TRUCK FIRES SERIES

Part 1 **Fire risk guide**

A detailed look at causes of fires in truck and trailers

The Truck Fires Series is in four parts and addresses the many ways in which trucks and their trailers can catch fire.

It also provides advice on how truck and tralier fires can be prevented.

ARTSA-I INSTITUTE

NBTA National Bulk Tanker Association

TIC TRUCK INDUSTRY COUNCIL TODAY'S TRUCKS SAFER GREENER ESSENTIAL

ACKNOWLEDGEMENTS

In 2019 the National Heavy Vehicle Regulator awarded the then Australian Road Transport Association (now known as the ARTSA Institute or ARTSA-i) and the National Bulk Tanker Association (NBTA) a Heavy Vehicle Safety Initiative Round 4 Grant to investigate truck fire prevention strategies.

In undertaking this work, ARTSA-i and the NBTA enlisted the technical expertise available within the Truck Industry Council (TIC) to assist in the development of the guidance material in these documents.

ARTSA-i, the NBTA and TIC wish to acknowledge the writing and editorial teams who provided their expertise and considerable time to allow these series of documents to be created.

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1 Introduction

Truck Fires have been a long-standing issue within the heavy vehicle sector. Recognising this risk, ARTSA produced a report in 2006 on "Why Trucks Catch Fire."[1] Despite highlighting the risks of truck fires, the heavy vehicle sector remains fire-prone.

NTI Insurance are the major heavy vehicle insurer in Australia.
Their report from 2020[2] states that:

- Over 10% of major losses were due to fire
- 32% of fires were in the engine bay and truck cabin area
- 55% of engine bay and truck cabin fires were due to electrical failure
- The balance of failures were mainly due to wheel and tyre issues

The impact of these fires can far exceed the actual loss of the truck and trailer equipment and its load. The disruption, safety risk to drivers and the public and environmental damage can be wide ranging.

Given the trend in fire claims in the last 10 years, this series of documents looks at the major causes of truck and trailer fires, and how these fires can be reduced.

The guidance material is arranged in four parts.

Part 1 – Fire risk guide	A detailed look at causes of fires in truck and trailers
Part 2 – Drivers guide	What drivers can do to lessen the risk of fires
Part 3 – Maintenance guide	What maintenance staff and fleet controllers can do to prevent fires
Part 4 – Fire investigation guide	Advice on how to conduct a fire investigation

This document is Part 1: **Fire risk guide**
All parts of this guide including the summary can be downloaded from www.artsa.com.au/fires

[1] See http://www.artsa.com.au/library/index.html
[2] See https://www.nti.com.au/news-resources/research/latest-report

2 Non-impact fires

The 2020 National Transport Insurance Accident Research Centre (NTARC) report noted losses due to fire during 2019 was the fourth largest category behind driver error, not at fault and inappropriate speed. They amounted to some 10% of total claims.

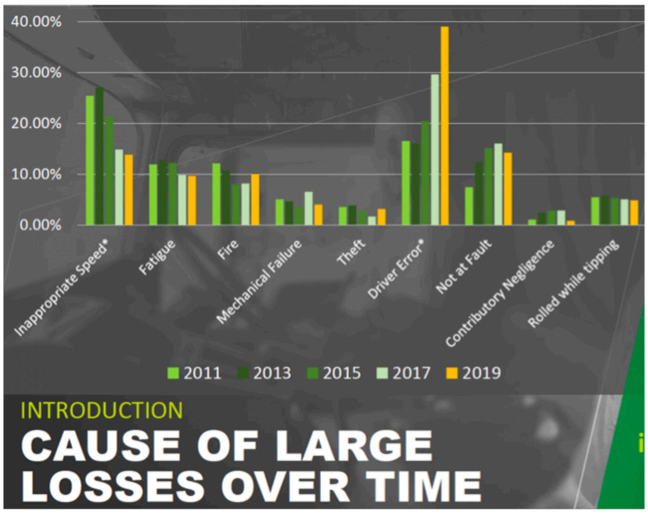


Figure 1: Comparison of insurance losses 2011 to 2019, NTARC 2020 report

Those fire related claims were attributed to four main areas of: starter power cables, fuel lines, wheel bearings and brake chambers.
For fuel tankers the losses mirror those for the general heavy vehicle fleet with fires also accounting for some 10% of all losses.

[3] Refer https://ntarc.nationaltransportinsurance.com.au/#introduction

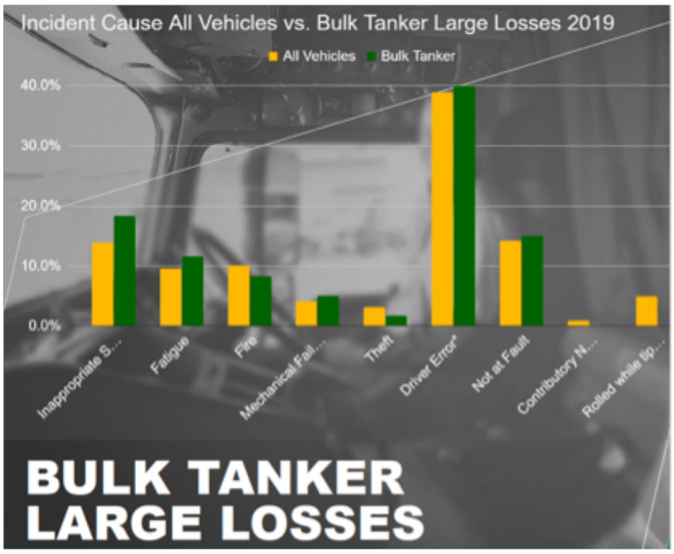


Figure 2: Bulk Tanker losses 2019, NTARC 2020 report

The average age of the motor vehicles involved in fires was 8 years, which suggests that regular servicing, maintenance and detailed inspections over the vehicles entire life are important for avoiding fires.

