Government of South Australia

INFORMATION BULLETIN 74

Vehicle Standards – Vehicle Services Section
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Conversion to Electric Drive

Introduction

This bulletin is for the assistance of people who intend to construct an electrically powered passenger car or light commercial vehicle. It applies to vehicles that are to be originally manufactured for electric drive (individually constructed vehicles or ICVs) and vehicles that are to be converted from petrol or diesel operation.

The bulletin covers the conversion to electric drive. People who wish to build a complete vehicle should also obtain Information Bulletin 18 *Individually Constructed Vehicles*, which contains the general requirements that must be met by all vehicles.

Australian Design Rules

Converted vehicles must meet the same design and safety requirements that applied to the original vehicle when it was manufactured. Where any system governed by an Australian Design Rule (ADR) is altered, it is necessary to show that the original requirements of the rule, or a later one, are still met.

The systems that may be affected by an electric drive conversion are:

- seat anchorages (ADR 3/...), seatbelt anchorages (ADR 5/...) and child restraint anchorages (ADR 34/...) – any structural alteration made in the vicinity of the seat or seatbelt mountings, or the child restraint anchorages, may reduce their strength;
- occupant protection (ADRs 10/..., 21/…, 69/..., & 73/...) - structural alterations, particularly about the forward portion of the vehicle, the removal of the original engine or large increases in vehicle mass made by the addition of the traction batteries and motors, may affect the energy absorption characteristics of the vehicle structure, instrument panel or steering column;
- demisting of windscreens (ADR 42/...) – the removal of the engine will necessitate the provision of an alternative source of heat for demisting air (or, perhaps, alternative demisting arrangements). A performance comparable to the original demisting system must be maintained;
- motor vehicle noise (ADRs 28/... & 83/...) – in general, electric vehicles are quieter than those fitted with internal combustion engines. Alternative gearboxes, chain drives and some electric control apparatus may increase noise levels and attention must be given to ensuring that this does not result in excessive external noise;
- emissions (ADRs 26, 27, 30/..., 37/... & 79/...) – the emissions requirements do not apply to purely electric vehicles; however, hybrid vehicles (i.e. battery vehicles with an internal combustion engine powering an onboard generator) will be expected to comply with the relevant emissions ADRs;
- braking systems (ADRs 31/... & 35/...) – large increases in vehicle mass, alteration of

the centre of gravity and/or removal of the normal vacuum or compressed air source will affect compliance with these rules and it is essential that braking performance be maintained within the limits set out by these rules. The addition of a secondary source of vacuum or compressed air will usually be required. The vehicle must continue to comply with the design rule requirement that vehicles have a brake failure-warning lamp that can be tested by turning the ignition switch to the "start" position.

Battery Restraint

The batteries that power the vehicle must be fixed in position so that they will not easily break free in a crash and thus create a hazard to the driver, passengers or other road users. The battery restraint system must adequately withstand at least the following crash accelerations:

Front impact	–	20 g (i.e. 20 times the battery weight);
Side impact	–	15 g;
Rear impact	–	10 g;
Vertical (rollover) impact	–	10 g.

Containment of Wet Cell Batteries

All batteries that contain liquid or give off gases, including batteries powering ancillary equipment, must be effectively sealed off from the vehicle interior so that any gas or spilled liquid cannot leak into the vehicle. The batteries must be either fully enclosed in a sealed compartment (or compartments) or must be individually sealed and externally vented.

Battery compartments must be constructed of corrosion resistant material or be fully lined with a durable corrosion resistant material, or coating, that will not shrink or crack under the vibrations and temperatures likely to be encountered in a motor vehicle.

Battery compartment seals must be made of a corrosion resistant non-porous material (open cell foam is *unacceptable*).

Except for any ducting used for ventilation, all battery compartment exterior openings or fittings (including the bore of any conduit) must be fully sealed so that the transmission of gases or flames is prevented (fully sealed and externally vented batteries need not comply with this section).

Any battery system which is sealed and externally vented, or contains a water replenishing device that connects a number of batteries, must be designed so that propagation of flame between battery cases cannot occur.

Venting of Battery Compartments

The design of the batteries, or battery compartments, must provide for venting directly to atmosphere of all gases given off by normal battery operation. This is of utmost importance with lead acid batteries because, during recharging, hydrogen can be given off in quantities sufficient to cause an explosion.

