ARTSA
Combination Vehicle Brake Code of Practice

Part 1

A Guide to the Selection of Braking Systems for Combination Vehicles

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Other Code Parts

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Caution

This Code of Practice is intended as a guide only. It is based on the collective experience and wisdom of ARTSA's member companies. It does not replace, vary or modify existing laws and regulations. Complaince with this Code is voluntary. Legal requirements should be met.

ARTSA cannot know, evaluate or advise regarding all ways in which a practice or procedure may be undertaken or its consequence. No guarrantee of accuracy is given. Anyone who uses this Code of Practice must satisfy themselves as to the approriateness in their circumstances of their use and all safety aspects.

To the extent permitted by law, ARTSA is not liable in negligence or otherwise for, liability arising from, and any costs incurred in connection with , damage, loss, injury or death concerning this Code of Practice or its use. If doubt exists, guidance should be sought from the manufacturers of the vehicle parts.

1 Purpose

The main purpose of this Code of Practice is to assist the Australian transport industry to achieve *good practice* with braking and stability performance of heavy combination vehicles. It is directed to both manufacturers and operators of heavy vehicles.

Another important purpose of the Code is to provide detailed information about the brake technologies in the Australia market place so that industry can have a better understanding of the features and characteristics. This Code of Practice is based on performance standards and does not recommend particular brake technologies. However, *good practice* does restrict the technologies that should be used in combination.

Electronic controls can now manage or even initiate braking events based on real-time performance. Adaptive braking systems such as mechanical load-sensing brakes and electronic brake distribution are widely avaialble. Hence technologies can be applied to produce substantial improvement to brake balance and hence to improved braking performance.

The mixing of brake technologies on one combination-vehicle should be implemented with insight. 'New' can work with 'old' if the technology choices are appropriate and the settings correctly made. This Code gives 12 principles and 31 recommendations that define *good practice* for the current range of brake technologies. It will also be necessary to correctly set-up brake technologies to achieve acceptable brake compatibility-balance.

The Code has been developed by the Australian Road Transport Suppliers Association (ARTSA) in consultation with the Australian Trucking Association (ATA), the Truck Industry Council (TIC) and the Victorian Transport Industry Safety Group (TISG). The financial support of the National Transport Commission, VicRoads and the Roads and Traffic Authority (RTA) NSW is gratefully acknowledged. The Queensland Department of Traffic and Main Roads supported testing that was conducted to verify some of the recommendations in the Code.

2 Scope

A heavy combination vehicle consists of a motive vehicle with a gross vehicle mass equal to 12 tonnes or greater, pulling at least one trailer that has a gross trailer mass of 10 tonnes or greater. This encompasses semi-trailers, tipper and dog trucks, B-doubles, A-doubles and triples (road-trains), and vehicles with a mixture of A- and B- train parts. In the Code, 'truck' means the motor vehicle, 'combination vehicle' means a truck connected to one or more trailers and 'vehicle part' means either the truck or a trailer as appropriate to the context.

New vehicle parts that are supplied to the market in Australia must comply with the applicable Australian Design Rules (ADRs). ADR 35 concerns commercial vehicle (truck) braking and ADR 38, heavy trailer braking. In-service vehicles must also comply with the Australian Vehicle Service Rules (AVSRs), which are broader than, but consistent with the ADRs.

Achievement of the recommendations of this Code must continue the compliance of the vehicle and its parts with the legal requirements. In some instances this will require computations or tests by accredited people. In other instances technologies can be set or adjusted within the existing compliance range that the manufacturers have established.

3 Code Structure

The ARTSA Combination Vehicle Brake Code of Practice is in five written parts, which are:

Part 1: Selection of vehicles for combinations – gives an overview of brake technologies and issues arising from the mixing of technologies. It is directed to people who specify and configure combination vehicles.

Part 2: A workshop guide to brake set-up – is directed to workshop managers and brake technicians. It considers the adjustments and set-ups that are available on heavy vehicles and gives some advice.

Part 3: Assessment of brake balance on combination vehicles – describes and illustrates the methods by which the brake balance is defined and calculated.

Part 4: Australian braking performance – provides reference information on brake system performance, and is of most relevance to all people with an interest in the technical aspects of heavy vehicle braking. In particular, it reviews braking rule requirements in Australia and compares these with typical performance levels and theoretically possible performance levels. Also, validation testing is reported on.

Part 5: Review of heavy-vehicle electronic brake control technologies – provides a detailed review of electronically controlled braking and stability technologies. It will assist Australian heavy-vehicle operators and others in the industry to understand the functions and limitations of the new technologies, and the language associated with them.

Additionally, the Code provides a brake calculator (in spreadsheet format) and a wall-chart for ease of reference.

This Code of Practice is additional to and does not seek to displace the Australian Air Brake Code of Practice that was issued by the Australian Trucking Association in 1999. The later Code provides an excellent reference on the operation of air brake systems. The present Code is focused on achieving acceptable brake balance on combination vehicles and on providing updated information about electronicalyy conrolled braking systems, which have developed substantially in the past decade.

4 Brake Performance Basics

There are five performance aspects that are important for combination vehicle braking:

- sufficient brake capability to achieve statutory stopping distances;
- directional control during heavy braking;
- a fast brake response on all parts of the vehicle;
- absence of excessive load shifts during braking; and
- about even brake wear.

Vehicles with good performance for these aspects are preferred because drivers will be able to brake with confidence and achieve above-average stopping performance. Also operators will experience relatively low vehicle maintenance costs.

Vehicles that have consistent or complimentary brake technologies that are appropriately set-up will excell. Other combinations of technologies might comply, but this should be proven by calculations (or tests).

Brake balance describes the extent to which the axles on a combination vehicle contribute to the braking effort in proportion to the load carried by the axle. Because the weight distribution on a commercial vehicle changes significantly with load level, whereas the retardation capability of the brakes may not, it is often difficult to achieve good brake balance for the range of loads that can occur.

A vehicle with good brake balance will not exhibit gross wheel lock-up during heavy braking. Wheel lock-up is undesirable because a locked wheel has a substantially reduced capacity to provide steering and road handling forces. Therefore a vehicle part that has many of its wheels locked on an axle group has a propensity to loose directional control. Figure 1 illustrates the main instability modes of semi-trailer and truck and dog-trailer combinations.

Furthermore, a locked-up tyre cannot provide peak retardation force so the potential minimum stopping distance performance cannot be achieved. A vehicle with good brake balance will achieve a relatively short stopping distance and remain directionally stable. A vehicle with poor brake balance will not, even though it may have substantial brake capability. Note that poor brake adjustment that results in uneven braking effort between sides of a vehicle part will also result in pulling to one side during braking.

'Perfect brake balance' is scarcely achievable. However, brake technologies exist that can adjust the braking effort appropriately for the load carried by a vehicle part ('adaptive brake systems'). The theoretically possible stopping distance occurs when the braking coefficients of each wheel equals the avaialble tyre-road friction coefficient. The time taken for the brakes to apply must be considered.

Electronic brake control technologies are now available for most truck and trailer models that manage the brake balance according to measures of actual brake performance, such as deceleration and relative wheel slips. Therefore, technological advancement is improving the capacity of combination vehicles to manage brake balance and thereby improve both the emergency braking performance and the brake-wear balance of heavy combination vehicles.

The calculation of brake balance involves determining the range of values on the vehicle of the braking coefficient (or 'friction utilization') ratios:

Brake retardation force / Weight force ('*the braking coefficient*')

of the axles and the vehicle parts. This is relevant because a radial truck tyre will lock-up when this ratio reaches about 0.9 on a sealed dry road (or lesser values on a wet or slippery road). The shape of a tyre friction curves for a radial truck tyre is illustrated in Box 1. Generally, a wheel is assumed to be locked-up when its *braking coefficient* exceeds the available tyre-road friction coefficient; which is the peak of the tyre curve.

The peak value of road-tyre friction that is avaialble depends upon the condition of the tyre tread and on the inflation pressure. The maximum allowable inflation pressure will be inapproriate when the vehicle is lightly laden because a drop in peak friction occurs. Consequently a ***Central Tyre Inflation System*** **(CTIS)** can manage tyre pressures and improve the tyre-road adhesion.

At low braking levels, brake balance is important because it determines the distribution of brake wear. Brakes that wear prematurely on one vehicle part or one axle group indicate either that there is poor brake balance at low to moderate brake pressures; or that brakes are dragging or poorly adjusted. The control level at which the brakes start to work is called the *threshold or onset* air pressure level. The closer all the onset pressure levels are, the better the low-pressure brake balance.

Vehicles with poor brake balance can develop ‘glazed’ brake linings or excessively heat-cracked brake drums or rotors. In extreme cases excessively hot brakes might ignite the axle grease. Excessive temperature at a few brakes is a sure indication of poor brake balance (or dragging brakes).

Timing balance concerns the extent to which all the brakes on a combination vehicle receive the instruction to start braking. Significantly signaling time delays can occur on long-combination vehicles. These are minimized if vehicle-designers bias the pneumatic design to deliver short response times to the trailer coupling; and the optimum hose and fitting sizes are used.

Electronically controlled brake systems usually have the capability for electronic signaling to following parts, which speeds the response. Some electronic controllers also pre-charge the trailer control line when a fast movement of the brake control occurs. Therefore electronic controls can improve brake timing balance.

Engineers refer to brake balance between vehicle parts as compatibility brake balance and between axle groups on the one vehicle part as distribution brake balance. Box 2 provides further information.

It is often difficult to get accurate torque values for the foundation brakes on vehicles. A simple guide is obtained as follows:

- The minimum average deceleration performance of a fully-laden heavy vehicle is taken to be 4.5 m/s^2 from 60 km/h. This figure is traceble to the Australian Design Rules.
- The average retardation force needed to achieve this deceleration is 4.5 kN / tonne.
- Because the brake balance on the vehicle is never perfect, a higher capability is needed. Assume a capability of 5 kN / tonne.
- The nominal radius of 11R22.5 and 295/80R22.5 tyres is about 0.5 m.
- The average torque is then 5 x 0.5 = 2.5 kNm / tonne
- For a 7 tonne rated front axle, the average brake torque of all the brakes during a stop at full air pressure (about 700 kPa on a North American truck) will be ~ 17.5 kNm. On a 20 tonne rated rear-axle group the brake torque will be ~ 50 kNm.
- If the brakes on an axle are generating 5 kN / tonne retardation, then the *Braking Coefficient* is 5 / 9.806 = 0.51. If the weight on the axle is halved whilst the brake level is unchanged, the *Braking Coefficient* becomes 1.02.