3 Necessary Conditions for Fire

This section discussed the elements necessary for fire to occur, vulnerable materials and typical ignition temperatures of those materials.

3.1 The Fire Triangle

Three elements are necessary for initiation and propagation of fire; oxygen, heat and fuel. Remove any one element and the fire will not develop:

Figure 3: Fire Triangle – remove any element, stops a fire

Oxygen is ever-present unless excluded by extinguishing action.

Fuel can be either:

- Combustible materials that ignite at higher than normal operating temperatures
- Flammable materials that can ignite at normal operating temperatures
- Explosive materials such as combustible or flammable vapours or gas

Heat is the source of energy that gets the fuel to ignition temperature.
Heat is therefore the primary culprit behind heavy vehicle fires. Without the generation of heat the "fire triangle" is not complete, and fire cannot occur. Whilst oxygen and fuel sources will always be present, the variable that causes fires is excessive heat.

The greater the supply of oxygen such as through air movement, the faster the fire will develop. However, wind can also cool hot spots and remove heat, so fire risk or severity may increase when the vehicle stops and therefore the wind stops. This is true for most wheel-end fires and some engine compartment fires.

3.2 Vulnerable materials

The typical materials that burn are:

- Wiring insulation. In most cases, wiring insulation does not burn easily as it has fire retardant properties.
- Polymer materials used as conduit, noise shields, insulation, flooring, trim, etc. These materials usually burn freely. Many polymers spread fire by flaming droplets.
- Fiberglass resin used in the cabin and aero kits. The glass fibres survive fire.
- Hydrocarbon fluids such as diesel fuel, lubricating oil and bearing grease.
- Rubber tyres, which burn freely with no fire resistance.
- Polymer and rubber hoses.
- Aluminium melts at 660oC which is a temperature that is commonly achieved in vehicle fires.
- Copper melts at 1083oC. Copper wire will sweat and melt in very hot locations in the fire.

By comparison, steel melts at ~1400o – 1500oC. and is almost never burns in vehicle fires.

3.3 Ignition Temperatures on Vehicles

The vulnerable locations on a vehicle under normal operating conditions are the turbo charger, exhaust pipe and brake drums or discs. Combustible material can be ignited at these locations.

As a guide, the normal temperatures found on a heavy vehicle are:

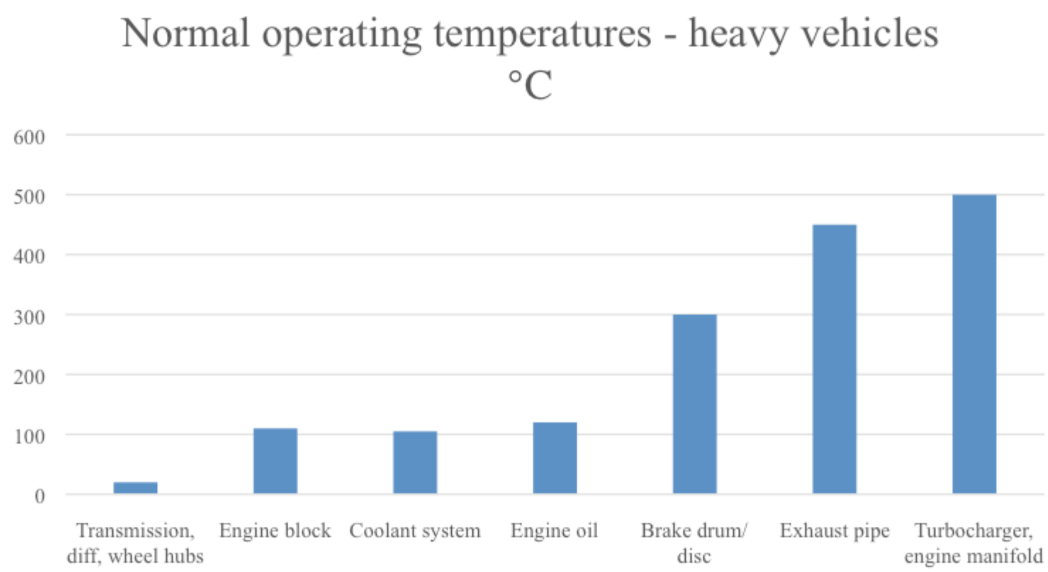


Figure 4: Normal operating temperatures for heavy vehicles

Under fault conditions, extreme temperatures can also occur due to electrical arcs, tyre rubs and bearing failures.

4 Heat characteristics, known causes and protections

The sources of heat on a heavy vehicle that have the potential of causing fire are:

1. Electrical Heat
2. Exhaust Heat
3. Brake Heat
4. Friction Heat
5. Chemical Heat
6. Deliberate Application of Heat

4.1 Electrical Heat

Characteristics:

Electrical heating occurs normally. Occasionally normal heating results in fire because the electrical component cannot withstand the temperature. Usually, the electrical heating is the result of a fault condition.

Usually the material that first catches fire is electrical wire insulation or plastic conduit.

Electrical heat has its origin at the battery and alternator. As a guide the fault current potential of a 12V battery is ~2,000A whereas the alternator is ~ 200A. The closer the circuit fault is to the battery, the greater the heat likely to be generated.

Additional electrical connections are often added to heavy vehicles as part of after-market fitment of equipment. These connections should follow the manufacturer's recommended connection points, which generally have electrical protection such as a fuse or circuit breaker.

The starter motor positive cable(s) are usually unprotected by circuit breakers because the rating needed to accommodate the starter motor current is too high to protect the cables from rubbing faults. Consequently, the cables are vulnerable to short-circuits arising from rubs between the cable and chassis metal features (chassis rails, bolt heads and steel-spined clamps). Manufacturers rely on the mechanical protection (outer conduit and/or double insulation) of the starter cables and suitable stand-offs to protect against this problem. Sometimes a metal protrusion separates the split conduit covering and may cause a rub on the cable insulation.

