WHY TRUCKS CATCH FIRE

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ARTSA
AUSTRALIAN ROAD TRANSPORT SUPPLIERS ASSOCIATION

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Foreword

The Australian Road Transport Suppliers Association Inc. (ARTSA) is an industry Association with over 50 members from the component and Original Equipment Manufacturers (OEM) sector. It is focused on providing technical expertise and representation to improve safety, productivity and efficiency in many aspects of the road transport vehicle industry.

ARTSA's interests cover vehicles and their components used in all aspects of the road freight transport and road passenger transport industries. ARTSA provides advice and support to members, regulatory agencies and other transport industry bodies concerning a range of issues. It also provides information in the form of explanatory codes on topics such as air suspension, braking, performance based standards, and load restraint.

This information paper has been authored by Dr Peter Hart of Hartwood Consulting. Dr Hart is a member of ARTSA and serves on the Executive. He has many years of experience as an industry professional and has written this paper to alert industry to some of the common pitfalls and traps that can lead to fires in vehicles. In Peter's words "there are too many truck fires."

Information on the Australian Road Transport Suppliers Association can be found at **www.artsa.com.au** or by contacting its Executive Officer on **exec@artsa.com.au**

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Melbourne
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NOTE:

This document is intended to show the reader the common reason for trucks catching fire. It is not possible to cover all the likely causes and this paper simply documents common faults and possible remedies.

ARTSA advises the reader seek to advice from an approved assessor and not rely solely on this general explanatory document.

– Do not rely on this document for detailed advice or decision making –

1. Overview

There are far too many truck fires. A careful examination of many burnt-out trucks suggests there are a few common causes. This document summarises these common causes and makes suggestions on how to avoid truck fires.

Whilst fire is possible under many initiating conditions, it is only rarely that a potential cause results in fire, as conditions are often not suitable for fire propagation.

The most common causes of truck fires are:

- Arcs on the starter (or battery cables), the alternator cable or the positive feed wire into the cabin.
- Flammable material resting against the turbo charger or the exhaust.
- Rubs on the fuel lines that result in leaks and then a fuel mist in the engine compartment.
- Turbo charger failures that cause excessive temperatures in the exhaust.
- Leakage of hot gases from the exhaust.
- Electrical arcs at terminals or connectors resulting from hot terminals that cause insulation to melt and catch fire.
- Addition of heavy add-on loads onto a circuit not intended for it. If the fuse rating is increased, the wiring may not be adequately protected.
- Tyres catching fire because they are flat or poorly inflated or rubbing on hard surfaces.
- Wheel bearing failures resulting in bearing grease catching fire. Sometimes overheated brakes do the same.
- Road debris that catches under vehicles and is combustible.

To minimize risks:

- Specify that vehicles have circuit breaker protection on the alternator, trailer feed and cabin power supplies from the batteries.
- Specify that the starter motor cable is double insulated, conduited and taped closed.
- Keep combustible parts, such as noise shields and fiberglass engine tunnels, well away from the turbo and exhaust.
- Check the wheel bearings regularly.
- Don't add heavy loads onto existing electrical circuits.
- Check for rubs on the fuel lines and on the turbo charger oil line.
- Check that the tyres are pumped up and cannot rub on hard surfaces.

Other useful precautions are to carry a fire extinguisher and to open circuit the batteries using an isolation switch when the vehicle is parked.

2. Necessary conditions for fire to occur

Fire takes hold under the following three conditions:

- Some material is heated to its ignition temperature.
- There is an adequate supply of oxygen (air).
- There is a propagation path for the fire.

The rate at which a fire spreads also depends on these factors. Well-oxygenated fires in materials that have low ignition temperatures spread quickly whilst fires in, for example, wheel bearing housings are usually slow to propagate.

The obvious materials that burn are:

- Wiring insulation (normally has an ignition temperature about 150°C).
- Plastic and polymer materials used as noise shields, insulation, flooring, trim, etc.
- Fiberglass used in the cabin.
- Hydrocarbon fluids such as diesel fuel, lubricating oil, bearing grease.
- Rubber tyres.
- Plastic tubing, straps, and air hose rubber coatings.
- Hydrogen build up in batteries.

Experience shows that metals are never the initiating materials. Solder always melts and aluminium often melts as a result of fire, but this is consequential.