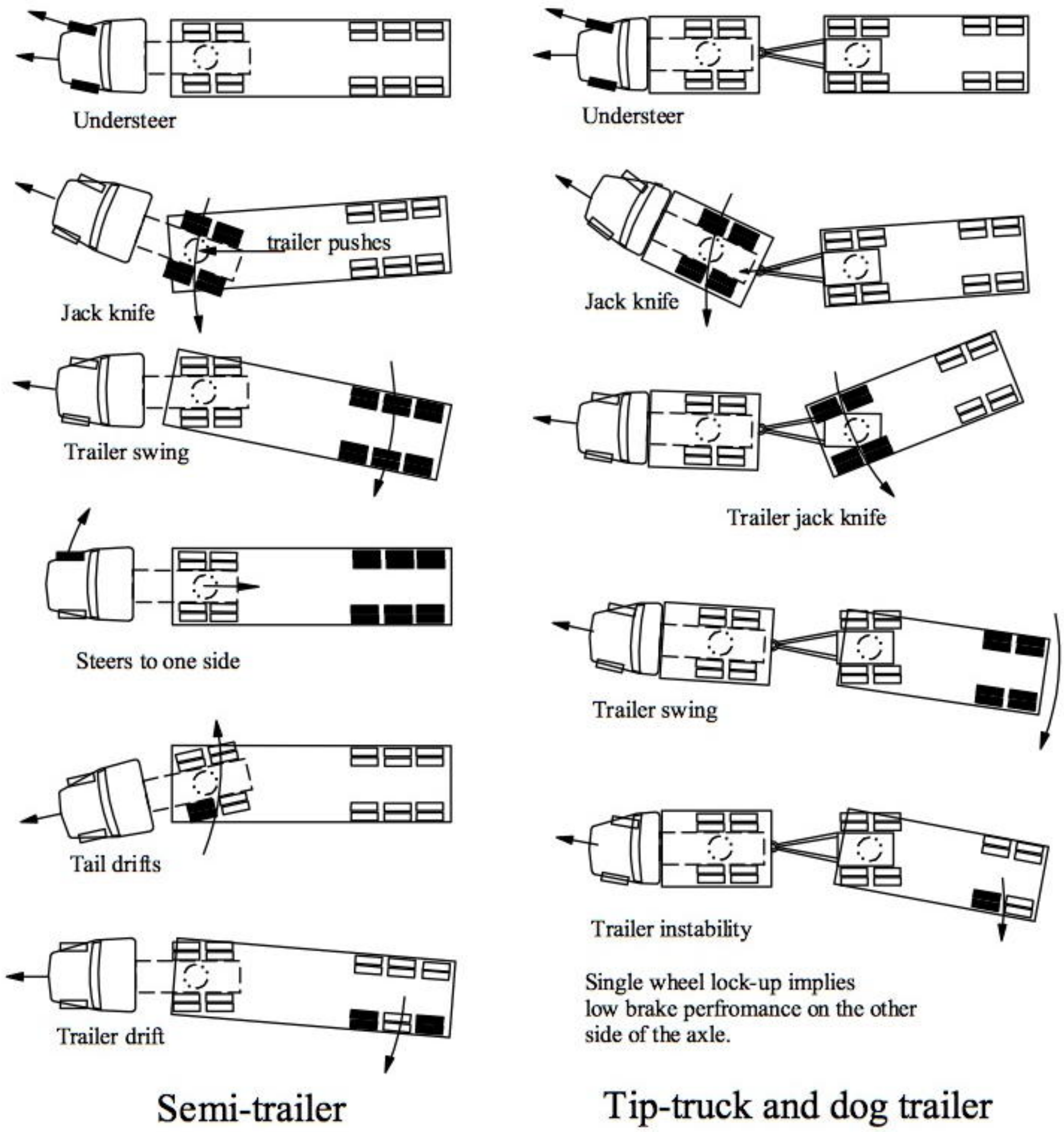


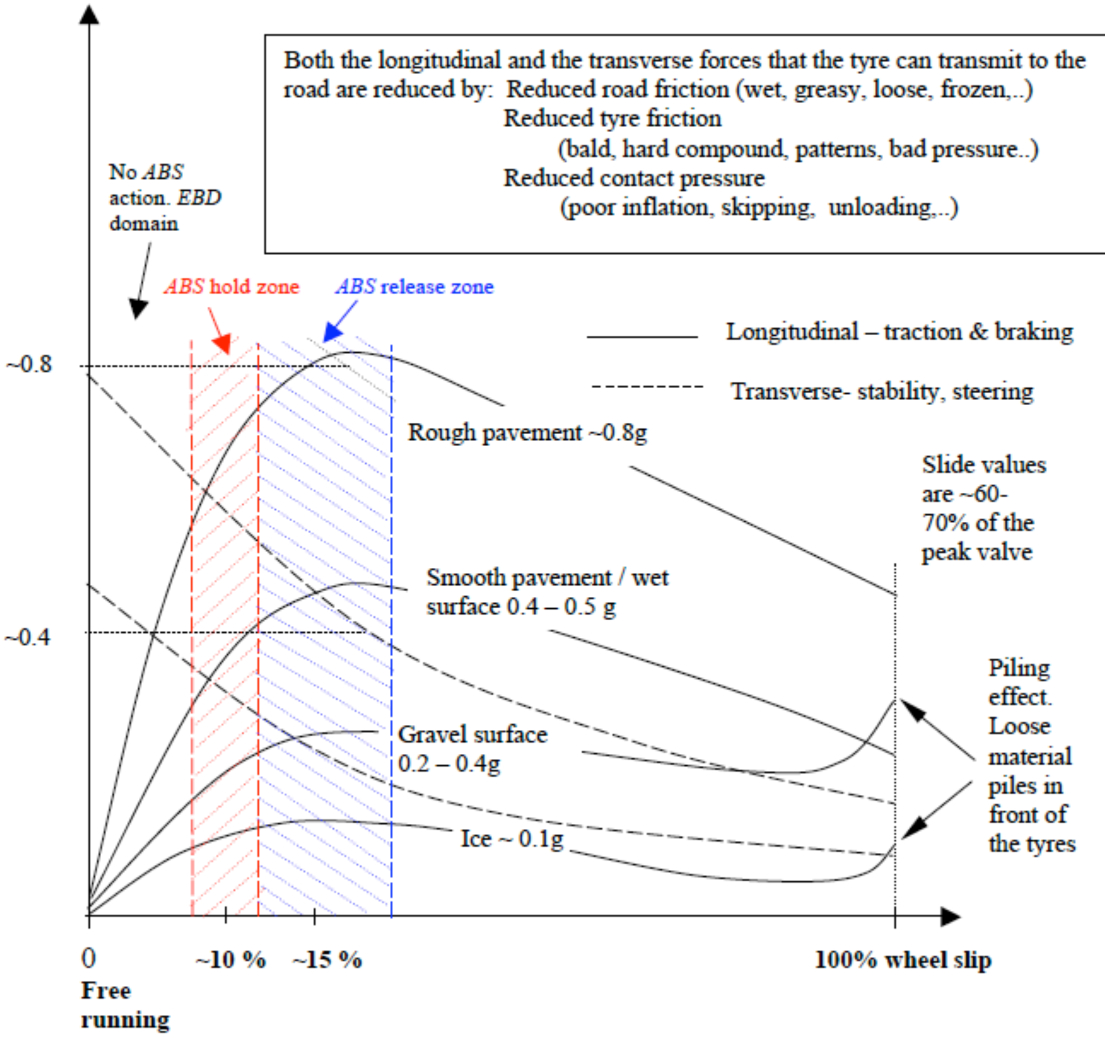
Figure 1 Directional instability resulting from wheel lock-up (black tyres) on a semi-trailer (left) and tipper and dog truck (right).

If the brakes have unbalanced side-side adjustment, then the truck will pull to one side during braking.

Box 1

Tyre Slip Curves

Braking / Stability Force per kilogram transmitted from tyre to road
(called the *braking coefficient* or *friction utilization*)



Wheel slip = 0 % when wheel is free wheeling.
100 % when wheel is fully locked.

Maximum braking forces occur somewhere in the wheel slip range 10% - 30%
Wheel slip always exists during braking. It is necessary to generate the retardation forces. The aim should be during heavy braking to have all the wheels slips less than ~ 10%.

The slip curve also applies to tractive effort.

Figure 2 The form of the tyre-slip curves for a radial truck tyre.

Electronic brake controls make control decisions based mainly on measured wheel speeds and computed *wheel slips* of the sensed wheels. Characteristically, radial truck tyres achieve a peak braking coefficient (and hence maximum retardation performance) on a sealed road when the *wheel slip* is about 15%. As a guide the available tyre-road friction on a dry smooth sealed road for a radial tyre is about 0.9. Course sealed roads are better in the wet but not as good in the dry (peak ~ 0.8).

Box 2

Brake Compatibility Balance Limits

Compatibility brake balance concerns the extent to which the braking effort is shared between the vehicle parts in proportion to the (laden and lightly laden) weight of the vehicle. The Australian Design Rules (and UN ECE Regulation 13) require the *vehicle braking coefficient* (called the ERC if it is measured), to be within an upper and a lower bound over a range of control levels. Figure 3 shows the limit lines. They are based on the prime-mover limits in UN ECE Regulation 13. This regulation has a more complex set of limits for the range of vehicle types. Australia has applied the prime-mover limits to all vehicle types.

A laden curve (blue) is shown. It may have been determined by tests or by computations. If the load is taken off the vehicle, the brake capacity does not alter. The brake coefficient curve transforms inversely with weight and so the curve lifts (red curve). For example, if the weight on the tyres halves then the curve would double in height. In practice, tyre skidding occurs for high braking coefficient values and this reduces the test curves somewhat.

If a *Load Sensing Brake System* is installed, the unladen curve must not cross the upper limit line. Vehicle manufacturers usually interpret the rule to not apply to electronically control brake distribution systems such as EBD and EBS.

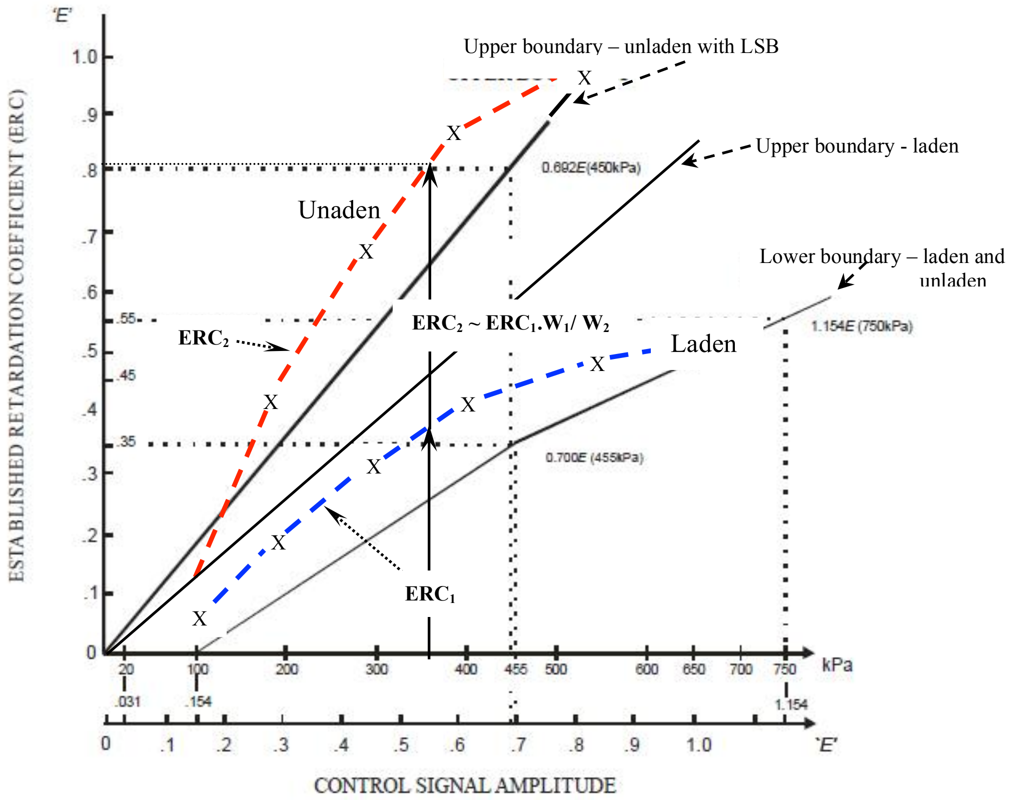


Figure 3 The compatibility limit curves from ADRs 35 and 38 (Figure 2 in the ADRs).

Notes: The laden and unladen curves transform according to the formula shown above (which assumes that no wheel lock-up occurs). As a guide W_1/W_2 is 2 - 3 for a truck and 3 – 5 for a trailer.

The *Established Retardation Coefficient* is the measured average deceleration after application time delays have finished. When the curves are calculated rather than measured, they are called *Vehicle Braking Coefficient* curves.

