the pressure within the oil-filled socket, which in turn has the potential to create an explosion.

[7] A kilovolt is a unit of electromotive force equal to 1,000 volts.

3.4. Seat of the fire

3.4.1. In conjunction with the Palmerston North Fire Service and KiwiRail's EF class high voltage expert, a visual examination of the scene was carried out to identify the source of the fire. After observing the burn pattern, the spread of the fire and the heat damage to equipment in the transformer compartment, the source of the fire was traced to where the high-voltage cable entered the transformer housing (see Figure 7).

3.4.2. The Commission considered a number of factors that possibly contributed to the degradation of insulation and the failure of a high-voltage cable assembly, including:

- damage sustained during previous use
- vibration or heat in service
- manufacturing defect
- damage sustained in storage or poor storage conditions
- installation damage.

3.4.3. The Commission notes that the replacement cables now supplied by the same manufacturer replace the oil-filled socket with modern solid insulating materials.

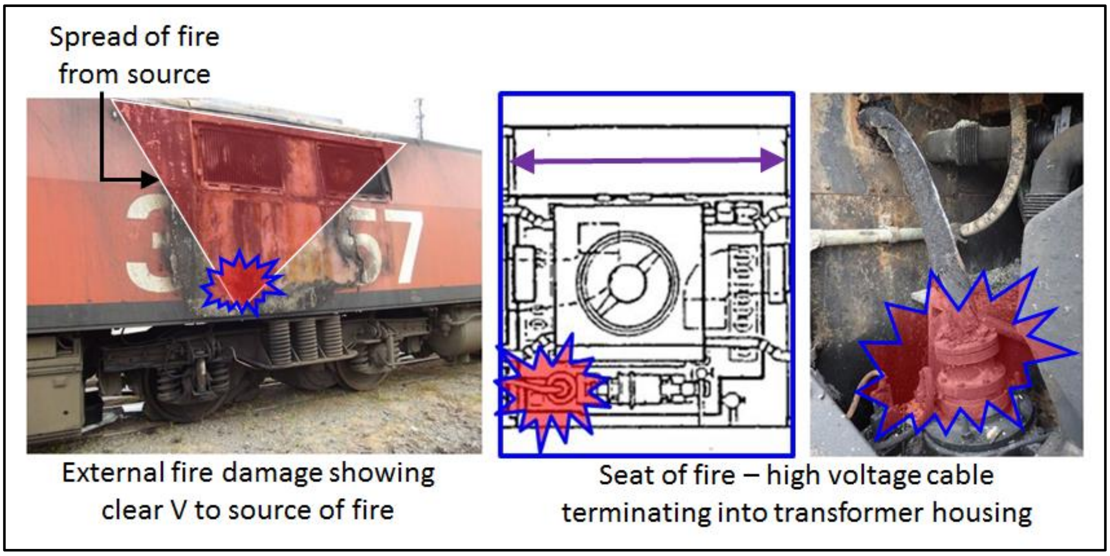

Figure 7
Seat of the fire – high-voltage cable terminating in the transformer housing

3.5. The history of New Zealand electric locomotive high-voltage cable failures

3.5.1. KiwiRail's records showed that since the commissioning of the electric locomotive fleet approximately 30 years ago there have been only three previous cable failures, none of which led to a fire.

3.5.2. The last recorded cable failure happened in December 2014 on this same locomotive, and the cause was not determined. The cable was replaced in January 2015 from KiwiRail's own stock.

3.5.3. The available records did not show whether the replacement cable was new or second-hand. It had passed KiwiRail's standard 5,000-volt insulation integrity test before it was fitted.

3.6. Fire detection, suppression and fighting equipment

3.6.1. There are currently no fire detection or suppression systems fitted to the EF class of freight locomotives, nor was there a requirement when they were manufactured.

3.6.2. The EF loco is divided into five compartments to minimise the possible spread of fire (see Figure 3).

3.6.3. Electric locomotives are fitted with 4.5-kilogram dry powder type fire extinguishers in each of the cabs.

3.7. Instructions to crew in the event of a fire

3.7.1. KiwiRail guidelines in the event of a fire are contained in section 3.2 of the Rail Operating Code – Vehicles on Fire (see Appendix 2), which states in part:

> *When a vehicle on a train is on fire, the Locomotive Engineer [driver] must use judgement to the best course to adopt in the circumstance, taking into consideration the proximity of fire-fighting appliances, the load of the vehicle, and the possibility of damage to bridges, adjacent vehicles and property.*

3.7.2. KiwiRail informed the Commission that it would expect its staff to put personal safety before company assets and equipment.

4. Analysis

4.1. Introduction

4.1.1. The electric locomotive fleet had been operating between Palmerston North and Hamilton on the North Island Main Trunk line for about 30 years. There had been three previous high-voltage cable failures recorded, none of which resulted in a fire.

4.1.2. The following analysis discusses what led to the fire within the transformer compartment.

4.1.3. The investigation identified three safety issues that, when addressed, will help to prevent a reoccurrence and improve the safety of both staff and any passengers in a similar event:

- the high-voltage cable assembly had been in service for less than 12 months, but the records available did not show if it was new or re-purposed[8], or detail the results of any test(s) performed on the cable assembly to ensure that it was in serviceable condition
- the operating procedures and training given to train crews to respond effectively in the event of a fire on a train were inconsistent across New Zealand's main rail operators
- the Natioinal Rail System Standards has no minimum standards for fire detection or suppression systems on the New Zealand rail network.

4.2. What caused the fire

4.2.1. The damage caused by the fire was contained within the transformer compartment. Commission investigators, assisted by KiwiRail's high voltage expert, removed and inspected the high-voltage plug that had been identified as the source of the fire (see Figure 8).

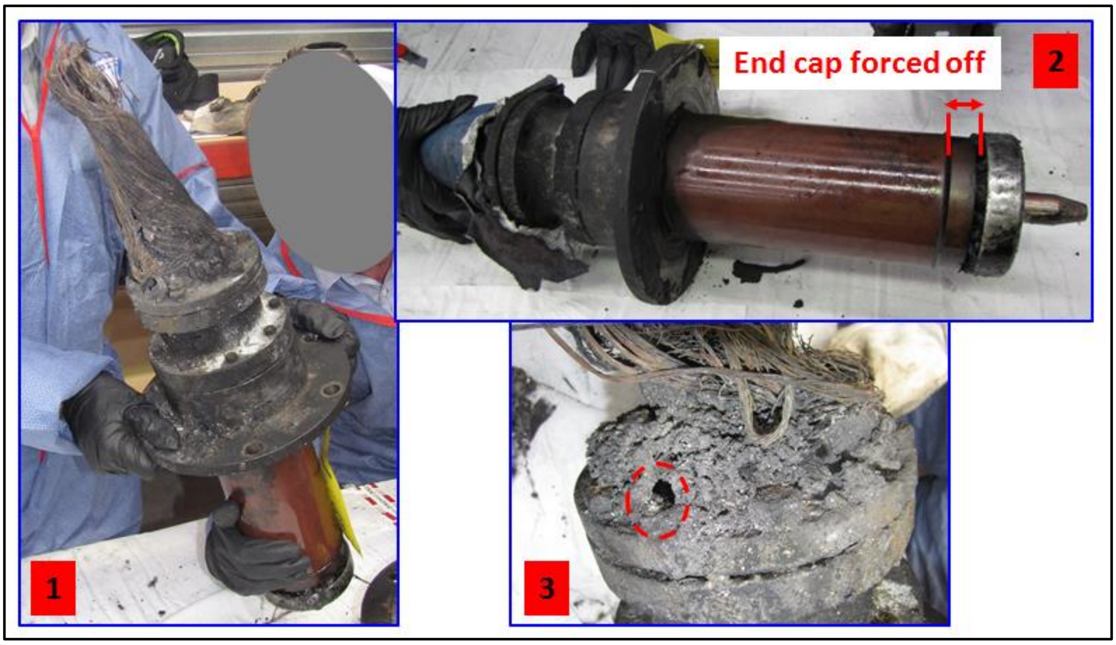

Figure 8
High-voltage cable plug removed from EF30157 transformer housing

Picture 1 – the cable plug assembly from EF30157
Picture 2 – the end cap was forced off the end of the plug assembly
Picture 3 – an exhaust vent hole formed through the cable from within the plug