Depending on battery type and the size of the vents, a forced ventilation system might be required. A forced ventilation system should:

- be corrosion resistant and designed in such a way that it will not ignite vented gases (e.g. by using flameproof motors);
- operate automatically:

  - when the batteries are on charge (including under regenerative braking, if used);
  - when the batteries are discharging; and
  - for a sufficient time after the batteries are taken off charge so as to remove the residual gases contained within the battery cases;
- operate by extracting gas from the battery compartment and not by blowing air into the compartment (this is to ensure that if the battery compartment leaks, it will not result in gas being forced into the vehicle interior);
- have an air flow rate well in excess of the gas formation capacity of the batteries under charge and, if necessary, large enough to cool the batteries during the charge and discharge cycles (advice should be sought from battery manufacturers about heat and gas generation);
- be adequately protected from mechanical damage.

The battery compartment ventilation system needs an air inlet and outlet. The inlet and the outlet should be at opposite ends of the enclosure. The inlet opening should be external to the vehicle (not underneath); if not, it must have a pressure sensitive valve to prevent reverse flow of gases and liquids into the vehicle interior. The inlet opening should not be placed in the vicinity of the ventilation system outlet. With the vehicle in motion the inlet should preferably be in an area where the local pressure is likely to be higher than static atmospheric pressure. A suitable position for an inlet is at the base of the windscreen. The outlet should be in an area where the localised air pressure is less than the static atmospheric pressure, a suitable position being on the side of the vehicle at the rear (the outlet must not be placed underneath the vehicle).

Labelling of Battery Compartments

Electric vehicles employ higher voltages than normal internal combustion vehicles and batteries contain chemicals, particularly acids, which may cause a hazard in the event of a crash. It is strongly advised that each battery compartment is labelled with the appropriate hazard symbols and an indication of the voltage likely to be encountered.

Power Unit

The electrical propulsion circuit must be isolated from other circuits in the vehicle. If safety equipment such as lights, brakes and windscreen wipers use the same power source as the traction motor, these services must be supplied in preference to the traction circuit. The design of any ancillary equipment supply should be such that satisfactory operation of all equipment, particularly brakes and headlights, is available throughout the discharge cycle of the traction batteries.

Controls

A master switch for isolating the power supply to the motor and its control apparatus must be located within easy reach of the driver. The master switch must isolate all electrical connections to the power source. If not of flameproof design, the switch shall not be placed within a battery compartment. It must be operable by direct mechanical action and must not rely on any electrical or electromechanical device.

Electrical Installation Standards

All electrical control apparatus, the motor and major ventilation system components must be effectively sealed or otherwise resistant to water and dust ingress.

All electrical installation work must be designed and executed in accordance with acceptable codes and standards. All power unit wiring and connections must be insulated (double insulated if appropriate) and provided with adequate mechanical protection. Where possible, all wiring should be located outside the passenger compartment or load space in order to minimise the possibility of contact by the operator or passengers. In places where the placement of electrical wiring in the passenger compartment or load space is unavoidable, the wiring should be contained within a rigid protective housing.

All wiring must be effectively secured to the chassis at regular intervals of not more than 600 mm, unless supported by a conduit or other rigid protective housing. The wiring should be kept away from moving and hot parts and be protected from chafing against sharp edges.

It is important to ensure that the size and insulation of the cable used in the traction circuit is suitable for its intended application. Most automotive cable is not designed for the higher voltages used in electric vehicles or for constant high current operations. The designer should make allowance for high peak currents in the stall and heavy acceleration modes.

All electrical control apparatus for the traction circuit should be designed on fail-safe principles; i.e. the failure of any individual component within the traction circuit should stop the motor.

Any traction circuit over-current protection device (e.g. a fuse or overload relay), shall not be placed within a battery compartment but, nevertheless, must be connected as close as practicable to the batteries (see also below under *Points to Remember*).

If a wire or cartridge type fuse is used for over-current protection and the vehicle has a direct current supply source, it is necessary to ensure that the fuse is rated by its manufacturer for use with direct current.