5 Characteristics of Brake Technologies Used in Australia

It is important to understand the range and characteristics of the brake technologies that are used in Australia, if brake technologies are to be successfully mixed on combination vehicles. This section provides an overview of the technologies in use. Further detailed information about electronic brake control systems is in Part 5 of the Code.

The great majority of the Australian vehicle fleet has S-cam ***drum brakes*** without electronic brake controls or load-sensing brakes. ***Disc brakes*** are now readily available and are making inroads, particularly on European manufactured trucks. Disc brakes allow the brake torque to be increased on the steer axle of a truck by making better use of the available space. Dust and stone damage of the rotor can be a problem in arduous service. Heating of the wheel bearings might occur if there is a good thermal path from the disc rotor to the wheel hub via for example an aluminium wheel).

Disc brakes have a higher brake torque per weight of the brakes than drum brakes. One important benefit is that the brake power on the front-axles of trucks can be greater with a disc than a drum brake, which can improve distribution barke balance.

Disc and drum brakes on the one combination vehicle are likely to have different onset brake pressure levels so wear imbalance can occur. They will also have different temperature characteristics so brake balance will alter when the brakes are hot. It is important that the braking coefficients of the disc brake axles are not higher than that of the drum brake axles; and that the onset pressures are adjusted to be about equal.

Automatic brake adjustment is always a feature of disc brakes. It is recommended that automatic brake adjustment be used on the vehicle parts when one part has them, so that the adjustments are broadly balanced.

Adjustable trailer valves have often been used to make minor (but potentially useful) adjustments to the brake balance between a towing vehicle and a trailer. There are four main types:

Predominance valves with a reducing lead to the trailer, which are used when the trailer rests on the towing vehicle (i.e. B-type vehicle). The reducing lead accounts for weight transfer from the trailer to the truck during moderate- to heavy-braking.

Predominance valves with fixed lead or lag to the trailer – this is appropriate when the trailer does not transfer weight during braking to the towing vehicle (i.e. A-type vehicle).

Ratio valves, which change the output pressure as a fixed proportion (ratio) of the input pressure.

Limiting valves, which limit the control air pressure to trailers to a pre-set maximum value.

The first three types of valves listed have adjustable characteristics across the complete air-pressure range and thereby alter both the onset and the emergency braking performance. Whenever air valves are installed in the control path there is likely to be an increase of the onset pressure of 15 – 30 kPa, which should be accounted for.

Trailer valves are often set in response to driver assessment of braking performance on a particular combination. Better practice is to set whem using gauges according to calculations. The danger is that the changed setting will be good for one trailer but poor for another. These valves are not adaptive; that is do not change with load level.

Limiting valves are sometimes used to prevent gross wheel lock-up on trailers. This practice limits the potential braking power and is no substitute for improving the brake balance. Changes to the settings of trailer relay valves on trucks will alter the legal compliance of the vehicle. In particular limiting valves are likely to cause a vehicle part to not meet ADR-level deceleration performance levels.

Adjustable trailer valves (such as predominance and ratio valves) are usually set to improve the 'feel' of the braking as reported by the driver. They can also be set to improve the wear balance between towing vehicle and trailer. An experienced driver should test drive the combination vehicle after the setting has been altered. Deceleration tests should be conducted using a decelerometer. Improved braking performance should be reported in both laden and lightly laden conditions.

Retractable (lift)-axles are now popular, particularly on trailers. An electronic or pneumatic control system causes one or two axles in a group to be lifted (using pneumatic force) when the weight on the group falls below present levels. ADR 42 specifies the 'prescribed transition masses' at which the lift-axle must have automatically lowered.

Lifting the axle(s) reduces the brake capability (and rating) of the group. Such systems are a form of adaptive brake control technology. They improve the brake balance in partly laden conditions by reducing the available brake capacity.

Load-sensing brakes **(LSBs)** use an air-control valve that applies an adjustable but pre-set transfer ratio between the input and output air control pressures. They adapt to load changes. The transfer ratio changes in response to static load changes, as indicated by air-bag suspension pressure or suspension mechanical-spring deflection. When LSBs are set-up appropriately the brake balance on lightly laden vehicles and combinations can be significantly improved.

Load-Sensing Brakes can be easily installed onto semi-trailers and on dog-trailers that have air-bag suspensions. Air suspensions provide a convenient load-level pressure signal that the LSB valve uses as a control. On trailers LSB valves should control each axle group. LSB valves can also be retrofitted onto trucks that have drive-axle group air-bag suspension. On trcuks only the rear axle group is usually controlled.

Load-Sensing Brake valves that sense mechanical spring deflection via a mechanism are also available.Operators have always been reticent to use LSBs on trailers with spring suspensions because the spring deflection alters as the springs sag. The LSB mechanism needs to be readjusted priodically.

Some older European and Japanese truck models have load-sensing brakes that act on the drive-axle group. American and Australian trucks never have LSB valves. Electronically controlled brake systems that alter the brake balance have largely displaced LSBs on trucks.

There is a long history of using load-sensing brakes on European trucks and trailers because of statutory European requirements for lightly-laden brake balance. Performance limits for Australian unladen vehicle parts that have LSBs are now in the Australian Design Rules 35 (trucks) and 38 (trailers). The limits are based on the UN ECE Regulation 13 limits applicable to prime-movers.

LSBs must be carefully set to avoid excessive reduction of the braking level as they effectively transfer some of the braking effort to other axle groups or vehicle parts on the combination vehicle. It is always necessary to calculate the brake balance on a vehicle that has an LSB on some or all parts. The set-up should seek to balance the static *braking coefficients* of the vehicle parts over the range of load levels. As a guide the ratio for unladen vehicles should not be set lower than 60%. Lower settings might give better brake balance, but might be too low when the combinstion is changed.

On semi-trailers the LSB controls all the brakes on the rear axle group. On a dog-trailer the LSB should control both axle groups because it is the vehicle part that has its brake capability altered. Because trailers usually experience a proportionately greater change in load level between fully laden and unladen states than trucks, the brake balance might be improved by using an LSB on the trailer only, but they must be carefully set. Using an LSB on a truck and not the trailer is not recommended. Further information is provided in Box 4.

North American made prime movers sometimes have ***'bobtail proportioning brakes'***. They reduce the brake power on the driver-axle group when there is no trailer connected. The brake relay valve that operates the drive-axle brakes has two ratios, which are 100% or 40%. When the trailer air supply is not active, the 40% ratio applies.

Drivers will notice the difference in pedal feel when load-sensing or bobtail proportioning brakes are used because the brake 'power' is reduced when the vehicle is lightly laden. It may take some time for drivers to get used to the differnce. Whilst there may be complaints, it is important to realize that the absence of gross wheel lock-up is an important safety benefit.

Antilock brakes (ABS) are now on the majority of new trucks*. This is a consequence of ABS being mandated in most overseas supplier countries. Australia trailers are likely to have S-cam drum brakes without load sensing brakes (LSBs) and without Antilock brakes. They are closer in character to North American than European trailers, as the later usually have adaptive brake controls and Antilock brakes.

Antilock braking systems monitor the wheel speeds of the sensed wheels and act to reduce the braking level when the wheel slip approaches the limit (about 15% slip for a radial truck tyre – Further information is provided in Box 1). ABS does not balance the brakes, rather it prevents gross wheel lock-up and thereby protects against loss of directional control. Additionally, it is desirable to have adaptive brakes so that the brake balance is improved when lightly laden and the call on the ABS system is minimized.

It is usual practice to sense wheels on one axle in a tandem-axle group. Usually the axle that is most likely to lock (which has the lesser weight during braking) is sensed. ADR 38 (trailers) requires that at least two axles be sensed in a trailer tri-axle group. This requirement is not mandated for trucks (ADR 35), but is recommended when tri-axle groups are used.

The ABS control action is either to:

- stop the increase of braking level ('hold'); or
- reduce the braking level ('release'); or
- do nothing ('pass').

A cycle of ABS operation involves holding, then possibly releasing and subsequently allowing pressure build-up; it is called a modulation cycle. This is done by a modulation valve, which is a solenoid-pneumatic valve that is in the brake line to a groupo of wheels on one side of an axle group.

The controller monitors the wheel slip relative to other wheels and decides to on the modulation action, which is applied to all controlled wheels tied to the sensed wheel. ABS should be set-up for the correct wheelbase / s-dimension, suspension type and tyre sizes.

The usual practice for a 6 x 4 prime mover is to sense four wheels and to control six wheel using four modulation valves (i.e. a 4S/4M system). Usual practice os to sense the steer axle and the rear axle in the drive-group (which is the usually the first to lock-up in the drive group). This is called the 'sense low' strategy. For an Australian semi-trailer four wheels are usually sensed (tri-axle group) and the wheels on each side modulated as a group (i.e. 4S/2M system).

The choice of configuration and sensing location does affect the performance of electronically controlled brake systems. Ultimately the electronics gets the majority of its information about the truck dynamic performance from the wheel speed information. The mechanical design of the truck affects the relative wheel speeds on different axles. Hence the choice that the vehicle manufacturer makes about which axles to sense should take account of the suspension design.

Australian detractors of ABS claim that it increases stopping distance because there is reduced braking effort during a modulation cycle. It takes time for the actuators to become recharged during modulation, which lowers the average retardation force. The propensity for ABS to waste stopping distance has greatly reduced over the past decade as the sophistication of the system has increased and ability to judge the 'hold pressure' has improved. ABS should not increase stopping distance on a sealed road. The benefits of better directional stability and achieving optimum tyre slip are significant. Therefore, wheel-lock protection is a desirable feature.

* "truck" means the motive vehicle; combination vehicle means the truck with trailer(s)

ABS may increase stopping distance on a loose surface because of the frequent modulation that is needed during moderate braking. On a loose surface gravel piles build up in-front of the locked wheels and tend to 'chock' them; which improves the traction. However, locked wheels cannot provide steering or road-handling forces so the vehicle ploughs straight ahead when it is braked heavily. Modern truck ABS has an optional gravel-road mode that can be activated using a switch at the driver's console; this is a recommended feature. Pulling out the electrical connector, which is an option for drivers when on very loose surfaces, will disable trailer ABS. This should cause the trailer ABS warning light to come on in the cabin.

ABS is now an entry-level technology for electronic brake control. Advanced control features are usually coupled with the Antilock function. **Electronic brake system (EBS)** is available on most European and some Japanese trucks; and on trailers. It is not available on North American or Australian built trucks.

EBS incorporates the Antilock function and a brake distribution function. **Electronic brake distribution (EBD) and / or Electronic stability control (ESC)** is coupled with Antilock function on some Australian trucks. Some North American trucks are available with **Roll stability system (RSS or RSP- program)** which will slow the vehicle by reducing the engine power when a developing roll-over risk is sensed. North American trucks are not currently avaialble in Australia with full ESC, although can be anticipated shortly.

Many truck ABS installations also have **Automatic traction control (ATC)**, which is also termed **anti-slip regulation (ASR)**. ATC autonomously applies the brakes on one or both sides of the drive axle group to prevent wheel slip under tractive-effort. Wheel slip can occur on loose or slippery surfaces. By braking the free-turning wheel or wheels, greater engagement with the surface can occur. ATC is implemented using an actuating modulator valve on each side of the drive axle group. The modulator valve can implement the usual ABS functions of pass, hold and release. It can also apply air pressure to activate the brake actuators.

On a 6 x 4 truck that has both ABS and ATC, the optimal performance cannot be achieved with only one axle in the drive group being sensed. The load shifts that occur on a brake-reactive suspension occur in opposite directions for braking and traction. Therefore, it is recommended that a truck with a bi- or tri-drive have sensors on two axles in the drive group.