4.2.2. An inspection of the high-voltage cable plug showed that the insulation had failed within the plug (see Figure 9 for cross-section detail). The breakdown of the insulation allowed a short to earth, causing an explosion that distorted the cable plug and started the fire. This happened

[8] A 'repurposed' item is one that has been used in service before being removed and put into stock as an available spare.

shortly after the locomotive had been parked on the electric departure road, when it was stationary and under no electrical load.

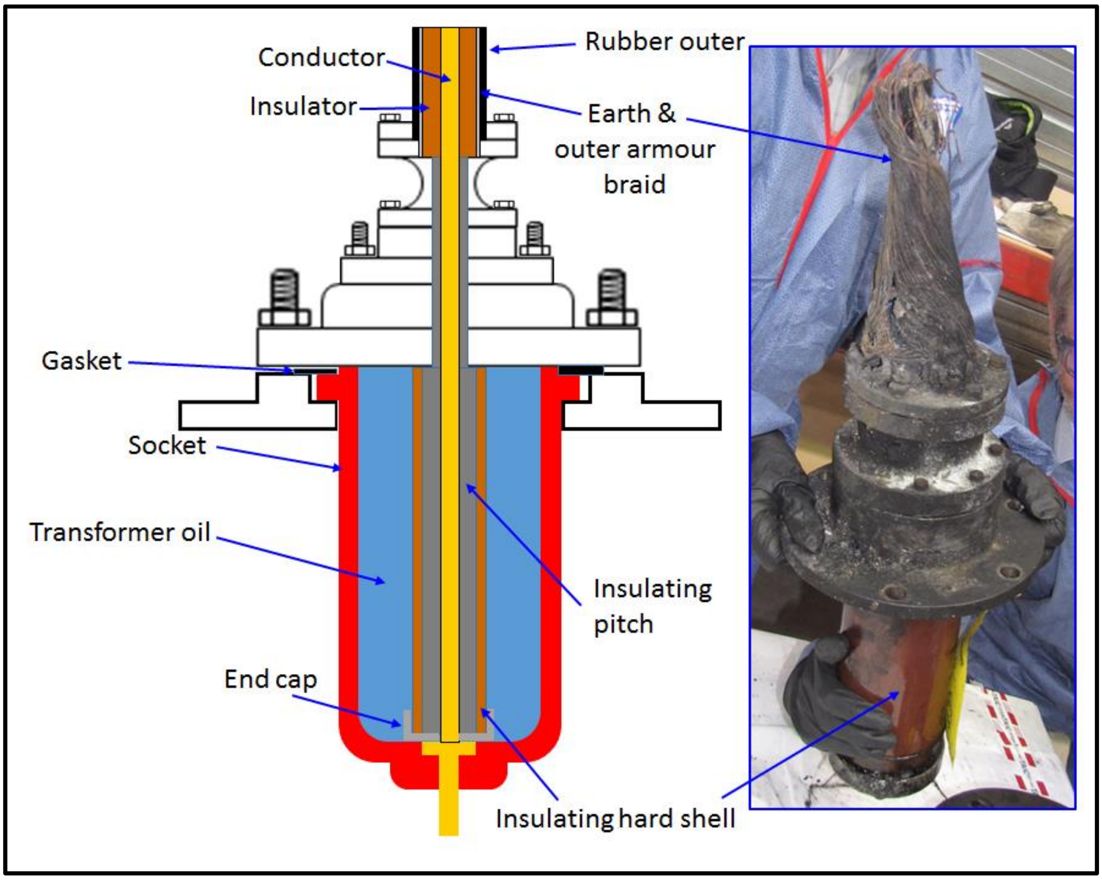

Figure 9
The high-voltage cable socket and plug assembly

4.2.3. An inspection of the high-voltage cable plug showed evidence of expansion in all directions due to an explosion:

- an explosive gas vent had occurred through the plug's copper earth screen just above the plug assembly. It had melted several strands of the earth and armour braid and exited through the rubber outer sheath (see Figure 10)
- the plug's insulating hard shell was burnt near the upper flange and the outer surface was distorted. The insulating pitch inside it had expanded and forced the end cap off (see Figure 10)
- the pressure build-up inside the oil-filled socket had breached the gasket seal between the cable plug flange and the transformer housing through an arc of approximately 60° (see Figure 11). The damaged gasket section allowed transformer oil to be forced out through the broken seal.