Copper, brass and steel are oxidized by exposure to fire but only melt at electrical arc points. Electrical short circuits may produce local hot spots with temperatures sufficient to melt these metals. Therefore, electrical short-circuits can usually be identified from solidification globules and arc craters on either electrical or adjacent earthed metal.

Aluminium can melt during a truck fire. Steel and copper do not, other than at arc points.

3. Causes of truck and trailer fires

The potential causes of vehicle fires will be considered under the following categories:

- Electrical causes.
- Turbo charger and exhaust fires.
- Hot brakes and wheel bearings.
- Tyre-related fires.
- Road debris fires.

3.1. Electrical causes

Failure of electrical insulation leading to short-circuit and arcing.

This cause also requires failure or inadequacy of the circuit breaker protection (if fitted).

In particular insulation rubs on unprotected battery cables to the starter motor, alternator, cabin supply and trailer box supply can cause fusion / 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. A circuit breaker is never fitted at the alternator terminals. Therefore, the alternator electrical cables should be designed to withstand more than the alternator rating current level continuously – 150% of the alternator rating as a guide.

Note that the starter motor terminals are usually uncovered, 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. This is expediency. Cabin and alternator power cables could and should have circuit breaker protection.

The starter motor cables are never protected by circuit breakers because it is impractical. This means that they are vulnerable to short-circuits. Manufacturers rely upon the mechanical protection (outer conduit and double insulation) of the starter cables and suitable stand-offs. Sometimes a metal protrusion separates the split conduit covering and causes a rub on the cable insulation.

The result of a rub between the alternator cable and an engine stud. The alternator cable was double-insulated with a split-conduit covering but the split worked its way around to the stud position. It had no circuit breaker protection at the battery end.

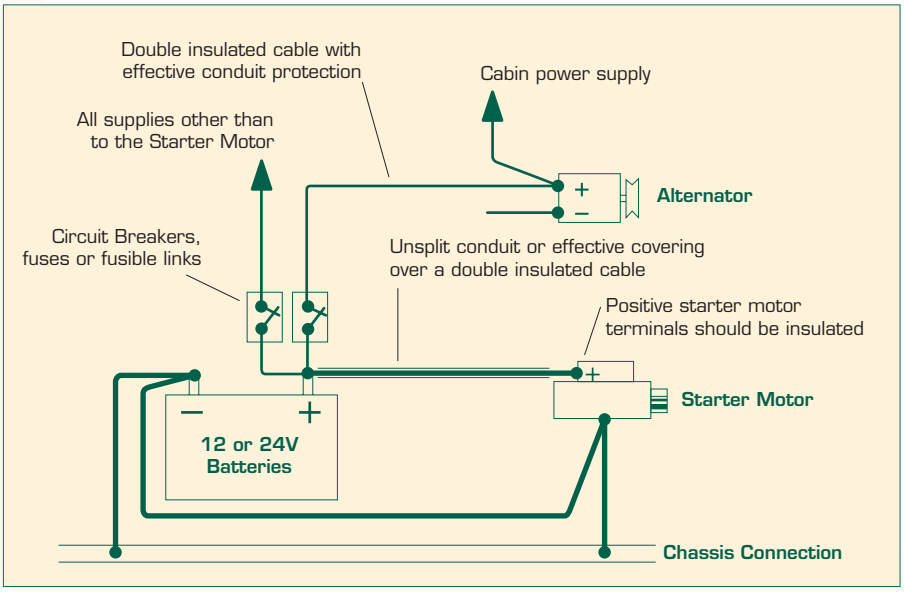
Excessive current flow leading to hot wiring and burning insulation.

This can result from inadequate wiring design. Trucks can operate continually with high electrical loads under hot ambient conditions which heats up the electrical system.

A conservative rule is to limit the continuous current draw to 5A/mm^2 of copper cross sectional area. For example, using this guideline, the current rating of a 2.5mm^2 V75 stranded automatic cable is 12.5A. Many designers would regard this as an excessively conservative rating. However, in my experience it is sensible for Australian conditions.

Occasionally a blanket screw used to hold the trim in place will damage a cable within the cabin wall. A hot point can occur with road use. Circuit breaker protection should be adequate to protect against this but sometimes is not.