Weight Considerations

One problem, which must not be overlooked, is the possibility that some mechanical components of the converted vehicle might become overloaded because of the increase in weight caused by the addition of the traction batteries and motors. This is particularly important with the tyre and axle loadings of converted passenger cars and light commercial vehicles. Check that the strength and fatigue resistance of every component is adequate for its new function (manufacturers can supply advice about these loadings) and bear in mind that a change in weight distribution can overload components (e.g. front axle) without there necessarily being an increase in the overall weight.

Remember that it is the weight of the laden vehicle that matters—allow *at least* 68 kg per passenger, plus 13.6 kg of luggage for each passenger, for a total minimum allowance of 81.6 kg per passenger.

This allowance is the legal minimum. Given the size of the Australian population, it is recommended that the allowance chosen is higher. The intended use of the vehicle should also be considered—a vehicle intended for shopping or as a family runabout will require a higher allowance than a vehicle used purely for commuting.

Brakes and Steering

If the original vehicle was fitted with air brakes, vacuum assisted brakes or power assisted steering, an alternative source of energy must be fitted. The power and capacity of the new

source must be of sufficient capacity to provide efficient functioning of the system and meet all the legal capacity requirements.

Points to Remember

Any electrical potential greater than 32 volts, connected to a low impedance source, such as a traction battery, must be regarded as dangerous. It is recommended that all electric vehicles that use such voltages be equipped with some form of automatic power disconnection device (such as a battery isolating inertia switch), to minimise the hazard of fire or electric shock in the event of a crash.

It is also strongly suggested that the master switch is readily visible to, and identifiable by, persons outside the vehicle. This will assist emergency and rescue personnel if the driver is unconscious or otherwise unable to ensure that the battery is safely isolated.

Similarly, it is suggested that the main battery insulated conductors are coloured according to:

- negative cables – black;
- positive cables carrying less than, or no more than, 32 V – red;
- positive cables carrying greater than 32 V – orange.

Vehicles not fitted with a conventional gearbox and using a voltage reversal switch to select reverse drive should be designed so that they cannot be accidentally placed in reverse. A switch with a lockout function is acceptable, as is a separate reverse enabling switch. As electric vehicles are normally much quieter than conventional ones the safety of bystanders should be given serious consideration. It may be necessary to install a reversing aid such as a closed circuit television, a proximity sensor or a reversing alarm.

To ensure satisfactory service over the range of climatic conditions found in Australia, it is recommended that electric vehicles be designed for prolonged operation at ambient temperatures ranging from -10°C to +50°C.

Consider using current sensitive overload relays instead of simple wire or cartridge type fuses in the traction circuit (current sensitive so that the current to the motor is reduced to a safe level when overload occurs). Solid-state apparatus is acceptable. This will ensure that a total loss of drive does not occur and if an emergency does arise, the driver will have the battery-isolating switch at his or her disposal.

It is strongly recommended that the charging supply socket be fitted with an interlock circuit, which immobilises the vehicle when the charging cable is connected. Consideration should be given to the ventilation of the charging station, and to installing “No Smoking” signs where ventilated batteries are used.

Alternative Standard

The electrical system of the vehicle will be acceptable if it can be shown to comply with the technical requirements of UN ECE Regulation No 100 *Uniform Provisions concerning the Approval of Battery Electric Vehicles with Regard to Specific Requirements for the Construction and Functional Safety*. It must be noted that such a vehicle is still required to comply with the other ADRs that may be affected by a conversion.

Special Notes

Before starting construction of an electric vehicle some knowledge can be gained by reading Australian/New Zealand Standard AS/NZS 3000:2000*: Electrical installations* (known as the Australian/New Zealand Wiring Rules), in particular, section 7.9 *Hazardous Areas*.

Before commencing work it is strongly recommended that the project be discussed with the Vehicle Standards Unit of Department for Transport, Energy and Infrastructure. They can be contacted on 1300 882 248.

Written correspondence should be addressed to:

Vehicle Standards
Vehicle Services Section
Department for Transport, Energy and Infrastructure
PO Box 2526
REGENCY PARK 5942

The facsimile number is 08 8348 9533.

Vehicle Standards is located at Kateena Street, Regency Park 5010.