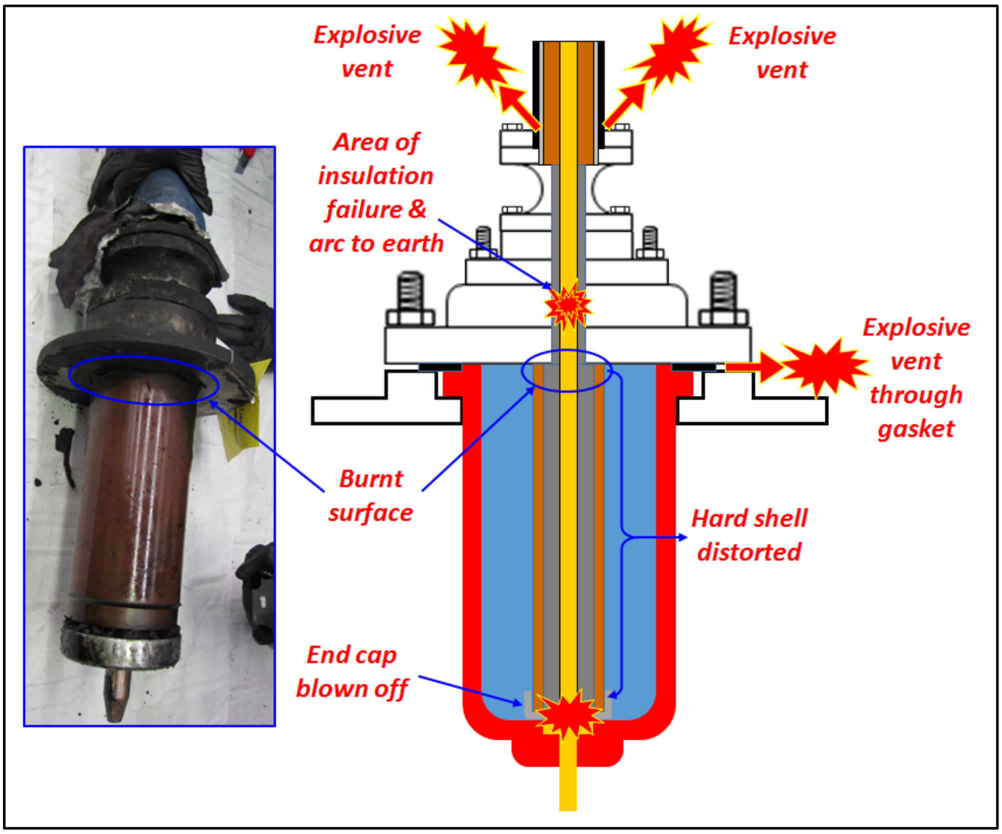

Figure 10
Diagram of cable failure

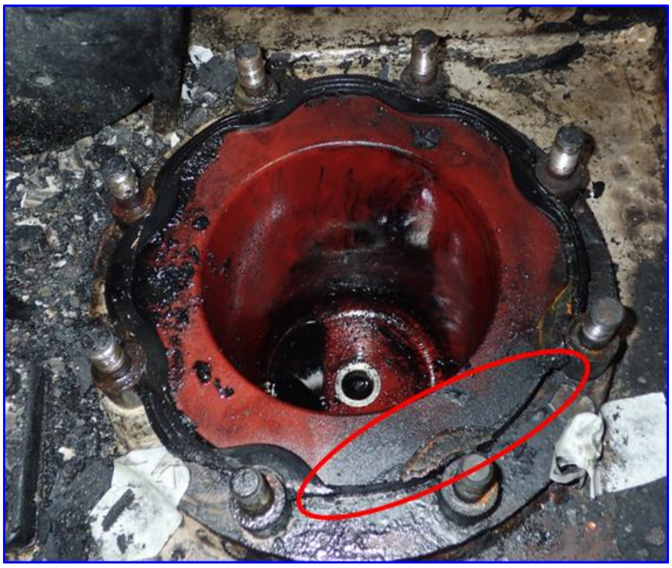

Figure 11
Damaged gasket between cable socket and oil-filled socket

4.2.4. The explosion caused by the high-voltage cable plug failure simultaneously expanded the high-voltage plug and forced oil out of the socket and ignited it. It also caused the electrical protection breakers on the locomotive to trip.

4.2.5. The oil socket was designed so that any leakage of oil was automatically topped up by a gravity feed from a multipurpose 3,000-litre oil reservoir. Once the oil had been ignited the fire received a constant supply of oil that fuelled the fire.

4.2.6. The maintenance shut-off valve was inaccessible and the oil supply could not be isolated due to its close proximity to the seat of the fire. This constant supply of fuel to the fire contributed to the difficulties faced by firefighters attempting to extinguish the fire.

4.2.7. Although the oil could not be isolated, the fire was contained within the transformer compartment by the fire bulkheads, as intended in the original design.

> **Findings**
>
> 1. A failure of the high-voltage cable plug insulation caused an explosion in the high-voltage cable plug and socket, releasing and igniting transformer oil.
> 2. The fire was sustained by a constant supply of fuel from a 3,000-litre oil reservoir, as the maintenance shut-off valve could not be isolated due to its inaccessibility and close proximity to the seat of the fire. However, the fire was contained within the transformer compartment by the fire bulkheads.

4.3. Cable assembly failure

Safety issue – the high-voltage cable assembly had been in service for less than 12 months, but the records available did not show if it was new or repurposed, or detail the results of any test(s) performed on the cable assembly to ensure that it was in serviceable condition.

4.3.1. KiwiRail obtains electric locomotive high-voltage cable assemblies from the original manufacturer of the locomotive, Brush Electric UK, which in turn sources them from a specialist external supplier. The cable that failed had been manufactured to a British Rail standard. Brush Electric UK was not aware of any similar cable failures on its locomotives that had resulted in a fire.

4.3.2. A high-voltage cable assembly failure had occurred on this locomotive within the previous 12 months. The cable assembly had been replaced from KiwiRail stock, but from the records available it was not possible to determine whether the replacement cable assembly was a new or 'repurposed' unit.

4.3.3. The high-voltage cable assembly had, however, been subjected to a standard KiwiRail 5,000-volt insulation integrity test, which it passed. This insulation integrity test was not representative of the 25,000-volt in-service conditions, but it was considered by KiwiRail to be a suitable and practical compromise test once the cable had been installed.

4.3.4. The condition of the replacement cable assembly when installed in January 2015 was determined by KiwiRail to be fit for purpose, but the reason for its subsequent premature failure is not clear.

4.3.5. It is essential that safety-critical components, which may include high-voltage cables, are properly identified and documented, and that detailed in-service maintenance records are kept.

4.3.6. A recommendation was made by the Commission in report R02013-104 for KiwiRail to address a similar issue after the derailment of a metro passenger train in Wellington on 20 May 2013. The Commission recommended that KiwiRail ensure that maintenance work carried out at its depots is undertaken in accordance with good railway engineering practice, safety-critical components are identified and documented, and all maintenance work is recorded in detail.

4.3.7. The Commission has made a recommendation to the Chief Executive of the NZ Transport Agency to address this safety issue.

Findings

3. KiwiRail's maintenance record keeping did not meet good engineering practice, as the available service records did not show whether the high-voltage cable assembly that had been in service for about 10 months was fitted new or repurposed, or record the results of any tests performed on the cable.

4.4. Fire preparedness of New Zealand rail operators on the controlled network

Safety issue – the operating procedures and training given to train crews to respond effectively in the event of a fire on a train were inconsistent across New Zealand's main rail operators.

4.4.1. The locomotive fire occurred within a major freight terminal with good road access. KiwiRail staff were able to provide expert knowledge regarding specific hazards. Other locomotives of the same class were close by and available to the Fire Service to confirm the internal layout. This assisted the Fire Service in fighting the fire; however, had it occurred away from a depot the circumstances may have been more difficult.

4.4.2. When the Fire Service arrived at the scene, vital time was lost whilst the firefighters were familiarised with the locomotive. They had no locomotive-specific information with respect to the:

- hazards on board the specific locomotive class
- internal layout of the vehicle and the locations of any isolation valves
- methods for fighting the fire specific to this locomotive class.

Had there been locomotive-class-specific details readily available to the Fire Service, the fire might have been extinguished more quickly.

4.4.3. When the high-voltage cable plug failure occurred, the on-board circuit breakers tripped as designed and the overhead power supply to the locomotive was isolated. However, unaware of this and without any formal fire training, a KiwiRail maintenance engineer used his best judgement and boarded the locomotive to activate the 'emergency pantograph down' button in the driver's cab before the Fire Service arrived. Despite his best intentions, in doing so he potentially exposed himself to unnecessary danger and potentially harmful fumes inside the locomotive. This may have been avoided if clear procedures or guidelines for action in the event of a fire had been available.

4.4.4. Neither the driver nor the pilot of locomotive EF30157 had received any training in the use of the fire extinguishers fitted to their locomotive or the actions to take in the event of a fire.

4.4.5. The Commission found that there was a range of documented fire policies, procedures and guidelines provided by New Zealand's main rail passenger operators. The procedures ranged from being very detailed to just instructing staff to use their best judgement. There was no consistent approach to training drivers and crew on the actions to take in the event of a fire. A recommendation to address this issue has been made to the Chief Executive of the NZ Transport Agency.

4.4.6. KiwiRail's current safety case lodged with the NZ Transport Agency does not mention fire risk or any related topics.