Electronic brake control (EBS) is widely available on European trucks and becoming avaialble on some Japanese trucks. EBS is characterized by electronic communication between its sensors (brake pedal, wheel speeds, pad wear ,..), controllers (solenoid controlled air relay and modulator valves) and external connections (control signals to one or multiple trailers). EBS manages braking pressures at each wheel to achieve distribution brake balance between axle groups, wheel lock-up protection and brake-wear management.

The Australian experience of EBS has been generally positive. Some problems have occurred because an EBS that is set for European trailers may be incorrectly set for most Australian trailers. Experience has been that that truck EBS can over-drive typical Australian trailers when lightly laden. This situation could be improved if truck manufacturers used a consistent Australian set-up. Recommendations about this are made.

Truck EBS incorporates a feature called **trailer response management (TRM)** (which is also called **coupling force control - CFC).** It sets the trailer brake control level according to the measured deceleration level, the brake pedal position and the assumed trailer characteristics. Usually TRM is set-up for European trailers and Australian trailers may be overdriven. The bias (lead or lag) given to the trailer by TRM is programmable. Therefore, it is wise to consistently connect trailers that have appropriate characteristics.

Note that TRM is not a feature of North American or Australian trucks that have electronic brake controls, even if they have **electronic trailer signaling (ETS)**. ETS provides a CAN signal from the truck to the trailer that gives the trailer brake control pressure level in electronic form.

Some truck EBS systems are now set-up with different trailer-response management settings depending on whether there is a trailer communicating via the CAN bus or not. It is assumed that any trailer communication indicates that the trailer(s) has a functioning EBS system and is therefore adaptive; if there is no communication then it is assumed that the trailer(s) does not have an adaptive brake system.

EBS is a sophisticated electronic brake control system that has may features that can be set by the vehicle manufacturer or the system supplier. These adjustments cannot be done by the workshop manager. Changes to tyre diameter, actuator size or body type will require reprogramming of the EBS controller. Virtually all the features of EBS can be customized or adjusted for a particular application.

Unfortunately EBS truck suppliers to the Australian market have not agreed on a consistent set-up for Australian trucks. It is recommended that the onset pressure level for the trailer(s) be set at 65 kPa and that the trailer(s) bias be set to zero.

Further, it is recommended that the trailer used behind an EBS truck have either a load-sensing brake system or a trailer EBS (i.e. an adaptive brake system) because this is the assumed configuration. This also will result in better brake balance.

Trailer EBS is available for semi-trailers and dog trailers and is used on a minority of new trailers. The Australian trailer builders have not promoted trailer EBS to its clients and this has limited the uptake.

For A-type trailers (which have a converter-dolly trailer), it is advisable to not install ABS / EBS onto the converter dolly trailer. A better approach is to use Load Sensing Brakes on the dolly trailer and ABS / EBS on the semi-trailer. This avoids one electrical connection per trailer, and improves the capacity of the electrical supply on a two- or three-trailer roadtrain.

Trailer EBS (Tr EBS) always includes an Antilock brake function, (electronic) load sensing function and usually includes a trailer roll-stability function. It responds to either a pneumatic brake control signal or (preferentially) an electronic signal (via the CAN bus).

Communication of stability and braking performance data routinely occurs between truck and trailers via the CAN (Controlled Area Network) electronic communication bus. This uses two of the seven pins in the usual electronic brake control connector (*ISO 7638:2003; either 5 pin: ABS or 7-pin: EBS. The 7-pin connector has two CAN-bus terminals).* The CAN bus is now a crucial connection for advanced electronic braking and stability control on combination vehicles.

Electronic brake distribution (EBD) refers to the control of the brake distribution balance on a vehicle part that has two axle groups (such as a truck or a dog trailer), so that the average wheel slip during braking of all the sensed wheels is about equal. EBS includes the EBD function and implements it via separate control signals to the front-group and rear-group brake relay valves. An electronic Stability Cotrol System (ESC) may not incorporate EBD

EBD is now a feature of 'advanced' antilock brake systems on some Australian trucks. In this case EBD is achieved by holding the build-up of brake pressure on the rear-axle group so that the average wheel slip of the sensed wheels on the rear axle group is about the same as that of the front axle group. This implies that the average braking coefficients of the two groups are about equal. EBD therefore implements adaptive (or load-sensing) brake control electronically. It responds to the actual wheel speeds, which are affected by the dynamic loads (i.e. the actual loads during heavy braking) and the friction levels. The EBD 'slip range' is identified in Box 1.

Electronic stability control (ESC) is available on both EBS and ABS 'platforms'. European ESC is built on EBS whilst North American ESC is (or will be) built with ABS. Electronic Stability Control can autonomously apply brakes on one side of a selected axle group to improve the trajectory of a vehicle when loss of directional control or roll-over instability are predicted. The assessment of loss of control and the prediction of how to correct it are the key performance issues. The UN ECE brake regulation R13 version 9 requires that an ESC system be able to:

- instruct the engine to alter the power level;
- assess the directional control requirements based on yaw acceleration and lateral acceleration, wheel speeds and the drivers braking and steering inputs;
- assess roll-over potential based on wheel speed differences between each side of the vehicle, yaw acceleration and brake control level, and in the case of trucks, the driver steering input;
- autonomously apply the trailer brakes (irrespective of the trailer brake technology).

ESC uses the a weight signal (which is usually an air-suspension bag pressure), relative wheel speed information, yaw acceleration, steering wheel orientation and brake pedal position sensor signals to assess the dynamic performance of the vehicle. ESC may also make test applications of the brakes on each side of an axle group to help determine the cornering performance. The sophistication of the assessments will probably increase as the experience is gained on Australian roads.

A key difference between truck EBS and advanced truck ABS is that the later does not implement Trailer Response Management. This is a significant difference that might flow through to different implementations of ESC. European ESC will assume that the trailer has European characteristics. It is hence recommended that Australian trailers pulled by ESC trucks have ABS as a minimum feature because the ESC might over-drive the trailer during emergency operation.

During emergency intervention, a truck ESC will probably brake the trailer. Typically the trailer brake control level will be about 50 % (~ 325 kPa). ESC systems can be set-up to not drive the trailer brakes and some manufacturers have chosen to do this. Hopefully design and in-service rules will specify how ESC should be set-up for Australian trailers. In any event, it is wise to have antilock brakes (at least) on all the trailers pulled by an ESC truck to avoid gross wheel lock-up occuring during emergency intervention.

It can be expected that **electronic stability control (ESC)** will become mandated in Australia on new heavy vehicles in the 2015 time frame. ESC is being mandated on new trucks in continental Europe and indications are that this will also occur in North America. Mandating ESC on trucks has been foreshadowed in the Australian National Heavy Vehicle Brake Strategy. It is not yet clear whether the USA will have consistent technical standards for ESC as those adopted in Europe. There are likely to be differences in how European ESC manages the trailer compared to North American ESC.

Operators should not use trailers without any electronic brake controls in conjunction with an ESC truck because the trailer might be prone to gross wheel lock-up during emergency avoidance maneuovers. Assuming compatible stability contorl systems are used on all parts, ESC might provide a 10 – 20 km/h improvement is crash-avoidance speeds.

Trailer roll stability system (TRSS) uses the relative wheel-speeds together with a yaw accelerometer and a load signal to assess the propensity for trailer roll-over during cornering. It is separate from, but usually coupled with trailer EBS. The basic system response is to slow the vehicle by applying all the (trailer) brakes at a moderate level when the safety margin for roll-over is assessed to be unsatisfactory. The system initially assumes that the roll-over threshold is 0.25g lateral acceleration. Test brake applications are conducted during cornering and the system reassesses the roll-over threshold level trigger level based on trip experience. If the lateral acceleration exceeds the current estimate of the roll over threshold, the trailer brakes are applied to slow the vehicle. Trailer TRSS does not cause any brake response on the truck.

It is generally accepted that combination vehicles usually roll over 'from the rear'. This occurs because the centre of mass of a laden trailer is usually higher than that of the truck. That is, the roll-over threshold of the trailer is lower than that of the truck. However, there is a view that roll-stability protection (which is inherently a feature of truck ESC) is more useful than trailer roll-stability, because truck ESC also receives the steering - wheel orientation information. Furthermore, truck ESC can reduce engine power to slow a vehicle before applying brakes, which improves drive-ability. Controlled demonstrations of the latest ESC and TRSS systems have demonstrated that both systems can be effective at preventing most roll-overs, when they are used separately. It is true that truck ESC will probably prevent trailer roll-over on the trailer pulled by the prime-mover.

Some North American built prime-movers have a **roll stability system / program (RSS or RSP)** that uses a yaw acceleometer and the wheel speed signals to judge when the truck is going too fast into a curve. This system is not as sophisticated as a truck ESC. Truck RSS is always coupled with ABS.

The ability of stability controls to deal with poor road conditions (which could be bumpy or have a loose surface) is important. ESC and TRSS use differences in wheel slip levels on each side of a sensed axle as one indication of cornering performance. If the road surface is variable, another factor exists that complicates the assessment. Further Australian experience of TRSS and ESC is needed to fully assess the likely safety benefits.

Another significant development of the CAN bus standards has been the ability to identify and address individual trailers on a multi-trailer combination vehicle. This is helping to improve EBS performance when all vehicle parts have an EBS.

The CAN is usually 12V or 24V for a nominal 12V or 24V electrical system. It is common for ABS trailer connections to be powered at 12V even when the truck electrical system is 24V. This reflects previous design-rule requirements. Despite this the CAN signals are usually at the nominal truck voltage. Trailer EBS systems are often multi-voltage – that is, can be powered at 12V or 24V. They assume that the CAN signal is at the same voltage level as the power circuit.

There can also be inconsistent five and seven-pin (braking) electrical connectors. These connectors comply with *ISO 7638:2003,* which is specified in the design rules. Either 12V or 24V keying can be used, as appropriate to the truck voltage. Occasionally incompatible plugs and sockets prevent coupling. Some multi-volt trailer systems now have connectors with both 12V and 24V keying. Truck operators need to be aware that voltage incompatibilities can occur.

European and Japanese trucks always have a 24V CAN, whilst North American and Australian trucks have a 12V CAN. A voltage converter is often used on European and Japanese trucks to supply the trailer ABS / EBS at 12V. Consequently the trailer ABS / EBS unit will not communicate via the CAN bus because the signals are at 24V. Check with the vehicle suppliers when voltage converters are used. It is desirable to avoid usign a voltage converter if possible.

Advanced dynamic stability control systems are being introduced onto the Australian market. **Brake assist (BA)** manages emergency braking events. Emergency braking is triggered when the throttle is released quickly and the brake pedal is pushed quickly and hard. BA aims to provide the optimal braking response in the circumstances to achieve a short braking distance whilst maintaining directional control and steer-ability. The driver is able to concentrate on avoidance manoeuvres. Brake Assist is usually coupled with Truck EBS.

Autonomous cruise control (ACC) is available with both truck EBS (European), advanced truck ABS (Australian) and Electronc Stability Control (Nth. American). ACC acts to slow a truck when the separation distance between the truck and the vehicle in front is assessed to be too short in cruise-control mode. It uses radar or camera images to judge the separation distance. ACC first gives a warning, then applies the auxiliary brake, and if necessary the service brake to slow the truck. It uses radar or optical methods to estimate the distance. In most implementations, the response (or the warning) occurs whether cruise control is active or not and the retardation action only occurs when the cruise control is set. The desired minimum following distance is adjustable. Either the adjustment is available to the driver via a console switch or it is pre-set.

Lane departure warning systems or lane assist (LDW) uses cameras that look forward together with image recognition siftware to identify when the truck has crosses a lane line without intention. The system monitors the trafficator stalk and the steering wheel to assess whether the movement was intended or not. In the first level of response a buzzer and / or steering column shudder occurs. At a higher level of response, the autonomous braking system might be engaged.