Electrical fires should not happen on circuit-breaker (or fuse) protected circuits. If they do the protection is poorly designed or has been modified. The protection level is sometimes inadequate when a light gauge wire (say for instrumentation purposes) is taken off a heavy current circuit. A fault on the light gauge wire is not adequately protected.



Above left: A starter motor cable tucked between a bolt stud and the battery box cover ignited this fire. The plastic conduit on the cable was split and the split worked around to the stud position. Note that the steel stud melted.

Above right: A suitable electrical protection scheme for the starter, alternator and cabin circuits.

Sometimes a heavy electrical load, such as a refrigerator, is connected to a light gauge circuit and the fuse rating is increased. If the wiring gets hot due to the high current level, there is a risk of fire.

Automatic reset circuit breakers were commonly used on American trucks. These reset after cooling down and continually energized a faulted circuit. They are no longer popular because of the poor level of protection they offer. Their use on fuel-haul trucks has long been outlawed under AS 2809.

Manual reset circuit breakers (or fuses) that have an excessive rating for the wiring they protect also offer poor protection against faults.

Fires sometimes start on additional heavy current cables that are run as a separate power supply to the trailer(s). If no circuit breaker is installed at the battery end, there is the possibility that a rub will lead to fire.

Hot terminals develop at slip connector points leading to melting of plastic housings and potentially to fire.

A mix of poor design and long-term deterioration of terminals contribute to this. Current levels can be within specifications although some specifications are too high. For example, as a rule 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!

Note that terminal contacts often degrade over time due to temperature cycling and the ingress of dust.

Stall of blower motors in the HVAC leading to excessive speed-resistor temperatures.

Fire may result when surrounding flammable materials experience elevated temperatures from the resistor overheating. A circuit breaker cannot protect against this because the resistors limit the current to tolerable levels. However, they may get unacceptably hot if the motor is stalled.

Combustible material resting against blower speed resistors.

Speed control resistors should be encased within a protective enclosure. Sometimes they are not! 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).

Batteries produce hydrogen gas.

Batteries produce hydrogen gas during normal operation. If there is a poor contact inside the battery, then a spark may occur and the battery can explode. This does happen occasionally but fire generally does not follow. Suitable ventilation of the batteries is sensible.

Occasionally starter relays weld on due to high inrush currents.

If the relay contacts weld together, the starter motor will run continuously and overheat, potentially leading to fire.

3.2. Turbo charger and exhaust fires

- Failure of turbo charger oil seals leading to engine oil being pumped into the exhaust causing excessive temperatures.
- Failure of the oil hose / tube leading to the turbo charger causing oil to be squirted onto the turbo-charger or the exhaust.
- Flammable materials being too close to the turbo charger or the exhaust. Sometimes these materials come out of the cabin via the shift tower hole.
- Fuel line leaks or failure resulting in aerosol fuel mixture on the exhaust-side of the engine. Very occasionally, a retread tyre blow out will damage fuel lines.
- Dripping of flammable fluids from the bottom of the cabin onto the exhaust / turbo. Occasionally this results from fuel line failure on the left side of the engine.
- Debris such as cloths coming through the gear shifter mounting hole and touching the turbo or exhaust.
- Gaps or holes in the exhaust pipe that allow hot gases to escape and strike combustible material (noise shields, cab insulation etc).
- Failure of a hydraulic brake hose close to an engine extractor pipe resulted in a spray of brake fluid which resulted in an explosive fire.

A failed turbo charger blade led to bearing failure and then seal failure. Oil pumped into the exhaust caused an exhaust-fire that destroyed the truck.

3.3. Hot brakes and wheel bearings

- Dragging brakes resulting in excessive brake temperatures and wheel-end fires in bearing grease that spreads to the tyres. Very hot bearings may also cause the grease to ignite.
- Dragging brakes commonly 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, very poor brake balance can result in disc brakes overheating, causing the bearing grease to ignite. This can occur if one vehicle in a combination is doing most of the braking.

3.4. Tyre-related fires

- Flat or poorly inflated tyres can rub either on guards, chassis or other tyres. Tyres can get hot enough to ignite.