When an electrical circuit carries current there is always some magnetic energy stored in the space around the circuit. When the current is interrupted the magnetic energy is transformed into its electrical form which generates a high voltage. A spark may then occur that could ignite flammable materials. Hot terminals due to poor electrical connections can occur on either the positive side or the negative side.

Electrical heating can occur whether the ignition key is on or off. The risks are slightly greater when the engine is running because more circuits are live, and the voltage is approximately 10% higher. Electrical fires can occur when the vehicle is parked. Often fires occur at night when the vehicle has cooled down and electrical wires have contracted slightly.

Known Causes:

- Short-circuit or abnormal circuit conditions. The current is too high, and the wiring or component gets hot.
- An electrical connection at a terminal has poor contact and the terminal gets hot at normal current.
- An electrical component has degraded under normal conditions and insulation fails.
- Internal failure of a battery allows release of stored chemical energy, which results in rupture and explosion of the battery.
- An abnormal voltage exists because of a component failure and the abnormal voltage causes sparking.
- Addition of heavy add-on loads onto a circuit not capable of supplying the load, for example, refrigerators and heavy-current trailer connections. If the fuse rating is increased, the wiring and connections may not be adequately protected, and wiring can melt through the insulation.
- Addition of circuits directly onto the battery terminals. Whilst a fuse might be in the added circuit, there is an electrically unprotected wire connection at the battery positive terminal that is very vulnerable to rubs.
- Static electricity builds up and the sparking ignites flammable material.
- Combustible contamination builds up on an electric circuit (such as inside an alternator or on a printed circuit board) and electrical tracking occurs between power terminals.

Protections:

- Activate the battery isolation switch when the vehicle is parked.
- Clean carbon and residue out of alternators and starter motors. This is particularly relevant for vehicles used to transport grains and other farm harvest goods.
- Don't add electrical loads onto existing electrical circuits. Establish new independent circuits from a protected terminal as recommended by the manufacturer.
- Check that clamps are not cutting into cables. Rubber-block style clamps are preferred. Avoid clamps that have a metal spine and a thin rubber insert. If the rubber insert comes out, a sharp metal edge could cut into the loom.
- Look for rub points on electrically unprotected cables, such as the starter motor cable, alternator cable or added cables in the battery box.
- Starter motor and alternator positive terminals should have insulating covers.
- Look for pinch points on electrical cables.
- Body builders are encouraged to use conduits that has slow fire propagation ratings, such as UL94 V0 or EN-ISO 11925 V2.
- The cabin supply cable should have a circuit breaker at the battery or supply end.
- Be conservative with ratings of electrical components. A rating that might be appropriate for a passenger car should be halved for a heavy vehicle because of continuous operation, vibration and dust.
- Don't ignore the smell of smoke. Stop and investigate.

4.2 Exhaust Heat

Characteristics:

Exhaust heat is generated at the turbocharger, exhaust manifold, muffler/reactor and exhaust pipe and tailpipe when the engine is running.

Exhaust temperature risks increase when the vehicle has been working hard for a long time and when the ambient temperature is high. Abnormally high exhaust temperatures are likely to cause turbo-charger failure and engine valve failure.

Known Causes:

- Engine over-fueling due to low boost air pressure.
- Poor adjustment of LPG top-up injection systems.
- Leaking of hydrocarbon liquids onto the exhaust such as (presented in risk order): petrol, diesel, engine oil, hydraulic fluid, transmission oil, steering fluid, glycol coolant.
- Leaks from high-pressure fuel lines that create an aerosol in the engine compartment, which is ignited by the exhaust pipe.
- Leaking of exhaust gases through a hole in the exhaust system onto combustible matter.
- Exhaust gases released normally from the tailpipe causing near-by vegetation to ignite.
- Combustible matter such as vegetation (grass, harvested grains, etc) lodging on the exhaust pipe.
- Combustible vehicle features, such as conduits or hoses running too close to the exhaust pipe.
- Failure of engine or hydraulic oil hoses close to an exhaust pipe.
- Failure of the oil seals inside the turbocharger that results in internal oil fire that sometimes escapes via the air-boost side.
- Failure of the internal separator in lithium-ion batteries leading to internal short-circuit and spontaneous fire.

Protections:

- Keep fittings on hoses that carry oil or fuel well away from the exhaust. Anticipate whether a hose failure at a fitting could spray fluid onto the exhaust pipe.
- Look for sign of oil leaks at fittings or hose rubs.
- Keep combustible items at least 200 mm away from an exhaust pipe unless a shield is installed, in which case a spacing of 100mm is advisable.
- Remove or avoid sharp bends on hoses that go into end fittings.
- Check for the build-up of combustible material around the exhaust pipe.

4.3 Brake Heat

Characteristics:

Brake heat occurs normally. The risk is that the brakes reach an abnormally high temperature, often because they are dragging, leading to tyres catching fire. The heat transmission path is via the wheel rim. The bead of the tyre starts to pyrolise and eventually spontaneously combusts. Aluminium wheel rims have higher thermal conductivity than steel rims and the tyres on these rims have a greater vulnerability to catching fire.

Known Causes:

- Wheel bearing failure. The brake is not running free because the hub is not centred.

- The spring brakes are on, partially or completely, because the air pressure in the spring brake system is low. This can be due to a hose failure or contamination inside the spring-brake air valves.
- Road strike has damaged a brake hose or actuator causing a leak of spring-brake air pressure.
- The spring brakes have not released at the back of a long combination vehicle because the insufficient air-pressure build-up time has been allowed. The vehicle is driven off with the rear spring brakes rubbing, which heats up the spring brakes.
- The trailer brake handpiece has been left partially on whilst driving causing the brakes to drag.
- The S-cam mechanism has broken and the brakes have not fully retracted.
- The trailer brake air coupling is not correctly connected, and the trailer air brake level is low.
- Combustible matter caught in the wheel area is ignited by a hot brake drum or disk.