Autonomous emergency braking (AEB) will apply the vehicle service brakes autonomously (i.e. without driver control) if a frontal collision is likely to occur. Like ACC it uses radar sensing of the region in front of the truck together with knowledge of steering wheel direction, speed and lateral acceleration to predict a pending frontal collision. Autonomous emergency braking (AEB) is now available on some European trucks. It is always coupled with Truck EBS and adaptive cruise control (ACC).

It is adviable that any trailer pulled by a vehicle with an autonomous braking system have, as a minimum, *Antilock* (ABS) brakes. This will protect against gross wheel lock-up on the trailer(s) during emergency operation. However, ABS is now a base level technology and significantly smarter and potentially safer technologies now exist, such as EBS / EBD and ESC that should be specified.

Heavy truck suspensions for dual bi- and tri-axle groups usually have some brake reactivity. That is, load shifts occur between axles within the axle group during heavy braking. This can disturb braking action because wheels on one axle are likely to lock-up before that on other axles. Trailing arm suspensions tend to transfer weight back whilst other suspension types transfer load forward to a greater of lesser extent. There is also a tendency for the vehicle part to dip at the front during heavy braking due to load transfers between the axle groups. Therefore, even unreactive suspensions experience some load transfers between internal axles because the chassis rails are now oriented one or two degrees down at the front. It is often assumed that air-bag suspensions are unreactive. This is an over-simplification.

Central Tyre Inflation Systems (CTIS) have become common in some niche applications, such as logging, over the past five years. CTIS automatically keeps the tyre pressure at each wheel at an a pre-set level that is approriate for the load being carried. CTIS also monitors tyre pressure and will alert the driver if there is a fault. A correctly set CTIS should increase tyre life and importantly, ensure optimum traction performacne and stopping distance performance because correct tyre pressure will deliver peak road-tyre friction.

Auxiliary braking systems (engine brakes, transmission retarders and tail-shaft retarders) can provide substantial retardation force that might cause wheel lock-up on the drive wheels on a poor road surface when the vehicle is lightly laden. Whilst auxiliary brakes are useful because they take the load off the service brake system, they can disrupt the truck brake balance. For this reason the Antilock brake system should have veto power over a powerful auxiliary brake. It is unwise for an auxiliary brake to apply (at high settings) automatically when the throttle is released. On a poor road surface this can lead to drive-group wheel lock-up. Auxiliary brake systems are often under the control of the engine management system. These can be set-up so that a driver input, such as touching the brake pedal, is necessary to trigger the auxiliary brake application.

The brake technologies that have been discussed fall naturally into categories. All electronic technologies provide wheel-lock protection; i.e. an antilock function. Many of the technologies (such as LSB, EBS and EBD) provide adaptive braking; that is, they adjust the braking level in response to a load-level signal or measured wheel slip performance. Stability control systems are examples of autonomous brake systems, which can apply brakes without driver input. Collision avoidance systems and advanced safety warning systems are now being introduced in Australia, mainly on European trucks. Figure 4 shows a hierarchy of sophistication of heavy vehicle brake systems.

There is no doubt that advanced braking and stability systems can improve heavy vehicle safety. It can make a heavy combination easier to drive. It is always important that the driver chooses to drive an enhanced-technology vehicle conservatively to achieve the full safety potential. It should also be noted that drivers will notice a difference in the brake 'feel' or response of vehicles that have adaptive and autonomous brakes. It is unwise to conclude that because a driver's first reaction might be negative, that the technology is unworthy.

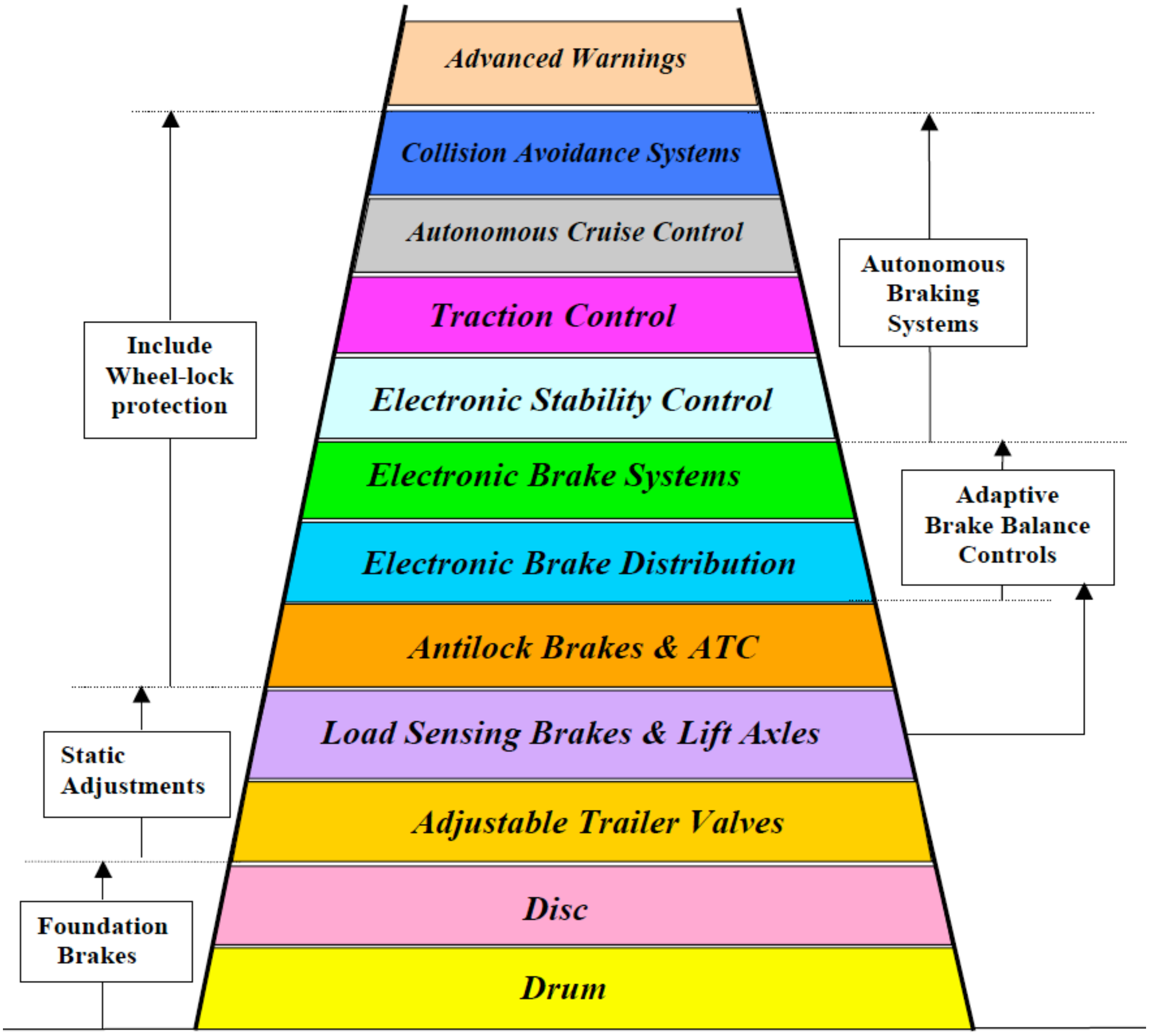


Figure 4 A sophistication hierarchy of brake and stability control technologies.

A detailed review of electronically-controlled brake technologies is given in Part 5. A tabular summary of the features of these technologies is at the end of this document.

6 Australian Heavy-Vehicle Standards and Performance

The individual new vehicle parts must be certified to comply with the Australia Design Rules; ADR 35 for trucks and ADR 38 for trailers. In-service vehicles (including combinations) must comply with the Australian Vehicle Standards Rules (AVSRs). State and Territory jurisdictions also have test standards that they apply to in-service vehicle parts. Table 1 (at the end of this Part) gives a summary of the statutory deceleration and force performance levels.

The test vehicle is usually the ‘worst-case’ in the model range; that is with the shortest wheelbase and the minimum tare weight. Note that the stopping distances must be achieved whilst the vehicle staying within a 3.7m lane width. Experienced test drivers can control the brake level to achieve short stopping distance with directional stability.

Some controlled tests on Australian laden long-combination vehicles are discussed in Part 5. It is clear that drivers – even in controlled tests – do not fully use the service brakes for fear of loosing directional control. The tests show that it is possible to stop the laden B-double flat-tray truck without any advanced braking technology at about 0.6g (6 m/s^2), which is about double the prescribed minimum performance (in the AVSRs). Most drivers would avoid braking at this level because of the risk of directional instability occuring.

Table 1 lists the Australian statutory deceleration levels for heavy vehicles. In-service heavy (combination) vehicles are required (by the AVSRs) to achieve a minimum deceleration level of 2.8 m/s^2, which implies a stopping distance of about 55m at 60 km/h. Road testing to verify this performance is done at 35 km/h. Alternatively a skid-plate tester might be used at ~ 5 km/h. Experience shows that the average brake retardation force tends to decrease (for drum brakes) as the starting speed for the tests is increased.

ADRs 35 and 38 have brake compatibility requirements and ADR 38 has brake distribution requirements. Figure 3 shows the ‘brake compatibility limits’ that must be met on new laden vehicles and on new unladen vehicles that have load-sensing brakes (LSBs). The tests are to be conducted on a test vehicle by braking to a stop on a sealed road from 60 km/h. The laden vehicle characteristics must be within the upper and lower limits with the prescribed static axle weights (6t for an axle with single tyres and 9t for an axle with dual tyres); and also at GVM / GTM load. The tests are usually conducted using a test load that has a low centre-of-mass height. High centre-of-mass heights will give a slightly different performance because the brake distibution balance on the vehicle is affected by load height and hence load transfer.

The *Established Retardation Coefficient* is the measured average deceleration after signaling time delays have elapsed. It is influenced by load transfer. When the curves are calculated rather than measured, they are called *Vehicle Braking-Coefficient* curves. The effects of load transfers should be accounted for in the calculations.

If all the vehicle parts have about equal braking curves, then a good degree of compatibility brake balance exists. This Code recommends that the trailer curve be no lower than the truck curve to minimize any tendency for jack-knife. If the trailer curve is too much higher than the truck curve, there is a risk of trailer swing at high braking levels; and if it is too low there is a risk of jack-knife. The design rules have fairly broad limit lines, which are based on the UN ECE Regulation 13 limits for prime-movers.

Australian practice is to design to have the trailer ERC characteristic in the upper half of the acceptable compatibility band and truck characteristic in the middle or lower half of the band. European practice is to have the trailer characteristic lower than the Australian trailer characteristic.

The lightly-laden compatibility limits in ADRs 35 and 38 are applicable to ‘variable proportioning brakes’. Vehicle manufacturers have generally interpreted the rule to mean that vehicles with *Load Sensing Brakes* must comply. Vehicles with *Electronic Brake Distribution* are not usually certified for the unladen compatibility requirements.

European vehicles are required to meet both laden and unladen compatibility limits. The unladen requirement can only be met if the vehicle has adaptive brakes. Therefore, European vehicle manufacturers set-up adaptive brake systems (LSBs or EBD) according to these limits. Consequently a European truck will usually be set-up assuming that the trailer(s) have adaptive brakes. Most Australian trailers do not.

North American heavy trucks are required to have a minimum *Vehicle Braking-Coefficient* at specified actuator pressures but there is no upper limit. Japanese heavy trucks are likely to comply with UN ECE Regulation 13, at least in the laden condition.

The brake distribution balance requirements in ADR 38 are:

- for a dog trailer the braking coefficient of at least one of the front axles must be greater than that of at least one of the rear axles for a deceleration of 0.3g (3 m/s^2) for a two-axle dog-trailer or for a deceleration of 0.15g (1.5 m/s^2) for a dog-trailer with three or more axles. This applies to both the laden and unladen vehicle.
- for a semi-trailer or dog-trailer that has a brake reactive suspension, it is required that the brake set-up ensures that wheel lock-up does not occur on an axle up to a deceleration of 4.5 m/s^2. This requirement only applies to the laden vehicle.