Findings

4. There are inconsistent levels of fire management documentation and training in place across New Zealand's major rail passenger operators.
5. KiwiRail relied on the best judgement of locomotive staff for dealing with the locomotive fire rather than providing documentation and training.
6. The firefighting effort was delayed due to the need to obtain information on the specific locomotive and associated hazards.
7. The Fire Service obtained information that was critical for the firefighting effort that may not have been available had the fire occurred away from a depot.

4.5. Comparing the New Zealand locomotive fleet fire standard to best practice

Safety issue – the New Zealand Rail Regulatory System has no minimum standards for fire detection or suppression systems on freight locomotives and passenger trains on the New Zealand rail network.

4.5.1. The Commission sought to ascertain international best practice in terms of fire detection and suppression systems within the rail industry. The European standard EN 45545 – Fire Protection on Railway Vehicles and the Australian standard AS 7529 – Railway Rolling Stock – Fire Safety, which makes reference to EN 45545, both define the minimum standard for locomotive fire protection to be:

- freight (diesel electric or electric) – fire detection systems
- passenger (diesel electric) – fire detection and fire suppression systems
- passenger (electric) – fire detection systems and the use of fire-retardant materials.

4.5.2. Neither of these international standards has been formally adopted in New Zealand as there is no clear mechanism to do this, and as a result there is no requirement for the fitting of fire detection and suppression systems in New Zealand locomotives. Where operators' policies do exist and such systems have been fitted, there is inconsistent adoption between operators on the controlled network (see Appendix 3).

4.5.3. In the case of this locomotive, had fire detection been fitted and activated, a quicker response to the fire may have resulted.

4.5.4. The Commission sought details of the status of the locomotive fire detection and suppression systems of the larger rail passenger operators within New Zealand. It compared those of four New Zealand rail owners/operators: KiwiRail, Auckland Transport, Greater Wellington Regional Council and Dunedin Rail with the international standards EN 45545 and AS 7529.

4.5.5. The comparison excluded (see Appendix 3 for comparison details):

- locomotives that had been mothballed or had life expectancies of less than two years
- locomotives used for shunting operations only, due to their being low risk and non-mainline operations.

4.5.6. Overall, only 48 out of a total 286 locomotives (see Appendix 3), or 16%, did not meet the minimum requirements of the international standards. A breakdown of this by owner/operator and function shows (see Figure 12):

- KiwiRail – freight – 31 out of 111 locomotives, or 28%
- KiwiRail – passenger – three out of 12 locomotives, or 25%
- Auckland Transport – passenger – 10 out of 67 locomotives, or 15%

- Greater Wellington Regional Council – 100% compliant
- Dunedin Rail – passenger – four out of 13 locomotives, or 30%.

The owners/operators of these locomotives have plans in place to address some of the shortfalls. An economic solution for the remaining locomotives is under consideration.

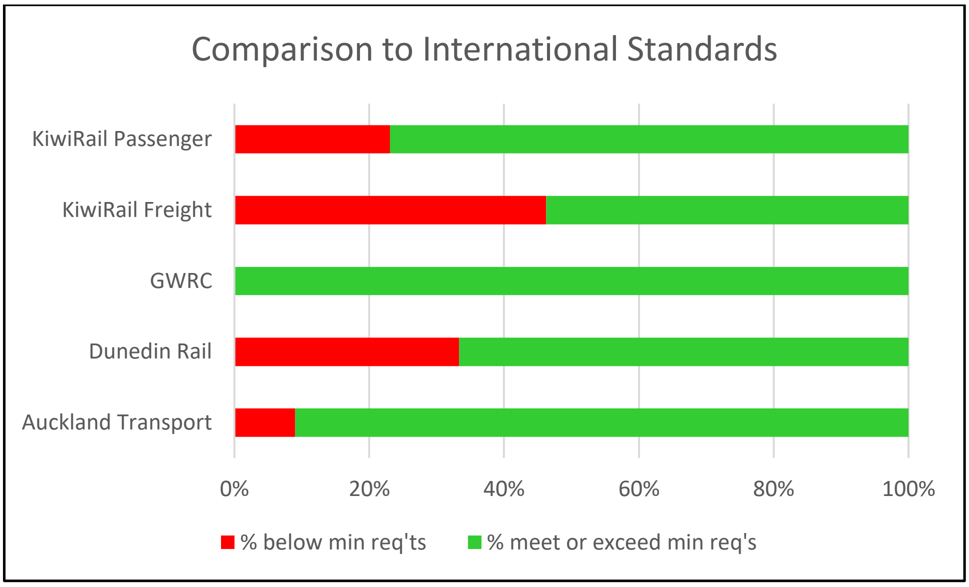

Figure 12
Percentage of operators' fleets compliant with international standards EN45545 and AS7529

4.5.7. Presently only 16% of the major New Zealand rail operators' fleets do not meet the requirements of the international standards for fitting fire detection and suppression systems. Where such systems are fitted, there is currently no consistency across the different operators. Adopting or developing a New Zealand national standard would provide consistency.

Findings

8. There is currently no national fire detection and suppression system standard adopted across the New Zealand rail sector.
9. Sixteen percent of the locomotives operating on the New Zealand rail network fall short of the international standards for fire detection and suppression on locomotives and electric multiple units.

5. Findings

5.1. A failure of the high-voltage cable plug insulation caused an explosion in the high-voltage cable plug and socket, releasing and igniting transformer oil.

5.2. The fire was sustained by a constant supply of fuel from a 3,000-litre oil reservoir, as the maintenance shut-off valve could not be isolated due to its inaccessibility and close proximity to the seat of the fire. KiwiRail's maintenance record keeping did not meet good engineering practice, as the available service records did not show whether the high-voltage cable assembly that had been in service for about 10 months was fitted new or repurposed, or record the results of any tests performed on the cable.

5.3. KiwiRail's maintenance record keeping did not meet good engineering practice, as the available service records did not show whether the high-voltage cable assembly that had been in service for about 10 months was fitted new or repurposed, or record the results of any tests performed on the cable.

5.4. There are inconsistent levels of fire management documentation and training in place across New Zealand's major rail passenger operators.

5.5. KiwiRail relied on the best judgement of locomotive staff for dealing with the locomotive fire rather than providing documentation and training.

5.6. The firefighting effort was delayed due to the need to obtain information on the specific locomotive and associated hazards.

5.7. The Fire Service obtained information that was critical for the firefighting effort that may not have been available had the fire occurred away from a depot.

5.8. There is currently no national fire detection and suppression system standard adopted across the New Zealand rail sector.

5.9. Sixteen percent of the locomotives operating on the New Zealand rail network fall short of the international standards for fire detection and suppression on locomotives and electric multiple units.

6. Safety actions

General

6.1. The Commission classifies safety actions by two types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission during an inquiry that would otherwise result in the Commission issuing a recommendation

(b) safety actions taken by the regulator or an operator to address other safety issues that would not normally result in the Commission issuing a recommendation.

Safety actions addressed during the inquiry

6.2. After the fire on EF30157, KiwiRail issued a Significant Information Notice (ML - 047 – see Figure 13) requiring the immediate inspection of the EF fleet for signs of:

- high-voltage cable damage
- oil leaks
- flammable debris, rags, etc.

KiwiRail **Significant Information Notice**

Expiry Date: 5/12/2015 ML - 047

Subject: EF Locomotive Fire Preventative inspection

Scope: EF Locomotives

Background: EF 30157 caught fire in Palmerston North yard. As precaution all other EF locomotives will have a safety inspection.

Action:
Inspect each EF locomotive before it returns to service.

Carry out a visual inspection of the transformer compartment from the walkway, looking through protection grill, for the following.