Protections:

- At each scheduled service, lift the wheels and check by hand that they rotate freely without lumpiness and that the wheel has minimal side-to-side movement.
- Use a trailer brake hand piece that springs to off.
- At a rest break, check the hubs for abnormal temperature as well as inspecting for accumulation of combustible matter around wheel area and any road strike damage to brake actuators and hoses.
- Take note of whether the vehicle rolls freely or is being retarded by dragging brakes.
- A 15 minute cool-down time is advisable before loading or unloading of dangerous goods liquid or gases when the brake drums or discs are very hot.

4.4 Friction Heat

Characteristics:

Friction heat results from surfaces that rub together as a result of failure, mis-adjustment or poor design. The material that catches fire is usually close to the rub point.
If a wheel-end is extremely hot due to dragging brakes or a tyre blow out, the fire might start when the vehicle movement stops.

Known Causes:

- A tyre that is significantly under-inflated. The bulge of the tyre rubs on an adjacent tyre or internal heating of the rubber sidewall occurs.
- An air suspension is not fully inflated and the tyre rubs on a hard metal surface, or rubber.
- A heavy-duty mudguard rubs on the tyres because of failure of the mudguard support.
- A loose component or cable rubs on a belt at the front of the engine.
- Vegetable matter rubs against the driveshaft. This risk is mainly on agricultural machinery that have guarded drive shafts. The guard can constrain the vegetable matter.
- Movement in trailer mezzanine support brackets can lead to heat generation from the surface hardening of metal fittings. This movement can generate hot metal filings that can cause a fire.

Protections:

- Use rest breaks to check the tyres for under-inflation, look for sign that a tyre has been rubbing and check that the airbag suspension has the correct ride height.
- Regularly inspect trailer mezzanine fittings for excessive wear.

4.5 Chemical Heat

Characteristics:

Chemical heating occurs under abnormal conditions. The features that separate the chemicals have failed and chemical reactions occur that release heat. Excessive temperature can then occur which can ignite gases and may result in an explosion. The greater the energy density the greater the risk.

Known Causes:

- Internal Lead-acid battery failure which results in explosion of hydrogen gas.
- Internal Lithium-Ion battery failure. Either the separator fails, or the battery experiences abnormal temperature of mechanical damage, which damages the separator or electrodes. A cascading release of stored energy occurs, which results in explosion and flame.
- Reactive chemicals come together because of a containment failure in the load space.

Protections:

- Identify loads containing a potential energy source, such as lithium-ion battery packs.
- Keep loads with energy sources separated from other loads.
- Keep potentially reactive chemical in separate load compartments.

4.6 Deliberate Application of Heat

Characteristics:

A person deliberately uses heat in the vehicle. This produces an unsafe temperature which ignites combustible matter on the vehicle.

Known Causes:

- Unsafe cooking inside the cabin
- Welding or other repairs using heat that are done without vulnerable materials being removed or adequately protected.

Protections:

- Isolate combustible materials from the heat source.
- Check before heating, welding or grinding that combustible material is not resting on or close to the metal being heated.

5. Fire prone areas in heavy vehicles

There are five areas in heavy vehicles that are typically at risk to catching fire.
These include:

- Electrical systems
- Engine compartments
- Wheel ends
- Truck cabins
- Load spaces

Each are discussed below with illustrative examples of fire causality.

5.1 Electrical systems

This section includes the various ways in which the electrical system can contribute to fire risk.
They include:

- Electrical insulation
- Wiring
- Terminals
- High pressure water sprays
- HVAC systems
- Battery boxes, starter relays and alternators
- Starter motor terminals
- Re-routing of cables
- Clamping points
- After market electrical equipment
- Lithium-ion batteries

5.1.1 Electrical insulation

Electical insulation failure can be caused by inadequate circuit breakers or fuse protection (if fitted). The purpose of this protection is to turn off the circuit when a high, dangerous current level occurs. In particular, insulation rubbing on unprotected battery cables to the starter motor, alternator, cabin supply and trailer box supply can cause fusion or arcs.

The fault current potential on the alternator line (assuming that it has circuit breaker protection in the battery box) is roughly equal to the alternator current rating. Alternator output is measured in volts and amps. The amperage output is usually the maximum output of the alternator measured in amperes. A circuit breaker is never fitted at the alternator terminals. Therefore, the alternator electrical cables should be designed to withstand more than the alternator current-rating level continuously. Use 150% of the alternator rating as a guide. OEM alternators may lack capacity to handle additional loads from aftermarket equipment and upgrades.

Some starter motor terminals may be uncovered or unprotected, even on fuel-haul trucks. If a spanner is dropped across them, a short-circuit and fire could result.

Some manufacturers run the alternator and cabin supply cables from the starter motor terminals rather than the battery terminals. When this is done, these cables are electrically unprotected and vulnerable to rubs.

The electrical insulation on auto cable usually has flame retardancy, that is, additives in the insulation that slow or suppress fire. Electrical conduits used on heavy vehicles are not required by law to be fire-rated to a particular standard, and therefore, usually do not possess fire resistant properties. Consequently, the plastic conduit often provides the fuel for fire at a short-circuit rub point, and the path for fire spread.

This alternator cable was double-insulated with a split-conduit covering but the split worked its way around to the stud position and rubbed, resulting in a fire. There was no circuit breaker protection at the battery end.

Lesson: ***Keep main cables away from protruding features***

Figure 5: A fire the result of a rub between the alternator cable and an engine stud.