There are no brake distribution requirements in ADR 35 and no explicit distribution requirements in the in-service rules. A vehicle that meets the performance standard does not exhibit gross wheel lock-up in either the laden or unladen condition. It has adequate compatibility and distribution brake balance.

Brake timing limits that apply in the Australian design rules are:

- at the trailer coupling: Pressure reaches 420 kPa by no later than 0.4s;
- at the least favoured brake actuator: Pressure reaches 60% by no later than 0.6s.

Vehicle parts that have electronic signaling have minimal time delay on the control path. This might reduce brake actuation time by 1s to the second trailer on a B-double and 1.5s or more on a road train. Whilst these improvements might seem small, the instantaneous brake balance during emergency braking greatly influences the initial trajectory of the vehicle.

In-service brake torque testing is conducted at road-side test or road-worthiness stations. Two different pass-fail criteria exist. These are either a minimum for each brake of 3 kN/tonne or 4.5 kN/tonne, depending upon the jurisdiction. The brakes on a modern vehicle part are capably of reaching the higher standard. Further, brake force levels should not vary by more than 30% between each sides of an axle. Often the performance is limited by tyre-slip on the roller when the vehicle is lightly laden. Tests should be conducted with at least half load on the vehicle part.

Finally, the Performance Based Standards project that the National Road Transport Commission has developed has adopted a brake performance standard for the element: Directional Stability Under Braking. The PBS braking standard is similar to the performance standard recommended in this Code. It differs in that different perforamcne levels are set for the different *Access Levels* applicable to PBS vehicles. Vehicles are deemed to meet the PBS standard is they have either an *Antilock* brake system or a *Load Sensing Brake System* on each vehicle part. A vehicle that meets the recommendations of this Code of Practice will comply with the PBS braking standard for Level 1 vehicles.

Box 3 shows some typical brake torque distributions on Australian trucks. Note that vehicles might differ significantly from the arrangements shown. Figure 5 illustrates that the typical laden trailer brake characteristic is above that of the truck. Figure 6 illustrated some typical brake balance distributions on trucks likely to be used on Australian roads. The brake torque levels of a large number of foundation brakes that are used in Australia is given in Part 4.

Box 3

Typical Australian Vehicle Characteristics with General Access Axle loads

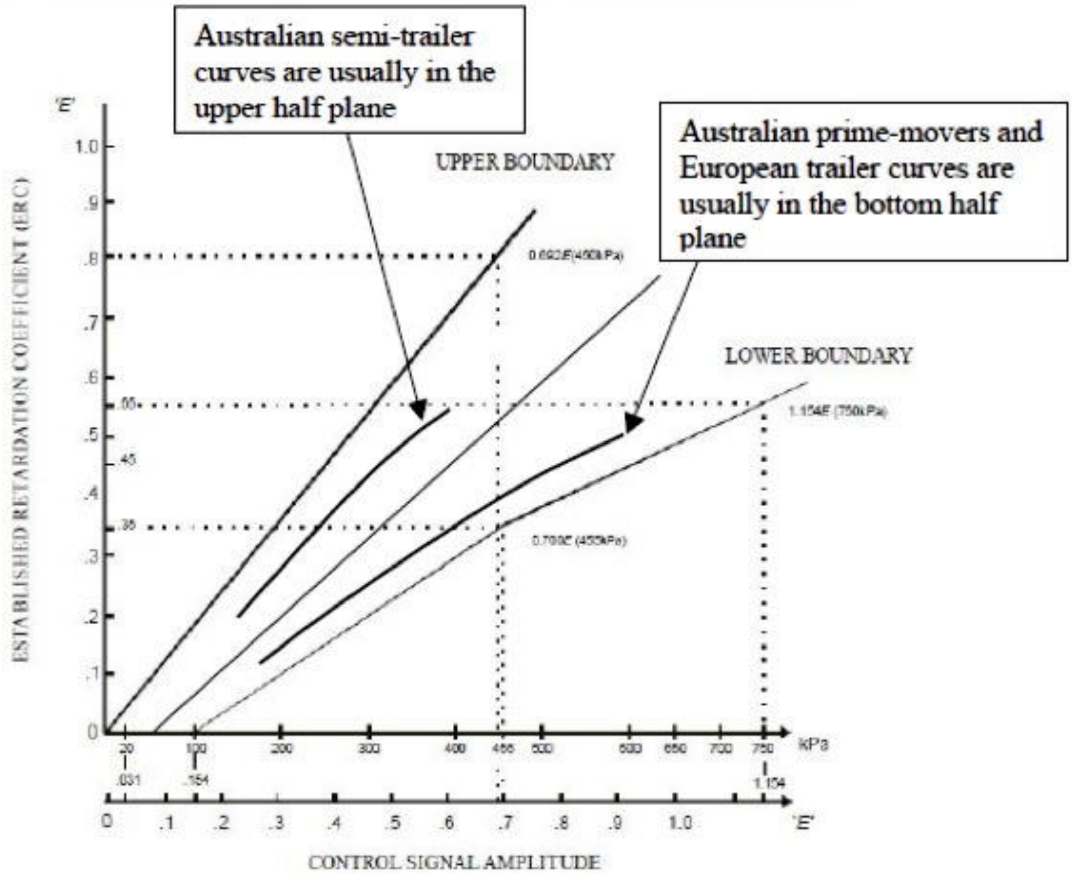


Figure 5 Typical laden truck and trailer brake characteristics.

Box 3 continued

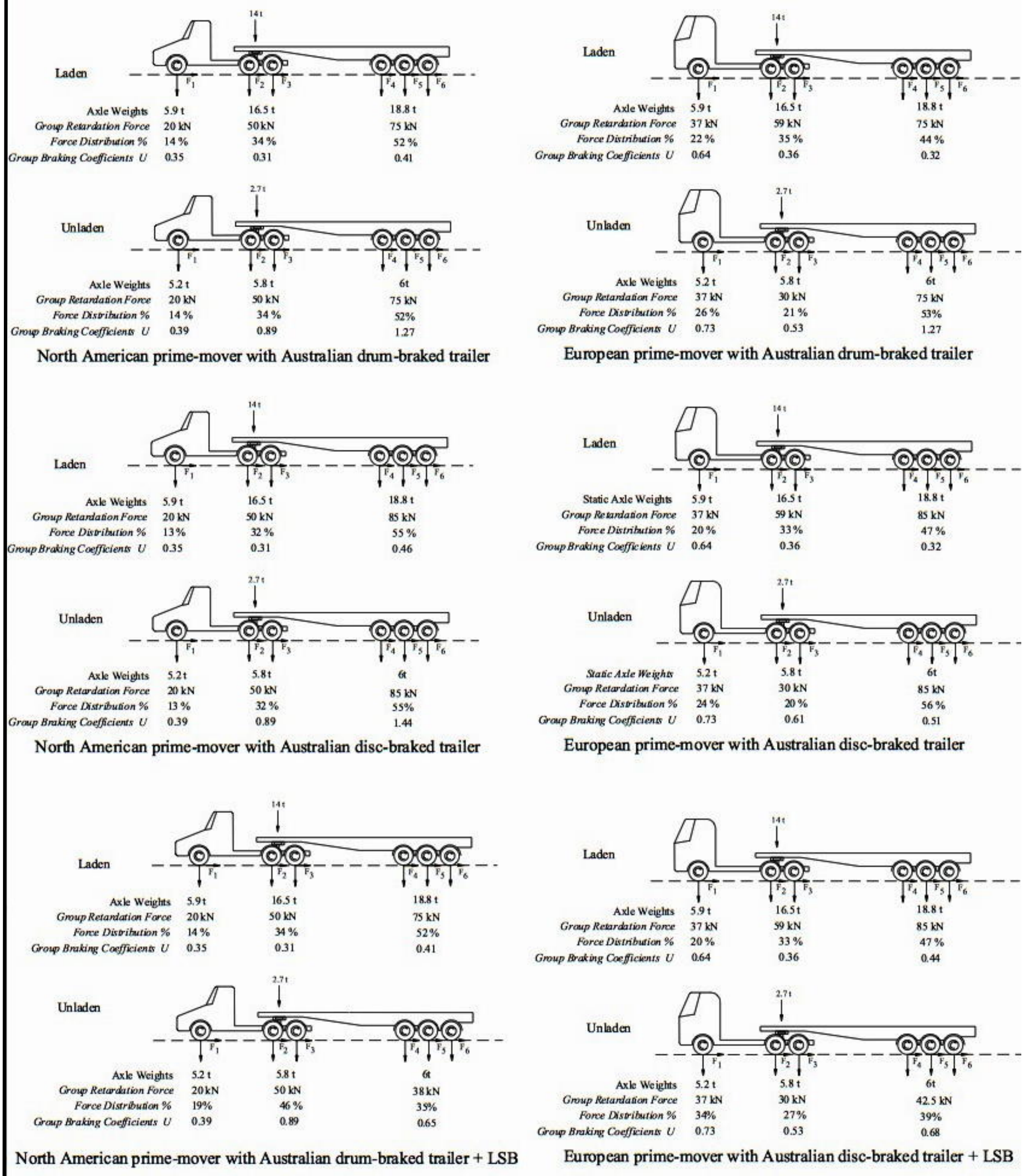


Figure 6 Typical brake distribution levels on North American and European trucks

7 Principles

The following eleven principles that should underpin brake technology selection, have been identified:

1. *More powerful brakes are not necessarily better. A combination vehicle with well balanced brakes for all loading conditions, will make the most of the available road friction and will be directionally stable when braked hard.*

   There is a view that the bigger the brakes the better. This is untrue. The braking capability must be adequate for the load to be carried. However, it is good brake balance that produces stable braking and good 'feel' during braking.

2. *A combination vehicle should not exhibit gross wheel lock-up during severe braking.*

   Gross wheel lock-up is defined as sustained wheel locking on an axle-group that has one or two axles; and sustained wheel lock-up on more than one axle in a tri- or quad-axle group. The reference deceleration is 0.45 m/s^2 at a speed of 60 km/h.

   A suitable <u>performance standard</u> is that a combination vehicle – irrespective of load and the available road friction - should be able to achieve a stopping distance that is no more than double the theoretical stopping distance with perfect brake balance, without gross wheel lock-up occurring. The worst-case condition occurs when the vehicle is lightly laden.

   A performance standard is necessary to provide a neutral basis for assessment of mixed brake technologies. The chosen standard is readily achievable with existing brake technologies and is easily to understand.

   If gross wheel lock-up occurs at low braking rates, then poor brake balance is indicated. Gross wheel lock-up means the pressence of wheel lock-up on single- or dual-axle groups, and wheel lock-up on more than one axle in a tri- or quad-axle group. Wheel lock-up can be tolerated on one axle in the latter groups because there are sufficient numbers of turning wheels in the group to provide the lateral stability forces.

3. *It is preferable to use the same brake technologies on each vehicle part in a combination. In particular, if one part has an adaptive brake technology then this is preferable for all parts.*

   This principle will assist operators to achieve balanced performance under all loading conditions.

   In some cases this principle is inconvenient as it limits the range of vehicle parts that can be connected. If the vehicle meets the performance standard in 2 then this principle is unnecessary.

4. *Where mixed brake technologies are installed, it is desirable to use the same brake technology on all the trailers of a multi-combination vehicle. Dolly trailers however, can have different brake technology to other trailer.*

   Like principle 3, this principal is intended to guide operators when trucks are configured. It is difficult (but not impossible) to achieve acceptable brake balance when the brake systems on each of the trailers, is substantially different.