  Once alight, tyres are extremely hard to put out. It is probably useless to use a single extinguisher on a tyre fire. One approach is to keep driving with the tyre on fire because the cooling air tends to keep the fire under control! This may or may not save the vehicle.
- Hoses, electrical wiring or plastic wheel guards not tied back can rub on tyres. This will produce high temperatures but generally just rub damage because the cooling air from the tyres tends to keep the rub point below ignition temperature.
- Plastic wheel guards can rub and become hot. In all cases in my experience they wear away without catching fire.
- Hoses rubbing on the tail shaft might be a minor risk.
- Air bag failures can cause tyres to rub on the underside of solid bodies. The tyres then heat up to ignition temperature.
- Overheated brakes can cause the tyre rubber to soften and cause bead failures.

3.5. Road debris fires

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 dead leaves attached can also catch fire under a truck.

4. Investigations

After the fire, whether large or small, the cause should be determined.

Before electrical fires occur it is common for there to be a smell of electrical insulation and / or faulty operation. Such tell-tale signs should not be ignored. Insulation failure often develops over time.

It is usually obvious where the fire started because of the distribution of the damage and the smoke and heat patterns. Usually (but not always) the damage is most intense near the source of the fire.

If the fire started under the cabin floor on the left side (the starter side), suspect an electrical fault on the starter / alternator / cabin wiring.

If the fire started on the right-hand side of the engine compartment suspect a turbo charger / exhaust fire.

Fire starting in the cabin is likely to be electrical in origin. Possible sites are at relay bases, switch bases and at heavy-duty terminal housings.

The main power harness run is a potential region of rubs leading to arcing damage. This is likely to be under the console towards the front.

Remember that fire will often damage electrical wiring and that arcs may occur as a consequence rather than as the initiating event. Electrical fires can either be caused by insulation damage leading to arcs or from excessive heat leading to burning (plastic) insulation or components. In the latter case arcs may not occur.

The starter motor cables and wiring inside the battery box should always be scrutinized for signs of arc damage. Evidence that steel parts have been exceedingly hot (causing bluing and / or melting) often indicates the site of a short-circuit.

Fires in the heater / air–conditioner unit will usually cause smoke to come out the vents. This is a tell-tale sign of a developing problem. Sometimes a fire outside the heater / air conditioner gets into the cabin via a melted duct or air intake.

Fuel lines usually run along the left-side of the engine and then along the left-hand chassis rail to the fuel tank(s). Developing rub marks may be evident at clamp points. Fuel related fires are usually explosive and will be heard or felt early on.

5. Inspections

A suitable fire extinguisher should always be carried in the cabin of a heavy vehicle.

The next best protection is to deliberately inspect for possible problems that could initiate a fire. Check to see that the equipment is in good condition. Every few months spend an hour scrutinizing the condition of:

- The starter motor positive cables and other positive cables coming from the battery. Look for rub marks. Repeat this on the alternator and cabin feed power cables. Tape up gaping splits in the conduit.
- Trace along any electrical cable that comes directly off a battery terminal and has no electrical circuit breaker at the battery. This cable is a potential fire initiator.
- The connectors and relay housings in the electrical control box. Any signs of excessive heat?
- Any signs that circuit breakers or fuses have operated? If so why?
- Fuel lines. Any rubs under clamps or elsewhere? Are the hoses and tubes in good condition?
- The turbo charger oil line. In good condition?
- Any leaks from the exhaust pipe?
- Any signs of debris building up near the turbo charger or the exhaust pipe?
- Any rubs between moving parts and hoses?

Additionally, ensure that drivers check the tyres regularly during a journey. Look for flat or poorly inflated tyres. Note any rubs. Correct the situation.

Drivers should be instructed to check that debris has not lodged under the vehicle whenever they run over bulky road debris.