5.1.2 Wiring

Fuses and circuit breakers, whether located on a truck or in your house, are sized and specified to protect the wiring and not the equipment creating the load. They need to protect the weakest link in the wiring circuit, this is typically the smallest cross section of the longest length of wire.
There are a lot of variables that need to be taken into account when designing a wiring system:

- Operating conditions - dusty and hot conditions with extreme levels of vibration.
- Mechanical strength of the wire
- Wire length
- Connector/terminals and their wire crimping type
- Whether the load is intermittent (brake light) or continuous (tail light)?

Use quality terminals to ensure best contact. As terminals weaken, the resistance across the joint increases resulting in heat being generated. The wiring can assist by taking the heat away from terminals, with heavier wires assisting in keeping terminals cooler.

In general, larger wire will result in lower resistance and voltage drop critical to ensuring the equipment operates as expected.

Wiring and terminals may get hot carrying the normal current continuously. This may result from inadequate wiring design. The wire gauge on heavily loaded circuits should have a good margin of safety. Wire gauge should be chosen for mechanical strength as well as electrical rating.

Trucks can operate continually with high electrical loads under hot ambient conditions. A conservative rule is to limit the continuous current draw to 5A/mm2 of copper cross sectional area. For example, using this guideline, the current rating of a 2.5mm2 V75 stranded automatic cable is 12.5A. Many designers would regard this as an excessively conservative rating. However, it is sensible for Australian conditions, where dusty and hot conditions occur and are experienced continuously during the summer season.

Lesson: circuit breaker rating should be carefully selected to protect the cable.

5.1.3 Terminals

A mix of poor design and long-term deterioration of terminals contribute to the melting of plastic housings because of hot terminals at slip connector points. Current levels can be within specifications although some specifications are too high. As a guide, a ¼" (6.3mm) blade terminal should be limited to a maximum of 15A continuous current. Automotive relays with ¼" blade terminals are often rated at 30A which is excessive for truck service.

Terminal contacts often degrade over time due to temperature cycling and the ingress of dust.
The slip terminals in Figure 6 were connected to a "cube" relay used to supply lighting circuits. The relay was positioned under cabin trim, which prevented any cooling. The terminals overheated, leading to a fire.

Lesson: Be conservative with terminal current loads. Locate fuse and relay holders where they can be cooled by airflow.

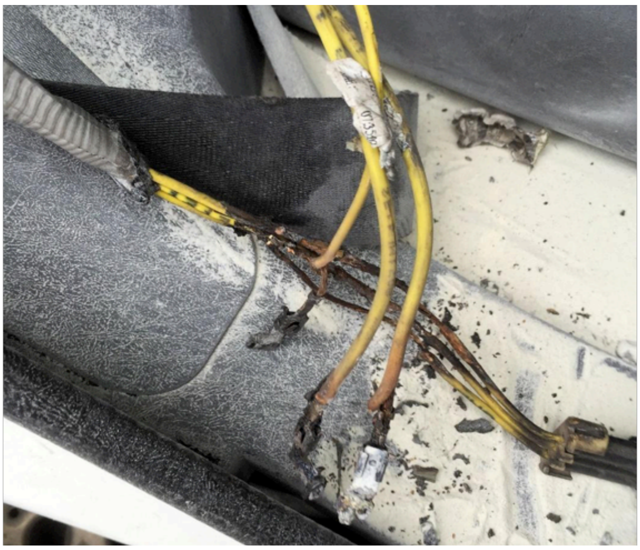


Figure 6: Overheated terminals at a relay started this minor fire.

Figure 7: Overheated terminals at a ¼” blade nominal 30A relay

Excessive heating of the relay polymer case shown in fig 7 demonstrates the decomposition brought about by high temperatures.

Lesson: Be conservative with current levels. Thick wires take heat away from the terminals.

5.1.4 High pressure water spray

Water spray from high-pressure cleaners or even road spray can penetrate exposed fuse boxes, alternators, terminals and other electrical equipment. Over time a layer of dirt from the water ingress can foul circuits resulting in stray electrical current that can cause heating or malfunction.

The OEMs, as required, will design protection for electrical components against road spray. However, high pressure cleaners, which can direct spray from unusual angles, can be problematic. Original covers must be retained, for example on any fuse boxes, and should be inspected regularly to ensure they are fitted and undamaged. Water retained inside fuse boxes may result in earth faults or control misbehaviour.

Some items such as batteries can’t be encased or protected from pressure washers or water as they require cooling or ventilation.

Lesson: Avoid excessive use of high pressure sprays around electrical circuits

5.1.5 HVAC systems

Fire may result when surrounding flammable materials experience high temperatures from the HVAC speed-resistor overheating. A circuit breaker cannot protect against this because the current level is within tolerable limits. However, the resistor unit may get unacceptably hot if the motor is stalled.

Most modern fan units use electronic speed control, such as pulse width modulation (PWM), eliminating the need for resistor unit.

Speed control resistors should be encased within a protective enclosure. If materials such as leaf litter gets in via the air intake, combustible material can rest against the hot speed control resistors which are often located in the air flow.

Lesson: Speed control resistors or electronics in HVAC can get hot and need regular inspection

5.1.6 Battery boxes, stater relays and alternators

Batteries produce hydrogen gas during normal operation. If there is a poor contact inside the battery, then a spark may occur and the battery might explode.

Starter relay contacts can weld together causing the starter motor to run continuously and overheat potentially leading to fire.

Stray currents in alternators can result in minor current leakage that over time can grow into a short-circuit.

Lesson: Keep the electrical system clean. Blow away debris in the battery box, around the alternator and starter motor and around the Power Distribution Module (PDM).

Figure 8: The accumulation of grain dust around the alternator on this blower motor resulted in a leakage of current via carbon-rich dust that developed over time into short-circuit and caused a fire.

5.1.7 Starter motor terminals

If the main return cable is loose or disconnected, the start current may return via minor earth paths. This can cause overheating on light-gauge earthing cables.