5. *A vehicle that has either Antilock protection (ABS function) or adaptive brakes on all vehicle parts can be assumed not exhibit gross wheel lock-up if it is set-up appropriately.*

   Wheel lock-up protection will eliminate gross wheel lock-up. Adaptive brakes that are correctly set will improve the brake balance. A vehicle with either (or both) of these features on each part is unlikely to lock-up wheels when stopping at 0.45g from 60 km/h on a sealed road. Therefore, it is likely that such vehicles will meet the performance standard.

An adaptive brake technology is one that adapts to different load conditions. For example, load-sensing brakes (LSB), electronic brake distribution (EBD) and electronic brake control systems (EBS) are all adaptive. Further descriptions are given in the following section.

6. *Brake systems that have adaptive control (such as EBS, ESC and load sensing brake valves LSBs) should be set-up according to manufacturer's recommendations and using the guidance given in this Code. The set-up greatly affects the performance.*

   Adaptive brakes should be set-up with some knowledge of the characteristics of the other vehicle parts in the combination. Whilst these technologies may be used on one vehicle only, they change the brake balance of the complete combination.

   If for example, only the prime-mover and not the trailer has adaptive brakes, then the brake balance of the combination is likely to be poor when lightly laden. The set-up of the adaptive brake controller should account for this.

7. *If a vehicle part has an intelligent brake system that can automatically apply the brakes to improve vehicle trajectory, other vehicle parts in the combination should have wheel lock-up protection (Antilock brakes as a minimum; preferably EBS / ESC).*

   Autonomous braking actions, particularly on the truck, might apply a high brake control level to the trailer(s). Wheel lock-up protection (ABS) is advisable on vehicle parts.

8. *Good brake balance improves the performance of Antilock braking systems.*

   If the brake balance is good the propensity for wheel lock-up is reduced. The antilock brake system will operate occassionally but not routinely. Full antilock wheel modulation does release brakes and the stopping distance may increase.

   Antilock wheel protection can trade stopping distance for lateral stability. Both are important. The better the inherent brake balance, the less the call on the antilock brake system and the better the stopping distance performance with directional stability.

   Whilst electronic brake control has much to offer, it is desirable to avoid antilock system operation rather than rely upon it. A truck with inherently good brake balance and brake adjustment will make a lower call on the wheel lock-up protection.

9. *Central Tyre Inflation System (CTIS) will improve road handling and emergency stopping performance.*

   A correctly set *Central Tyre Inflation System* will produce optimum tyre-road friction levels. This helps a heavy vehicle to hold the road and to stop in a relatively short distance.

10. *The higher the roll stability index, the better for brake balance.*

    Vehicles with high centres of mass are likely to experience substantial load transfers during heavy braking. Load transfers disturb the brake balance and this disturbance is difficult to compensate for.

11. *Vehicle manufacturers should publish the brake force values as a function of actuation pressure for the brakes on the vehicle.*

    This information is important for basic brake balance calculations. Some information is publicly available for trailers. It is not usually published for trucks. Part 3, Section 11 lists publicly-available brake-torque information.

8 Summary of the Code's Recommendations

The following thirty-three recommendations of this Code of Practice give guidance about the mixing of brake technologies on combination vehicles. They are indented to define '*good practice*' with the selection and set-up of vehicle brake technologies. Further elaboration is given in other Parts of this Code.

Brake Compatibility Recommendations

1. *The onset (or threshold) pressures of all the brakes on a combination vehicle should be in a 15 kPa range.*

   This will ensure that all brakes in good mechanical condition apply at about the same control level.

2 *Vehicle manufacturers should adopt the following design levels for onset braking pressure: Trucks 70 kPa and Trailers 65 kPa.*

   These values are achievable on Australian vehicles. The values are consistent with international (ISO*) recommendations. The slightly lower value for trailers helps to have the trailer brakes come on quickly and counteracts timing delays.

   * ISO Standard 20918:2007 specifies an onset pressure range of 50 – 80 kPa. Australian

   experience is that this is too wide to achieve acceptable brake wear.

3. *Vehicle manufacturers should set the foundation brakes so that the brake compatibility characteristics pass through the point ERC = 0.35, E=0.435 (290 kPa) when the vehicles are laden to 'legal' axle-weight limits. A tolerance of ±10% should be applicable. See Figure 7.*

   As a general observation of Australian practice, the truck characteristics are set too low and the trailer characteristics too high. This recommendation aims to promote a common design point for trucks and trailers.

With Adjustable Trailer Relay Valves

4. *Trailer predominance valves should be set-up using air gauges so that the bias setting (to either the truck or trailer) is known. The setting should be based on the known air-system characteristics of the truck and trailer.*

   It is not acceptable for the trailer relay valve to be set-up in an ad-hoc way and to then rely upon the driver's report. It is appropiate to do some basic brake calculations and to set the valve using gauges so that the change in brake balance is known. Be aware that adjustment of a trailer relay valve will change the certification status of the vehicle. Therefore calculations or tests are necessary to verify continuing complaince with rules.

5. *The characteristics of adjustable trailer relay valves should be appropriate for the type of combination vehicle.*

   That is, reducing lead for a semi- (or B-type) trailer and a constant lead for a dog or road-train (or A-type) trailer. The different characteristics account for the load-transfer behaviour of trailers during heavy braking.

6. *Limiting valves (which limit the trailer control level to some preset value) and ratio valves (which give a fixed ratio between the input and output pressures) should not be used*

   Limiting valves reduce the potential emergency braking performance and invalidate the vehicle brake certification. Ratio valves are likely to produce gross brake imbalance in some loading conditions at high control levels because the bias that they give gets greater with control level. There are better solutions, such as an appropriately set load-sensing brake valve.

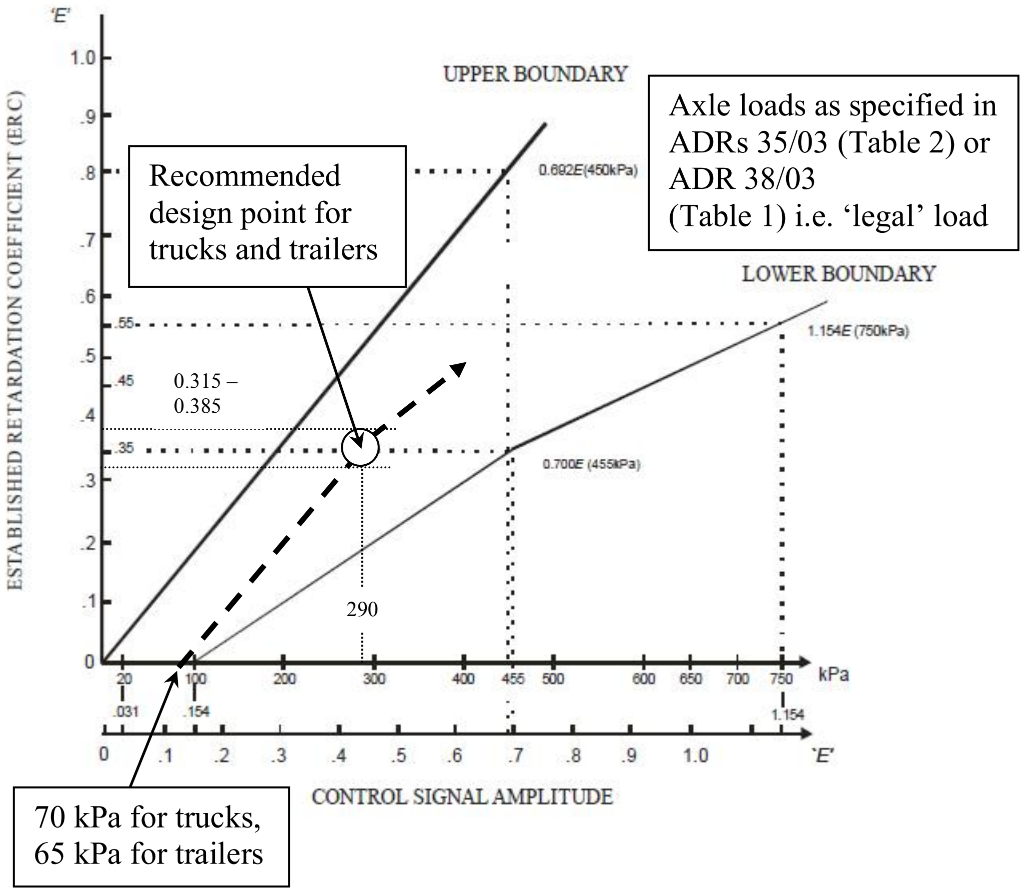


Figure 7 Recommended characteristic positions

With a Load Sensing Brake Systems (LSB)

7. *Load Sensing Brakes can be used on a trailer (and not on the truck) to improve the brake balance. They should not be used on a truck only.*

   LSBs should always be set-up for a particular combination. The LSB must be set appropriately so that the trailer braking coefficient curve is close to but not below the truck curve. It is unlikely that this positioning of curves can be achieved if the LSB is on the truck only.

   Trailers experience a greater change in weight between fully laden and lightly laden conditions than do trucks. Consequently an LSB can be successfully used to reduce the braking level of a trailer to achieve better brake balance when lightly laden. See Box 5 for an illustration.

   Calculations of the vehicle braking coefficients should be conducted to verify that the LSB valve shifts the unladen vehicle-part braking curves closer together.

8. *When an LSB is installed it is always necessary to verify that the vehicle compiles with the unladen brake compatibility limits in the applicable ADR. The aim is to have the unladen curves close together. Further information is in Box 4.*

   As a guide, the unladen setting of Load-Sensing Brake valve(s) should not be set to less than 50% of the full-load setting (100%).

There is a danger in setting LSB valves too low because any vehicle reconfiguration could result in poor brake balance. If the vehicle is a dedicated combination than an optimum setting can be used.

If an LSB is used on a semi-trailer(s) and not on the truck, as a guide a suitable LSB setting when the semi-trailer is unladen is 60% of the fully laden setting (100%). However, the set-up should be based on calculations.

9. *If a trailer with an LSB is pulled by a vehicle without an LSB, antilock brakes should be used on the towing vehicle to protect against jack-knife.*

   The antilock brakes will protect against any tendency to jack-knife that arises if the LSB setting is too low.

With Antilock Brakes (ABS)

10. *Anti-lock brakes are the base-level electronic control technology. It is desirable to specify systems with advanced features such as Electronic Brake Distribution or Electronic Stability Control.*

    There has been remarkable technical progress over the past decade. ABS now provides a platform on which other advanced controls are built. It is preferable to use a system that has adaptive brakes as one of its features. Aim higher!

11. *ABS should be used on towing vehicles, particularly on lightweight ones, to give protection against jack-knife, unless adaptive brakes are installed.*

    Relatively light-weight vehicles are likely to have a large variation in the axle braking coefficients between laden and unladen conditions. Adaptive brakes will reduce the axle braking coefficients so that gross wheel lock-up does not occur. Otherwise, antilock protection is recommended.

12. *Vehicles with ABS should also be fitted with automatic brake adjusters.*

    Otherwise, ABS modulation cycle time will be increased.

13. *When ABS is installed on a towing vehicle, an ABS electrical connector should always be provided for the towed vehicle.*

    Otherwise, a trailer with ABS will not be powered. Note that there is no design rule (ADR) requirement to provide a connector.

14. *Truck ABS should be wired to have veto control over powerful auxiliary brakes.*

    Auxiliary brakes act through the drive-axle group and may contribute to wheel lock-up. Truck ABS should be able to disable the auxiliary brake to assist in regaining wheel rotation. ABS systems have an output that can be used for this.

15. *For trucks that are (or could be) used on unsealed roads, an 'off-road mode' should be available and be controllable at the driving position. At each ignition start, the ABS should revert to on-road mode.*

    This feature allows limited wheel lock-up and shortens stopping distance on loose surfaces. It provides a reasonable balance between stopping performance and lateral stability performance. Most current generation ABS systems have this feature.