1) All cable terminations on the transformer (No evidence of heating at cable terminations)
2) Check heat exchanger for damage or blockage
3) No signs of significant oil leaks from transformer, pipes, and radiators (look for puddles of oil)
4) Inspection of compartment body filter on outside wall, looking for blockage and blackness (walkway side indicative condition of all filters)
5) Check for debris, rags etc

If any of the inspections reveal a problem this must be rectified by the depot before locomotive re-enters service.

Record on a SAP work order for each locomotive and close when inspection is completed

Author: J Finlayson
Date: 25th November 2015

Approved for distribution by: S Murray
Date: 25th November 2015

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Figure 13
Significant Information Notice ML - 047 (see Appendix 4)

6.3. Additionally, KiwiRail performed insulation integrity tests on all of the high-voltage cables in the EF fleet and found one high-voltage cable assembly with a lower-than-expected reading. This cable was replaced as a precaution.

6.4. Periodic testing of the EF class fleet has been implemented in the KiwiRail planned maintenance system. All results are reported to engineering staff for appropriate action to be planned as required.

6.5. KiwiRail has also introduced a Polarisation Index test[9] as a final quality check after the high-voltage cable assembly has been fitted. This post-installation test confirms that the difficult installation has not affected the quality of the cable insulation.

6.6. KiwiRail confirmed to the Commission that all the old-design, 'oil-filled socket' type cables have been used up, and that the newer-design cables available from the original manufacturer use modern insulation to replace the oil bath.

6.7. In December 2016 KiwiRail announced that the EF class locomotives will be removed from service and replaced with diesel-electric locomotives by the end of 2018.

[9] Polarisation Index test – the ratio of two insulation tests separated by a time period.

7. Recommendations

General

7.1. The Commission may issue, or give notice of, recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector. In this case recommendations have been issued to the National Rail Safety System Executive and the NZ Transport Agency, with notice of these recommendations given to KiwiRail.

7.2. In the interests of transport safety, it is important that these recommendations are implemented without delay to help prevent similar accidents or incidents occurring in the future.

Recommendations

7.3. The Commission found inconsistencies between New Zealand's main rail passenger operators in respect of their documented fire policies and procedures. In this case the operator had not mentioned the risk of fire in its safety case and therefore it had not been considered a principle risk to its operation. As a consequence there were no locomotive-specific fire-fighting instructions and the fire-fighting effort was delayed until the Fire Service had familiarised themselves with the locomotive layout. Inconsistencies were also found between operators in respect to the level of fire management documentation and the level of fire training provided for train drivers and crew.

7.3.1. The Commission recommends that the Chief Executive of the NZ Transport Agency ensure that in their safety cases the access provider of, and operators using, the National Rail System consider fire in rail vehicles as a risk to the safety of their operations, and must demonstrate that they have mitigated that risk as far as reasonably practicable. (001/17)

On the 31st March 2017, NZ Transport Agency replied:

> *The Transport Agency confirms that it will implement this recommendation. As it may involve significant work for some operators, the Transport Agency will need to carry out detailed planning to be able to provide the Commission with a definitive timeline. Likely actions include:*
>
> - *The Transport Agency notifying affected operators*
> - *Safety case variations being requested and approved (if required)*
> - *Conducting a safety assessment of system changes associated with the recommendation, to test that the safety risk is being managed so far as reasonably practicable.*

7.4. The Commission recommends that the Chief Executive of the NZ Transport Agency, when conducting safety assessments of each rail licence holder, ensure that they have identified and assessed the risk of fire in a rail vehicle. The Chief Executive should ensure that they have, as far as reasonably practicable, minimised the risk and have measures in place to deal with the outbreak of, and reactions to, fire events. (002/17)

7.5. Although the high-voltage plug assembly had been tested, the test was not representative of in-service conditions. The cable had been in service for less than 12 months when it failed, and maintenance records were unable to show whether the cable was new or repurposed or the results of any tests carried out before and after fitting.

7.5.1. The Commission recommends that the Chief Executive of the NZ Transport Agency, when conducting safety assessments of each rail licence holder operating on the National Rail System, ensure that systems are in place that record in detail the maintenance history of safety-critical rail vehicle parts and that any tests on replacement parts are appropriate to simulate in-service conditions. (003/17)

On the 31st March 2017, the NZ Transport Agency replied in relation to recommendations 002/17 and 003/17:

> *The Transport Agency confirms it will implement these recommendations. This will occur through our risk based assessment programme. The programme has a 12-18 month cycle to assess all current rail operators, although the Transport Agency will prioritise those that present a greater risk.*
>
> *The Transport Agency believes that the enduring requirement of fire risk identification and mitigation and assurance is important. We do however note that the priority of rail risks may change over time and it considers that it is essential that the scope and focus of assessments adapts to the current risks and environment identified through the Transport Agency's risk based approach. For that reason it may prove difficult to eventually close these recommendations because of their on-going nature. However, when the Transport Agency has carried out the initial work in respect of all rail operators, we will engage with the Commission to discuss our perspective on how we can continue to gain assurance of the safety outcomes in question.*

7.6. International standards exist for fitting fire detection and suppression systems on freight locomotives and passenger trains. However, they have not been formally adopted across New Zealand. As a result there is currently no minimum national fire standard for trains operating on the New Zealand rail network. Where operators have identified the need to fit such systems, an inconsistent approach has been adopted.

7.6.1. The Commission recommends that the National Rail Safety System Executive adopt or develop a New Zealand Fire Standard that incorporates, but is not limited to:

- minimising sources of fire ignition
- restricting fire propagation
- the use of fire-resistant materials
- the provision of appropriate firefighting equipment
- ventilation systems to protect crew and passengers from harmful smoke and gases
- the installation of fixed fire protection systems
- the ability to self-rescue or relocate the train in the event of a fire in a tunnel or similar hazardous location. (004/17)