Lesson: Check that the starter motor return cables are tight.

Figure 9 The main return cable was left off the starter motor.

Figure 10 Starter current flowed via the chassis-rail earth link, which overheated.

5.1.8 Re-routing of main cables

Wherever possible do not re-route main electrical cables. Any re-routing can present a risk that vibration and rubbing against sharp edges can result in insulation failure and short circuits leading to fire.

Figure 11: Re-routing of main battery cable to starter motor.

The main battery cable was in split plastic conduit. It was re-routed inside the battery box by placing it on top of a bolt thread. The bolt thread rasped through the insulation and led to a fire.

Lesson: Keep electrical cables away from sharp or serrated edges.

5.1.9 Clamping points

Clamping points for cables are always points of vulnerability for rubbing leading to breaching of insulation and heat generation which then causes a fire.

Figure 12: A cable rub at a clamp point caused this short-circuit.

Lesson: Regularly check for cable rubs at clamp points.

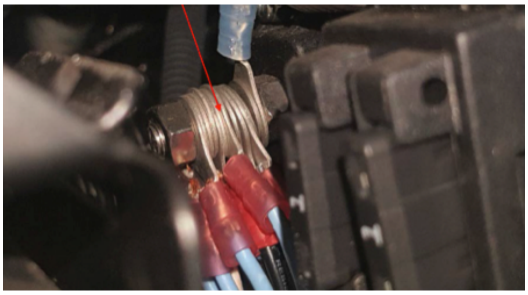
5.1.10 After market electrical equipment

Any after market equipment fitment needs to be conscious of the fire from inappropriate installation practices. Examples include:

- Over-rated electrical fuses which leads to a risk of terminals becoming hot due to poor seating.
- Poor earth connections which generate heat and can start fires with the wire insulation generally being the first to ignite.

Lesson: Avoid stacking terminals, over rated fuses and poor quality return connections

Figures 13: A 100A fuse in a 60A rated fuse holder.



Figures 14: Stacking of ring terminals on a return stud in an aftermarket telemetry system.

Figures 15: Poor quality return connection.

5.1.11 Lithium-ion batteries

Increasingly, Lithium-ion batteries are being carried as general freight.
Lithium-ion batteries have a high energy density and a low tolerance for mistreatment. Keep them cool and protect them against knocks and stacking pressure.

Lesson: Keep lithium-ion batteries cool and protect them against knocks and stacking pressure

Figures 16: Lithium-ion batteries can explode.

5.2 Engine compartment

There are five areas in heavy vehicle engine compartments that are typically at risk to causing or catching on fire. These include:

- Engine failure
- High pressure fuel lines
- Low pressure fuel and hydraulic lines
- Turbo chargers and exhausts
- Coolants

Each are discussed below with illustrative examples of fire risk.

5.2.1 Engine failure

Mechanical failures in the engine, such as:

- Pushrod failure leading to rocker cover failure.
- Hole in a piston can result in pressurization of the oil lubrication system, resulting in excessive crank case pressure with the oil being pushed out of the engine breather can cause oil to escape. If oil contacts the turbo charger or the exhaust pipe, a fire will occur.
- Rocker cover cracks can result in engine oil spraying onto the exhaust pipe or turbo charger and causing a fire.

Lesson: Guard against engine oil leaks, particularly near the exhaust pipe or tubocharger.

Figure 17: An engine failure resulted in the engine cover breaking.
In this case an engine failure caused an oil leak into the turbo-charger.

5.2.2 High pressure fuel lines

If a high-pressure fuel line cracks a spray of fuel will fill the engine compartment and is likely to reach the exhaust pipe, causing an explosion.

Fuel lines to injectors vibrate due to internal pressure pulses and this can result in fatigue cracking where the tube enters a swaged end. It is important to ensure the fuel lines are correctly restrained and that vibration dampers are in place and regularly inspected.

The high-pressure (HP) pump supplies fuel with pressure spikes with each of the pump's compression cycle and each injectors spray cycle, which results in vibration that may result in metal fatigue of the pipes and fittings. These elements often have specialist vibration dampers and supportive brackets to ensure the components last the life of the engine, if they are not tampered with!

There is frequent servicing, in and around the engine cylinder head where the HP plumbing is located. Some of the pipes are single-use items and once they have been loosened they need to be replaced. With the high pressure in the pipes, they can deform once they have been loosened, hence being a one-time use part, needing to be replaced as per the OEM procedure.

If any of the fittings are tampered with, either loosened or tightened, they need to be replaced and refitted in accordance with the specific OEM procedure. Check for broken clamps and signs of rubbing on tubes

Lesson: Ensure OEM fitment is secure, particularly around vibration dampers.

5.2.3 Low pressure fuel and hydraulic lines

Low pressure fuel lines and hydraulic and steering lines cause drips rather than sprays. Hydrocarbon fluids will not get to exhaust pipes unless they are very close to the exhaust.

Hose failures can occur because of rub-throughs and excessive bending at the crimped hose ends. Hoses that are bent around a sharp radius to get into an end fitting are vulnerable to split damage. These types of fitting should be replaced with a suitable elbow.

Lesson: Hose routing and regular maintenance are critical in minimising fire risk

5.2.4 Turbo charger and exhaust system

Potential causes of fires at a turbo charger are:

- Combustible debris lodging on turbo charger
- Internal oil seal failure
- Over fueling of engine leading to high exhaust temperatures

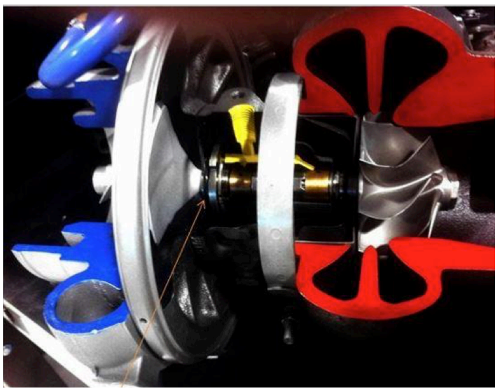


Figure 18: The turbocharger oil seals shown in a cut-away turbocharger.