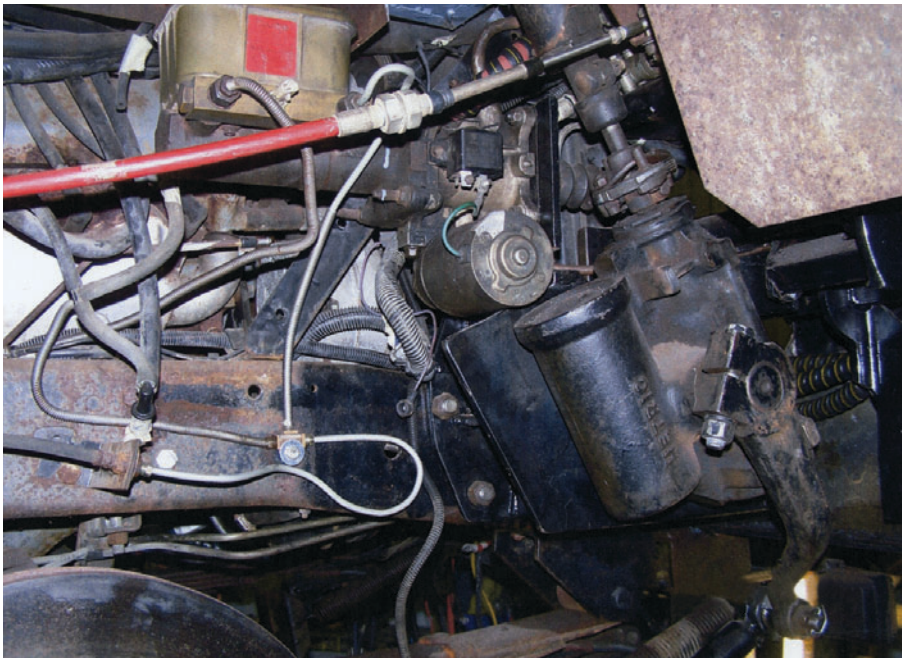
Complaints by drivers of electrical smells or of electrical misbehaviour on unrelated functions should not be ignored. When the truck is parked up, ensure that the battery terminals are disconnected.

Draw up an inspection checklist and have it actioned at each major service.

6 Vehicle specification and precautions

When choosing a vehicle, consider the following features that could affect the vulnerability to fire:

- The main electrical cable from the battery to the cabin and the alternator should have a circuit breaker at the battery end.
- The starter motor cable should be double insulated and have additional plastic conduit protection. Unsplit conduit or split conduit that is taped the full length are preferred because there will be no gaping open at bends.
- Automatic reset circuit breakers should not be used.
- All electrical connections to the battery positive terminals other than the starter motor cable should have a circuit breaker, fuse or fusible link at the battery.
- Fuel lines running inside the engine rather externally are to be preferred.
- Engine tunnels too close to turbo chargers without adequate heat shielding could be a problem.
- Check that electrical circuits are not taken directly from the battery terminals without circuit protection (fuses or circuit breakers).
- Check that additional electrical loads are not connected onto existing electrical circuits as there is a risk of overload.
- Insist that truck manufacturers put plastic covers over the positive starter-motor terminal(s). These terminals are always live and should be covered by insulation. Very few manufacturers do this!
- Check that the oil line to the turbo charger cannot rub and is not pulled tight.
- Fixtures such as noise shields and mud flaps should be well away from the turbo charger and the exhaust pipes. A minimum clearance of 200mm is recommended but this may need to be greater depending upon the circumstances.
- Poor brake balance, particularly on combination vehicles, is a potential cause of wheel-end fires. Avoid over-braked vehicles in combination with under-braked vehicles (particularly those with load proportioning valves). Disc brakes that are working too hard get very hot and grease could catch fire.
- Vehicle manufacturers should be able to demonstrate that a stalled fan motor in the low speed setting does not catch fire.
- Check that the air intake for the cabin air-conditioner is not located where it can catch leaf matter.
- A battery isolation switch is a worthwhile protection because it allows the batteries to be disconnected on an unattended truck.
- Check that the tyres do not rub on hard surfaces when the airbags are deflated.
- Regularly check the tyre pressures. Nitrogen over compressed air can reduce tyre temperatures.
- 'P-clamps' are a common site of rubs on electrical cables, fuel lines and hoses.
- Check that the wire gauge used on heavy current circuits (such as the air-conditioner fans, the headlamps and the trailer lighting circuits have generous wire gauges and do not rely upon a single ¼" blade terminal.
- Check that there is electrical insulation between the battery terminals and metal covers.



Failure of a brake hose in close proximity to the exhaust extractor pipes probably caused this fire.

- The ratings of electrical devices should be conservatively chosen by manufacturers because components sometimes degrade over time due to prolonged operation in high ambient temperatures and dust ingress.
- Keep sufficient separations between parked vehicles to minimize the risk of fire propagating from one vehicle to the adjacent vehicle.

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