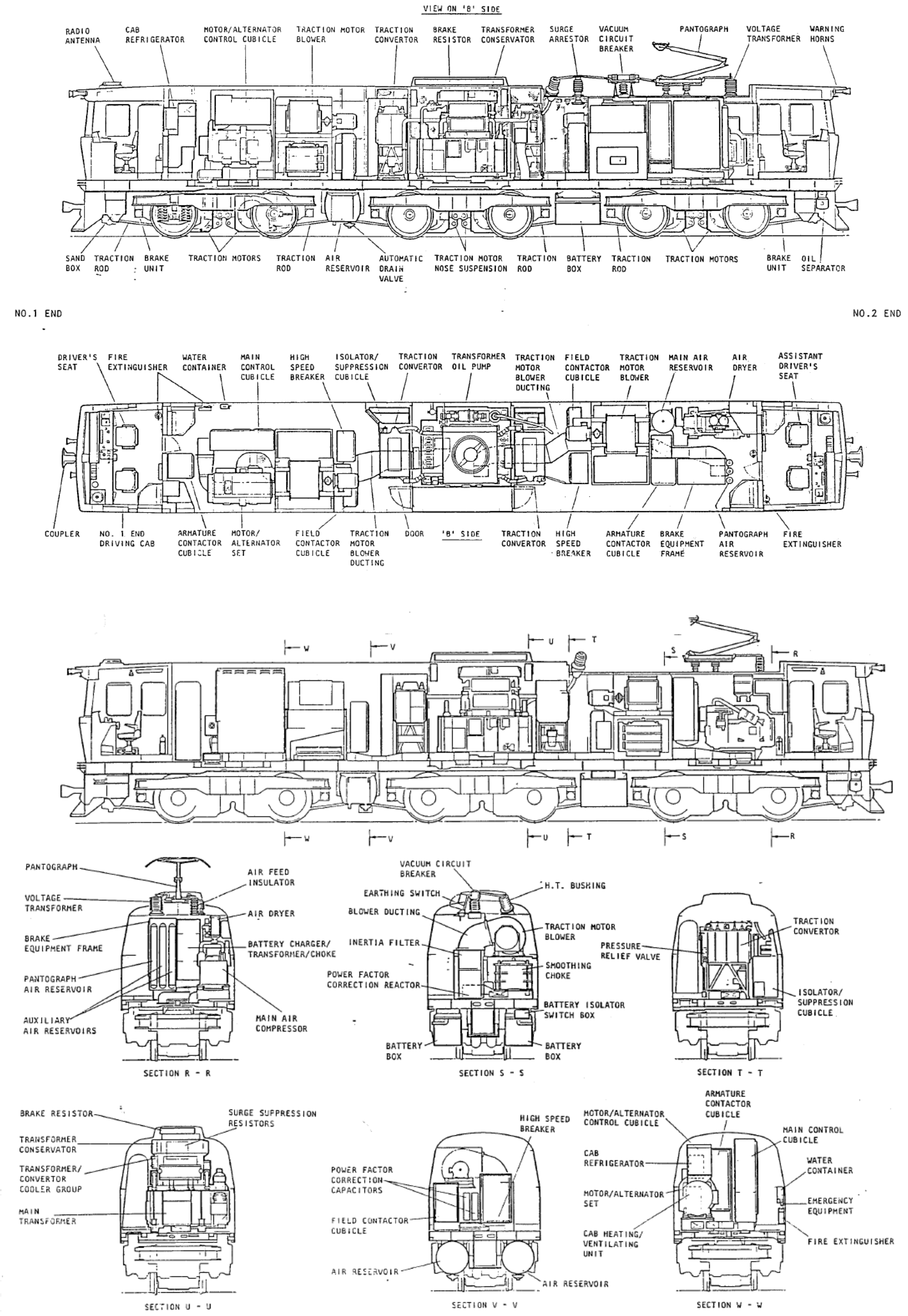
On the 30th March 2016, the NRSS Executive replied:

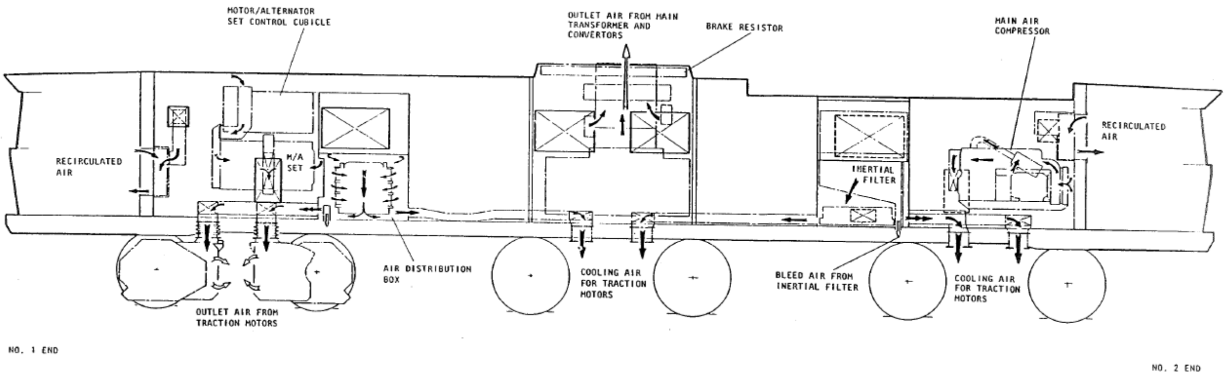
> *The NRSS Executive noted that the request to 'adopt or develop' would not be within the scope of the NRSS Executive to undertake, but does recognise that such matters are required to be considered for the operating environment. Therefore the NRSS Executive can propose, through relevant NRSS documentation, the consideration of relevant international standards for the interoperability environment.*
>
> *These standards would also incorporate, but not be limited to those specific areas as identified by the Commission, due to the systems approaches that will be required to sustain the Commission's recommendations. The NRSS Executive noted in particular, that rail fire safety is a complex issue and one that requires a system's approach across all aspects including infrastructure, rolling stock and operations to achieve and sustain safe outcomes.*

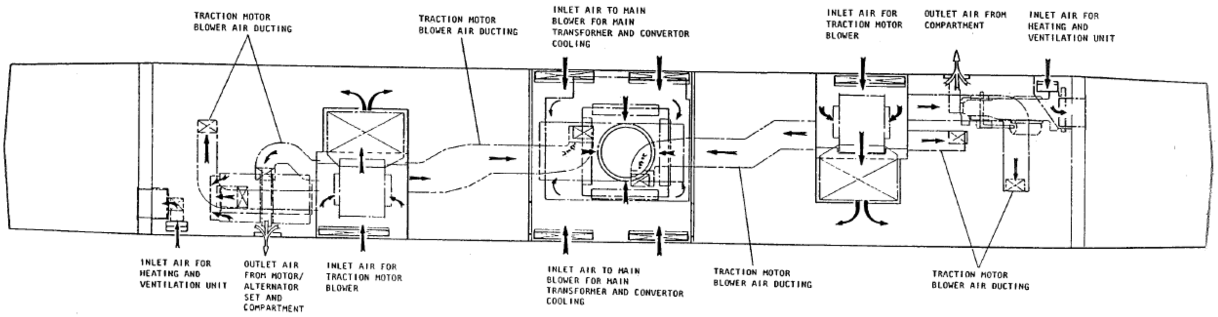
8. Key lessons

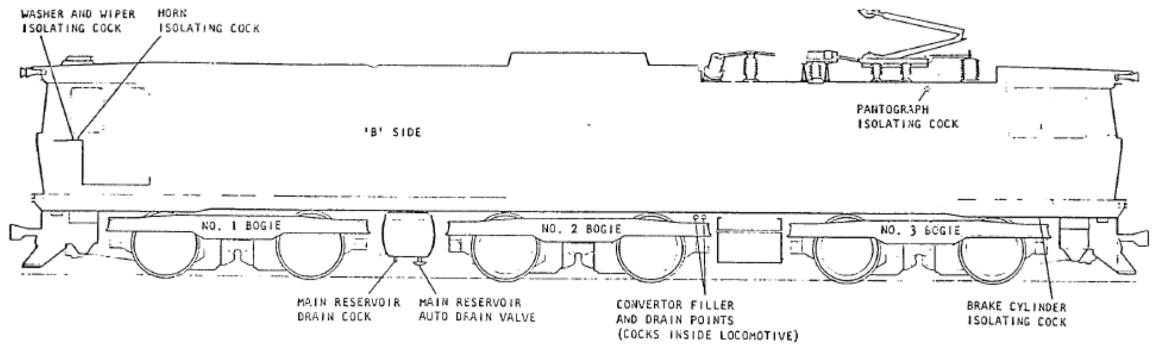
8.1. Operators of public mass transport systems must provide their staff with guidelines, procedures and training to enable them to deal effectively with a fire, instead of relying on their best judgement.