Figure 19: Mechanical failure of the turbo charger resulted in a failed oil seal.

In this example a failed turbocharger blade led to unbalanced running resulting in bearing failure and then seal failure. Lubrication oil was pumped into the exhaust where it ignited. The fire then escaped into the engine compartment.

Lesson: Turbo charger oil seals and bearing have a finite life and need replacement in accordance with OEM instructions.

5.2.5 Coolant

A small coolant leak will, after the water evaporates, result in a residual deposit of ethylene glycol powder. This powder is combustible with an auto-ignition temperature of 410 Degrees . It can be ignited by the exhaust pipes but not the engine.

Lesson: Coolant leaks need to be monitored and residual powders cleaned during service.

5.3 Wheel ends

There are four areas around wheel ends that are typically at risk to causing or catching on fire. These include:

- Brakes
- Wheel bearings
- Spring brake relay valves
- Tyres

5.3.1 Brakes

Fires can occur from:

- Dragging disc brakes resulting in excessive brake temperatures that cause the wheel oil seals to weep. Oil can get onto the hot discs.
- Dragging drum brakes cause extreme drum temperatures that will heat the wheel rim and may overheat the tyre bead. A tyre fire can occur.
- Dragging brakes can occur on the last trailer in a road-train because the air supply to the rear trailer is often depleted and slow to recover.
- Very occasionally, extremely poor brake balance results in disc brakes overheating, particularly when disc brakes and drum brakes are mixed on a combination vehicle. This can occur if one vehicle in a combination is providing most of the braking effort.
- Drum-brake trucks are more vulnerable than disc-brake trucks because the ability of heat to transfer via the wheel rim is easier for a drum-brake than a disc-brake. Therefore, direct ignition of the tyre is more likely on a dragging drum brake than a disk brake.
- A dragging disc brake can also get red hot. The most likely consequence is that the wheel oil seals will fail, and an oil or grease fire will occur.

Figure 20: Trailer drum brake shoes showing destruction of linings due to dragging brakes

Trailers with low slung brake actuators and air hoses are vulnerable to road strike. Road strike may result in loss of air pressure in the brake system. If the road strike results in partially dislodging air hoses or damaging the actuators, a minor air leak may occur during transport that is not obvious to the driver. A dragging spring brake may follow, which can cause extreme disk/drum temperatures and can result in a wheel end tyre fire.

Disk brake actuators are particularly vulnerable because they usually protrude below the level of the axle. Drum brake actuators tend to be protected behind the axle.

Figure 21: Low slung disc brake actuator.

Poor quality hose attachments sometime cause tubes to split leading to spring brake drag.

Figure 22: Low slung air hoses – vulnerable to damage.

Lesson: Scheduled maintenance programs for brakes are critical to minimise fire risk.

5.3.2 Wheel bearings

Fires can occur from:

- Inadequate or contaminated lubrication.
- Overloading leading to excessive forces on the bearing.
- A faulty or worn out bearing.
- Inadequate pre-load due to the axle nut being set too loose.
- Excessive pre-load due to the axle nut being too tight.

Failure of wheel bearings can result in dragging brakes. Stub axles usually have two bearings separated by approximately 100 mm. Excessive bearing wear or failure results in the wheel axis being slightly off the centre line of the axle. This then leads to dragging brakes.

Failure of one bearing usually leads to degradation and eventual failure of the second bearing due to circulating metal fragments. Usually it is the smaller diameter bearing on the outside that fails first.

Water contamination of bearing grease frequently occurs after road “fording”. Hot components rapidly cool and suck water into the wheel-end cavity via the seals. The bearing failures occurs due to lubrication breakdown and contamination, generally occuring some weeks later.

Example: A failed outer wheel bearing on this semi-trailer front axle failed and the brakes dragged as a consequence. Excessive brake drum temperature led to excessive wheel rim temperature causing a tyre fire which destroyed the entire trailer.

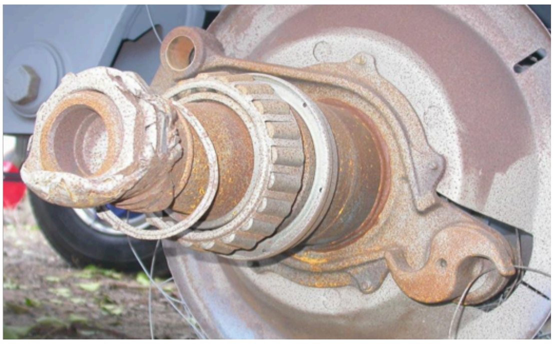


Figure 23: Failed outer wheel bearing

Fires caused by bearing failures are common, particularly on trailers. Trailer wheel bearing maintenance is often less frequent compared to prime-mover / rigid truck / bus wheel bearing maintenance.

Example: Both bearings on the front axle have been destroyed. It can be difficult to identify the bearing failure mechanism afterwards.

Lesson: Scheduled maintenance programs for wheel bearings are critical to minimise fire risk.

Figure 24: Failure of wheel bearings on the front axle resulting in a trailer fire

5.3.3 Brake valves

All brake valves can clog with carbon particles from the air compressor, however leaking spring or park brake relay valves will result in brakes dragging while driving. Air compressors with unloader type valves or that are worn out can generate carbon debris in the pneumatic system which can cause engine oil to burn.

Lesson: Brake valves, particularly spring/park brake valves should be periodically checked for leaks.