APPENDIX

Australian Design Rules

A modified vehicle is required by law to continue to comply with the Australian Design Rules to which it was originally constructed (or later versions), except as allowed for in the *Road Traffic (Vehicle Standards) Rules 1999*. A brief description of each ADR mentioned in this bulletin is contained in this appendix.

The ADRs are contained in a number of volumes known as editions. Currently there are two editions in operation:

- the *Australian Design Rules for Motor Vehicle Safety* (Second Edition) covering vehicles manufactured on or after 1 January 1969 to 30 June 1988, and:
- the *Australian Design Rules for Motor Vehicles and Trailers* (Third Edition) covering vehicles manufactured on or after 1 July 1988.

The applicability of each ADR is based on the date of manufacture and the category of the vehicle. Each ADR has an applicability table that specifies this information. The applicable ADRs are individually listed on the compliance plate of Second Edition ADR vehicles. For Third Edition ADR vehicles, the compliance plate contains the vehicle category and the date of manufacture, from which the applicable ADRs can be determined.

The different ADR versions are numbered in two different formats:

- ADR 4, ADR 4A, …. in the Second Edition, and
- ADR 4/00, ADR 4/01, … in the Third Edition.

Note: ADRs are subject to change and therefore builders and modifiers must refer to the most recent version of the applicable ADR prior to commencing any work.

ADR Summaries

ADR 3/... *Seat Anchorages*
Requirements for seats and seat attachments to reduce failure in crashes.

ADR 5/... *Seat Belt Anchorages*
Requirements for seat belt anchorage points to ensure that seat belt assemblies are securely fixed to the vehicle structure in specified areas and provide a safe and comfortable restraint system.

ADR 10/... *Steering Columns*
Requires that steering wheel and column assemblies must collapse under specified forces to reduce injuries to drivers on impact and limits the horizontal intrusion of the steering column into the cabin.

ADR 21/… *Instrument Panel*
Provides for instrument panels to be suitably padded and free of any sharp projections and edges to reduce head injury on impact.

ADR 26 Engine *Emission Control*
Defines limits of carbon monoxide emissions from passenger car engine exhausts under idling

conditions.

ADR 27 Engine *Emission Control*
Additional to the requirements of ADR 26, defines limits of passenger car and passenger car derivative engine emissions of carbon monoxide and hydrocarbons (also oxides of nitrogen in ADR 27A) in all phases of operation.

ADR 28/... *Motor Vehicle Noise*
Specifies maximum levels of external noise that motor vehicles, other than motorcycles, may emit.

ADR 30/... *Diesel Engine Exhaust Smoke Emissions*
Limits the smoke density emitted from diesel engine exhausts.

ADR 31/... *Hydraulic Braking Systems*
Requires split hydraulic braking systems and brake failure warning devices, and specifies stopping performance of passenger cars to ensure safe braking under normal and emergency conditions.

ADR 34/... *Child Restraint Anchorages*
Specifies requirements for anchorage points behind each rear seating position of passenger cars to facilitate the satisfactory installation of child restraint systems.

ADR 35/... *Commercial Vehicle Braking Systems*
Specifies braking requirements for commercial vehicles under both normal and emergency conditions. Also requires a brake-failure warning device.

ADR 37/... *Vehicle Emission Control*
Limits fuel evaporation and exhaust emissions from motor vehicles in order to reduce air pollution, and requires operation on unleaded petrol.

ADR 42/... *General Safety Requirements*
Specifies a wide variety of general design and construction requirements to ensure safe operation of the vehicle, e.g. mudguards, windscreen demisting, bonnet latches, engine and transmission controls, etc.

ADR 69/... *Full Frontal Impact Occupant Protection*
ADR 73/... *Offset Frontal Impact Protection*
These ADRs specify the level of vehicle crashworthiness to be met in a full frontal crash, side impact crash or an offset frontal impact crash to minimise the likelihood of injury to vehicle occupants.

ADR 79/... *Emission Control For Light Vehicles*
Specifies the exhaust and evaporative gas emissions of light vehicles (less than or equal to 3.5 tonnes GVM) fuelled by both leaded and unleaded petrol, diesel and LPG in order to reduce air pollution.

ADR 83/... *External Noise*
Defines limits for external noise generated by motor vehicles, motorcycles and mopeds to reduce the contribution of motor traffic on urban and community noise levels.