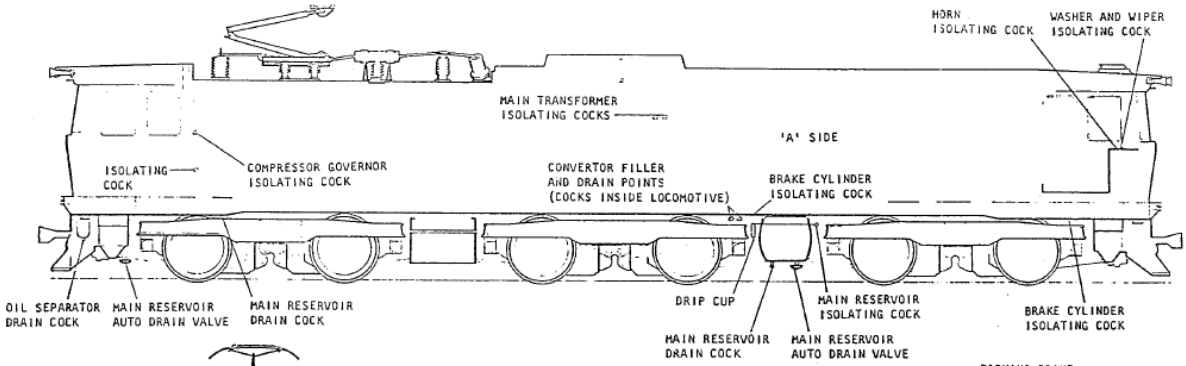
Appendix 1: EF locomotive schematic layouts

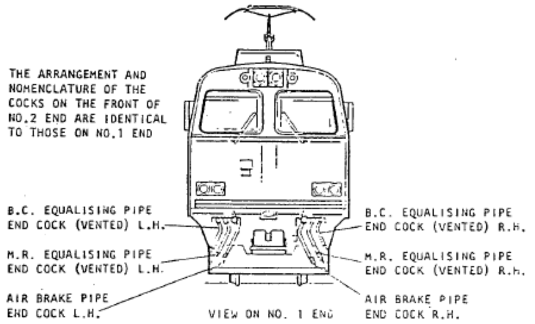


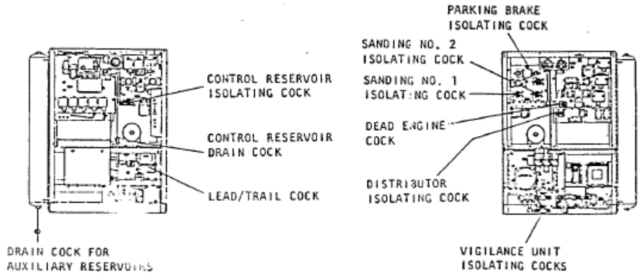

MOTOR/ALTERNATOR SET CONTROL CUBICLE
OUTLET AIR FROM MAIN TRANSFORMER AND CONVERTORS
BRAKE RESISTOR
MAIN AIR COMPRESSOR
RECIRCULATED AIR
M/A SET
INERTIAL FILTER
RECIRCULATED AIR
AIR DISTRIBUTION BOX
COOLING AIR FOR TRACTION MOTORS
BLEED AIR FROM INERTIAL FILTER
COOLING AIR FOR TRACTION MOTORS
OUTLET AIR FROM TRACTION MOTORS
NO. 1 END
NO. 2 END


TRACTION MOTOR BLOWER AIR DUCTING
TRACTION MOTOR BLOWER AIR DUCTING
INLET AIR TO MAIN BLOWER FOR MAIN TRANSFORMER AND CONVERTOR COOLING
INLET AIR FOR TRACTION MOTOR BLOWER
OUTLET AIR FROM COMPARTMENT
INLET AIR FOR HEATING AND VENTILATION UNIT
INLET AIR FOR HEATING AND VENTILATION UNIT
OUTLET AIR FROM MOTOR/ ALTERNATOR SET AND COMPARTMENT
INLET AIR FOR TRACTION MOTOR BLOWER
INLET AIR TO MAIN BLOWER FOR MAIN TRANSFORMER AND CONVERTOR COOLING
TRACTION MOTOR BLOWER AIR DUCTING
TRACTION MOTOR BLOWER AIR DUCTING


WASHER AND WIPER ISOLATING COCK
HORN ISOLATING COCK
PANTOGRAPH ISOLATING COCK
'B' SIDE
NO. 1 BOGIE
NO. 2 BOGIE
NO. 3 BOGIE
MAIN RESERVOIR DRAIN COCK
MAIN RESERVOIR AUTO DRAIN VALVE
CONVERTOR FILLER AND DRAIN POINTS (COCKS INSIDE LOCOMOTIVE)
BRAKE CYLINDER ISOLATING COCK


HORN ISOLATING COCK
WASHER AND WIPER ISOLATING COCK
MAIN TRANSFORMER ISOLATING COCKS
'A' SIDE
ISOLATING COCK
COMPRESSOR GOVERNOR ISOLATING COCK
CONVERTOR FILLER AND DRAIN POINTS (COCKS INSIDE LOCOMOTIVE)
BRAKE CYLINDER ISOLATING COCK
OIL SEPARATOR DRAIN COCK
MAIN RESERVOIR AUTO DRAIN VALVE
MAIN RESERVOIR DRAIN COCK
DRIP CUP
MAIN RESERVOIR ISOLATING COCK
BRAKE CYLINDER ISOLATING COCK
MAIN RESERVOIR DRAIN COCK
MAIN RESERVOIR AUTO DRAIN VALVE


THE ARRANGEMENT AND NOMENCLATURE OF THE COCKS ON THE FRONT OF NO.2 END ARE IDENTICAL TO THOSE ON NO.1 END
B.C. EQUALISING PIPE END COCK (VENTED) L.H.
M.R. EQUALISING PIPE END COCK (VENTED) L.H.
AIR BRAKE PIPE END COCK L.H.
B.C. EQUALISING PIPE END COCK (VENTED) R.H.
M.R. EQUALISING PIPE END COCK (VENTED) R.H.
AIR BRAKE PIPE END COCK R.H.
VIEW ON NO. 1 END


CONTROL RESERVOIR ISOLATING COCK
CONTROL RESERVOIR DRAIN COCK
LEAD/TRAIL COCK
DRAIN COCK FOR AUXILIARY RESERVOIRS
PARKING BRAKE ISOLATING COCK
SANDING NO. 2 ISOLATING COCK
SANDING NO. 1 ISOLATING COCK
DEAD ENGINE COCK
DISTRIBUTOR ISOLATING COCK
VIGILANCE UNIT ISOLATING COCKS

Appendix 2: Rail Operating Code section 3.2 – Vehicles on fire

KiwiRail
Rail Operating Code
SECTION 4.1 – Motive Power Unit Inspection and Operating Instructions

3.0 FIRES

3.1 TRACKSIDE FIRES

If a Locomotive Engineer encounters a fire at the side of the line or on adjacent property, Train Control must be informed. If a track gang is encountered, the train must be stopped and the Ganger advised of the fire if the Locomotive Engineer has been unable to contact Train Control.

If fires endanger bridges, buildings, or other property and arrangements cannot be made for other members to reach the location within a reasonable time, the train crew must take the necessary steps to suppress the fire where possible.

DANGER: Beware of High Voltage Overhead Wires

3.2 VEHICLES ON FIRE

When a vehicle on a train is on fire, the Locomotive Engineer must use judgement as to the best course to adopt in the circumstances, taking into consideration the proximity of fire fighting appliances, the load in the vehicle, and the possibility of damage to bridges, adjacent vehicles or property.