5.3.4 Tyres

Tyres do not readily ignite, but once ignited they burn freely, releasing intense amounts of heat, smoke, and fumes. The predominant causes for tyre fires are from wheel bearing failures, long-term inflation below recommended levels, and overheated brakes.

Tyre fires often start after the vehicle stops due to the loss of cooling air flow to the heat source, and in particular a hot wheel rim. They are difficult to extinguish. Extreme rubber softening from heating can cause the tyre material to flow. If water is used to extinguish, the rubber is less dense than water and will float, causing further spread of flames. Due to heat retention in the rubber a re- flash of the flames is possible.

Tyre fires can occur because:

- Flat or poorly inflated tyres rubbing on mudguards chassis or other tyres.
- Air bag failure causes the suspension to drop and tyres rub on the underside of solid bodies.
- Overheated brakes cause the tyre rubber to soften and cause the tyre bead to ignite.
- Welding on inflated wheels causing gas build up internally which can be seven times higher than initial inflation pressure and cause the wheel and/or the tyre to burst without warning.
- Contaminants such as residual repair cements and residual sealants on retreads that lower the flash point of the tyre.

Lesson: Tyre maintenance both by the driver and mechanic is critical for reducing fire risk.

Figure 25: Fire caused by a tyre rub on a metal mudguard. Note the bearings have not failed.

5.4 Truck cabins

There are several areas in truck cabins that are typically at risk to causing or catching on fire. These include:

- Refrigerants
- In cabin devices

5.4.1 Refrigerants

HC based refrigerants are being promoted as an aftermarket replacement for R134a in vehicle air conditioning systems. These gases, such as “M30”, are typically a pure blend of propane (R290) and isobutane (R600a), which can be very effective as a refrigerant gas. Their use may result in significant cost savings, however, these HC based refrigerants are highly flammable and if the gas leaks can cause an explosion.

Lesson: The use of HC based refrigerants as replacements for R134a is not recommended.

5.4.2 In cabin devices

Any cooking activities should be undertaken away from the truck in a suitable place where the bush fire risk is minimised. Whilst microwave oven can be used, they can start fires if left unattended.

Lesson: Avoid any heat generating activities within truck cabins.

5.5 Trailers

There are several areas on trailers that are typically at risk to causing or catching on fire.
These include:

- Mezzanine brackets
- Road debris

5.5.1 Mezzanine brackets

Friction rubbing of mezzanine bracket supports can result in heated metal rubbings accumulating on top of vulnerable freight (cardboard, paper, plastic). This can occur where road vibration create movement between the mezzanine deck and the support brackets.

Lesson: Look for wear marks on mezzanine trailer brackets

Figure 26: Rubbing between the mezzanine support bracket and beam leading to generation of hot metal fragments.

5.5.2 Road debris and animal strike

Trucks can run over road debris that lodges under front or rear axles. If the debris is combustible it can ignite.

Trailers with low slung brake actuators and air hoses are vulnerable to road strike. Road strike may result in loss of air pressure in the brake system. If the road strike results in partially dislodging air hoses or damaging the actuators, a minor air leak may occur during transport that is not obvious to the driver. A dragging spring brake then follows, which can cause extreme disc/drum temperatures and eventually result in a wheel end fire.

Disc brake actuators are particularly vulnerable because they protrude below the level of the axle. Drum brake actuators tend to be protected behind the axle.
Drivers must not drive on if a brake actuator has been struck, unless it can be verified that the spring brake is being held off.

Brake system is designed to receive preferential air supply. If the vehicle suspensions starts sagging or the air suspension seat drops, it indicates poor air supply or a leak which could result in brake drag. Stop and check.

Occasionally trucks run over road debris that lodges under front or rear axles. If the debris has metal in it and is combustible (such as a mattress) the sparks from the dragging metal can cause the debris to ignite. Tree branches with dry leaves attached can also catch fire under a truck.

Drivers who know they have driven over road debris need to stop to check that it did not get caught and/or damage the truck/trailer.

Lesson: Road debris should not be ignored and drivers need to stop and investigate

5.6 Specialist vehicles

Specialist vehicles may be at risk of catching fire due to the nature of the operation. Three examples covered here are:

- Vehicles with metal booms and work platforms
- Waste compactor trucks
- Dangerous Goods Tankers

5.6.1 Vehicles with metal booms and work platforms

There are many vehicles including cranes and elevated work platforms where parts of the equipment can come into contact with overhead power lines. If an elevated metal part of a vehicle touches a medium or high voltage line, a tyre explosion can occur which can lead to a fire.

Lesson: Vehicles with overhead equipment needs to consider protective devices to warn of proximity of overhead power lines.

Figure 27: Tyre explosion resulting from contact with high voltage line.
These can also lead to tyre fires.

5.6.2 Waste compactor trucks

Waste compaction trucks can accumulate volatile liquids in the sump of the compactor. The sump is usually at the back of the engine compartment where it is heated by the exhaust and by waste heat from the engine. The heating can lead to ignition of volatile liquids.

Lesson: Ensure hot exhaust are well insulated from areas where volatile liquids might accumulate.

Figure 28: Fire risks can occur if volatile liquids accumulate close to hot exhausts.

5.6.3 Dangerous Goods Tankers

Bulk Dangerous Goods Tankers are vulnerable to static electric sparks that can occur during fuel discharge. Fuel flow through rubber or plastic hose generates static electricity. The static electricity is neutralized by providing a conducting (wire) path from one end of the hose to the other. If the path is broken a spark is likely to occur. If the spark occurs where there is an explosive atmosphere, a fire is likely to occur.

Figures 29: Fuel tankers have vulnerability to fire.

Shielding of the exhaust and the space below the back of the cabin should conform with AS2809.1:2020 Road tank vehicles for dangerous goods

Lesson: Bulk Dangerous Good Vehicles have a range of vulnerabilities to fire and need careful attention to both on-going maintenance and driver inspection practices