3.2.1 Extinguishing a Dynamic Brake Fire

The following procedure is to be used in the event of a dynamic grid fire on a DBR, DC, DFT and DX Class locomotive:

1. *Suspend use of dynamic brake immediately a brake grid fire is discovered and use serial braking for the remainder of the grade.*

   ***NOTE:** The serial braking rules for the locality must still be observed.*
2. *Coast or drive the locomotive to an accessible location that has pressurized water available, is clear of tunnels, bridges and preferably overhead catenary wires.*
3. *Stop the locomotive and apply the locomotive and train brakes.*
4. *Shut down the diesel engine.*
5. *Open the battery knife switch.*
6. *Apply sufficient handbrakes on the train for the locality.*

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7. *Spray water into the dynamic brake grids, until the grid insulation has cooled to the point where it will not spontaneously reignite.*

> ***IMPORTANT: Overhead Traction Wires***
> *If stopped under or near overhead traction wires, before water is used, overhead power must be isolated, earthed and a permit to work issued.*

8. *The locomotive can now be restarted and operated normally for powering operation but no attempt should be made to use dynamic brake. The fault is to be written up in the 54D repair book for attention.*

> ***NOTE: DX Class Locomotives***
> *No.5 Traction Motor will have failed, so locomotives must not be restarted and must be towed to destination.*

3.3 FIRE PRECAUTIONS

The best protection against fire is cleanliness. This applies particularly to the engine and engine room, the underframe mounted equipment and bogies.

Diesel fuel alone is not readily flammable. A lighted match will not ignite fuel oil in a clean container, but it will readily ignite diesel fuel spilt on paper or any other substance which can act as a wick.

To minimise the risk of fire, never leave waste rags, or paper in the engine room or use naked lights for inspection around the power unit. Report any arcing in electrical equipment and pay prompt attention to any overheating.

Cotton waste is prohibited on any locomotive, EMU and Railcar as it is a fire hazard. Cotton waste may also damage diesel engines, gearboxes, air compressors and electrical equipment.

Appendix 3: Table comparing New Zealand rail vehicles to fire best practice

Details provided to the Transport Accident Investigation Commission by the operators.

						Fire			
	Class	Role	Power	Qty	Built	Detection	Suppression	Lifespan	Overall
KiwiRail	DBR	Freight	Diesel Electric	3	1980	No	No	Mothballed	
	DC/P	Freight/Shunting	Diesel Electric	~30	1980	No	No	<2yrs	
	DFB	Passenger/Freight	Diesel Electric	12	1980	8 (*3)	8 (*3)	15+yrs	
	DFT	Freight/Passenger?	Diesel Electric	12	1980	No	No	<2yrs	
	DH	Shunting	Diesel Electric	6	1979	No	No		
	DL	Freight	Diesel Electric	48	2011	Yes	No	25+yrs	
	DSC	Shunting	Diesel Electric	31	1965	No	No		
	DSG	Shunting	Diesel Electric	24	1982	No	No		
	DSJ	Shunting	Diesel Electric	5	1985	No	No		
	DXB	Freight	Diesel Electric	14	1975	No (*4)	No		
	DXC	Freight (Coal)	Diesel Electric	32	1975	17	17 (*2)	10+yrs	
	DXR	Freight	Diesel Electric	2	1975	Yes	No	15+yrs	
	EF	Freight	Electric	17	1988	No	No	(*5)	
	AG/AKV	Passenger	Generator	13	1980	Yes	Yes		
	TR	Shunting	Diesel Hydraulic	7	1936	No	No		
Wgtn	Matangi	Passenger	Electric	48	2010	Yes	No		
Auck	CAF - AM	Passenger	Electric	57	2015	Yes	No		
	ADL	Passenger	Diesel Electric	10	1980	Air Con Only	No	TBC (*1)	
Dunedin Rail	DJ	Passenger	Diesel Electric	6	1968	2	2		Tgt 2020
	Railcar	Passenger	Diesel Electric	1	1972	Yes	Yes		
	Gen car	Passenger	Generator	6	1970's	Yes	Yes		

*1 - ADL's run a 16min shuttle service Papkura to Pukekohe, no electrification before 2025, battery EMU trials planned 2016
*2 - 8 DXC's being upgraded by June '16
*3 - 4 DFB for Wairarapa Line have fire detection & Suppression, 9 being upgraded and remainign 3 likely to be standardised
*4 - Identified as requiring Fire Detection - Capex FY17
*5 - Currently being discussed how to upgrade or replace

= Good condition or plan in place

= Low risk (shunting) or longer term plan

= No current agreed upgrade or replacement plan

Appendix 4: KiwiRail Significant Information Notice

KiwiRail

Significant Information Notice

Expiry Date: 5/12/2015

ML - 047

Subject: EF Locomotive Fire Preventative inspection

Scope: EF Locomotives

Background: EF 30157 caught fire in Palmerston North yard. As precaution all other EF locomotives will have a safety inspection.

Action:
Inspect each EF locomotive before it returns to service.

Carry out a visual inspection of the transformer compartment from the walkway, looking through protection grill, for the following.

1) **All cable terminations on the transformer (No evidence of heating at cable terminations)**
2) **Check heat exchanger for damage or blockage**
3) **No signs of significant oil leaks from transformer, pipes, and radiators (look for puddles of oil)**
4) **Inspection of compartment body filter on outside wall, looking for blockage and blackness (walkway side indicative condition of all filters)**
5) **Check for debris, rags etc**

If any of the inspections reveal a problem this must be rectified by the depot before locomotive re-enters service.

Record on a SAP work order for each locomotive and close when inspection is completed

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Date: 25th November 2015

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Recent railway occurrence reports published by the Transport Accident Investigation Commission (most recent at top of list)

RO-2014-104	Express freight train striking hi-rail excavator, within a protected work area, Raurimu Spiral, North Island Main Trunk line, 17 June 2014
RO-2013-103 and RO-2014-103	Passenger train collisions with Melling Station stop block, 15 April 2013 and 27 May 2014
RO-2015-101	Pedestrian fatality, Morningside Drive pedestrian level crossing, West Auckland, 29 January 2015
RO-2014-101	Collision between heavy road vehicle and the Northern Explorer passenger train, Te Onetea Road level crossing, Rangiriri, 27 February 2014
RO-2012-103	Derailment of freight Train 229, Rangitawa-Maewa, North Island Main Trunk, 3 May 2012
RO-2012-105	Unsafe recovery from wrong-route, at Wiri Junction, 31 August 2012
RO-2013-107	Express freight MP16 derailment, Mercer, North Island Main Trunk, 3 September 2013
RO-2012-104	Overran limit of track warrant, Parikawa, Main North line, 1 August 2012
RO-2013-104	Derailment of metro passenger Train 8219 , Wellington, 20 May 2013
Urgent Recommendations RO-2015-101	Pedestrian fatality, Morningside Drive level crossing, West Auckland, 29 January 2015
RO-2013-105	*Capital Connection* passenger train, departed Waikanae Station with mobility hoist deployed 10 June 2013
RO-2014-102	High-speed roll-over, empty passenger Train 5153, Westfield, South Auckland, 2 March 2014
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RO-2012-102	Train control power failure, 26 April 2012
Interim Report RO-2014-103	Metropolitan passenger train, collision with stop block, Melling Station, Wellington, 27 May 2014
RO-2013-108	Near collision between 2 metro passenger trains, Wellington, 9 September 2013

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