16. *If only one axle is sensed in an axle group, the axle most likely to lock-up during braking should be sensed (i.e. 'sense-low strategy'). This recomendation is applicable when only one axle in a multi-axle group is sensed.*

    The sense-low startegy ensures that wheel lock-up does not occur in the controlled axle group during braking. This is the best result for good directional control and it avoids any tyre flat spotting. A tri-axle group should have two axles sensed to achieve acceptable wheel lock-up protection.

Note that it is preferable to sense two axles in a bogie or tri-axle group, although this is not usdually done.

17. *It is recommended that the dolly trailer of an A-type vehicle have load-sensing brakes and the supported trailer have an ABS / EBS.*

    A Load Sensing Brake System (LSB) will minimize any propensity for wheel lock-up on the dolly trailer. The EBS and RSS features are not paramount on a dolly trailer. By not installing electronic brake control on the dolly one electrical connection is avoided, which helps to improve the capacity of the elecrical supply for electronic units on a roadtrain.

With Automatic Traction Control (ATC)

18. *If the truck has both Antilock brakes (ABS) and Automatic Traction Control (ATC), (at least) two axles on the drive-axle group should be sensed. That is, the recommended system for a 6x4 truck has 4 modulators and 6 sensors.*

    The proposed system enables the full performance of ABS and ATC to be achieved. If only one axle is sensed then both a 'sense-high strategy' and 'sense-low strategy' are being used, which is undesirable. This recommendation is particularly important is the drive group suspension is brake-reactive.

With Electronic Brake Distribution (EBD)

19. *When Electronic Brake Distribution is used on a truck, the trailer should have Antilock brakes as a minimum. It is preferable for the trailer to have an adaptive brake system such an LSB or Trailer EBS.*

    Truck EBD will reduce the drive-group brake power to achieve about balanced wheel slips on the sensed axles. Proportionately the trailer will take more of the braking load. There is a risk that gross wheel lock-up might occur. Therefore ABS should be installed as a minimum. An adaptive brake system would better balance the truck and trailer.

With Electronic Braking Systems (EBS)

20. *Trailers attached to vehicle parts with EBS should either have load-sensing brakes (LSB) or Trailer EBS.*

    EBS implements Trailer Response Management. Poor brake balance can occur if the trailer is not matched to the truck. EBS is usually set-up assuming that a European trailer (which has an adaptive braking feature) is being towed. Therefore, the trailer should have an adaptive brake system; otherwise the vehicle is likely to exhibit gross wheel lock-up.

21. *Suppliers of EBS vehicles into the Australian market should develop an Australian set-up specification. In particular, the truck should be set for a trailer onset braking level of 65 kPa and there should be no 'lead' given to the trailer.*

    Effectively the recommendation is to assume that the trailer does not have EBS or LSBs. A different set-up will be approriate for a fleet having trailers with EBS or LSBs.

    Truck EBS should be set so that the onset-braking pressure of the truck is 70 kPa.

Box 4

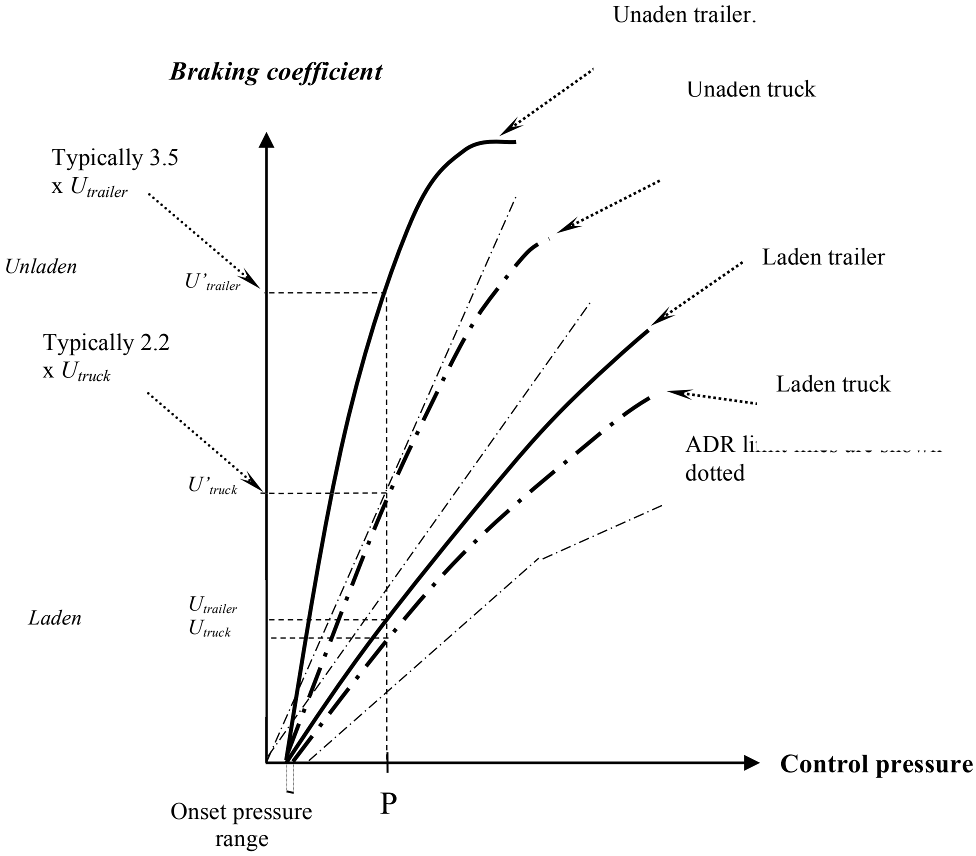


Figure 8(a) No load sensing brakes.

Setting of Load Sensing Brake Valves

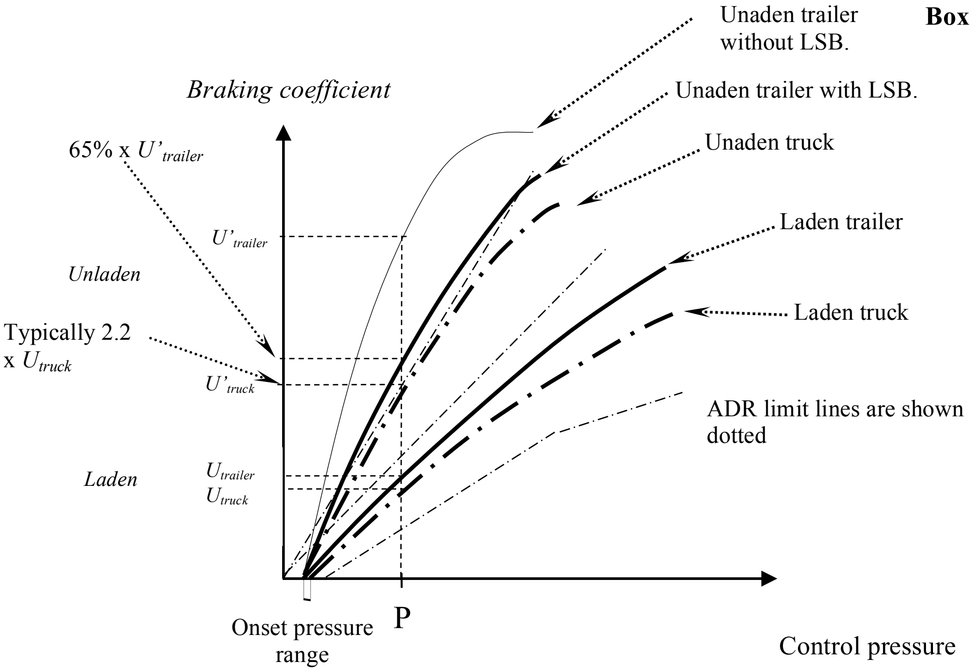
LSBs can improve the compatibility brake balance when they are used only on the trailer, if the trailer curve moves closer to the truck curve. Because trailers usually experience a greater proportional load change between the fully-laden and the unladen conditions, the curve for the unladen trailer will be well above that for the unladen truck. This is illustrated in Figure 8(a). Typically the trailer experiences a weight change between laden and unladen conditions of at least 3. For the truck this ratio is typically about 2.

In 8(a) the unladen curves for the trailer are well above that of the truck. There is a risk of trailer swing. In 8(b) a load sensing valve has been used to drop the trailer curve down. The LSB setting in this illustration is 65%. It produces a much better balance when lightly laden that the unmodified combination. The trailer characteristic is slightly above the truck characteristic, which is desirable.

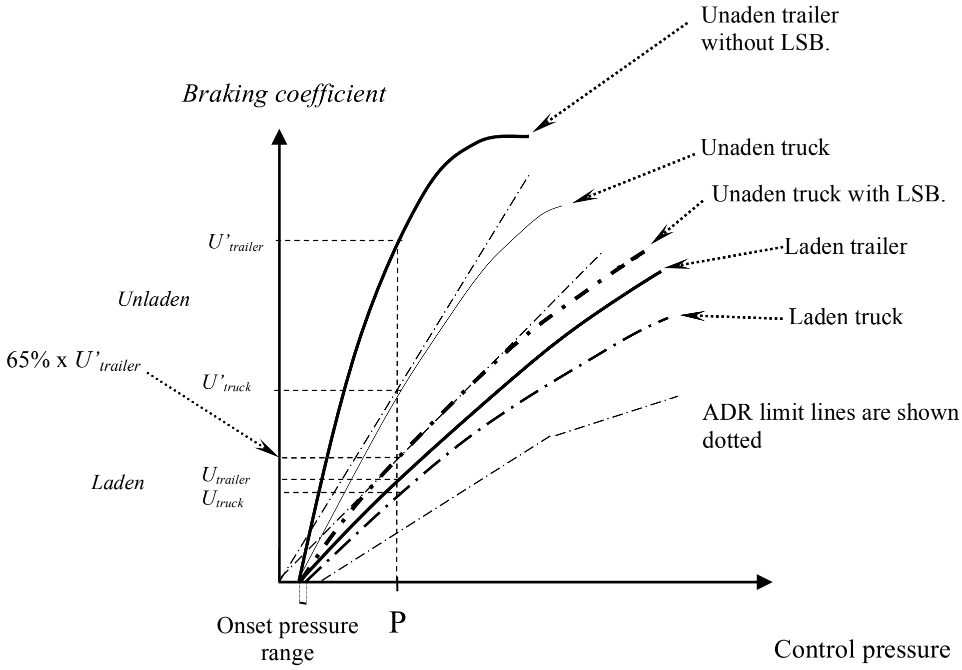
Figure 8(c) shows that if only the truck has a *Load Sensing Brake System* , then the situation is made worse. The LSB on the truck will reduce the truck curve and move it away from the trailer curve. This increases the risk of trailer swing when the vehicle is lightly laden.

The closer are the truck and trailer curves the better. That is, the smaller the distance between U_{truck} and $U_{trailer}$&U'_{truck} and $U'_{trailer}$ respectively, the better. The unladen performance is the most demanding.

Box 4 continued



8 (b) Load sensing brakes on the trailer only



8 (c) Load sensing brakes on the truck only

Figure 8 The effect on the characteristics of adding a load sensing valve to the trailer is illustrated.

(a) Without LSBs

(b) Trailer only has an LSB

(c) Truck only has an LSB

With Electronic Stability Control (ESC):

22. *If the truck has an Electronic Stability Control system then the trailer should, as a minimum, have an Electronic Brake System (Trailer EBS).*

    The ESC will activate the trailer brakes during operation. The brake level is typically about 50 %. A trailer EBS will be best able to manage the emergeny braking event. The antilock brake function that is included in EBS should prevent gross wheel lock-up occurring. The EBS function will set the brake level to that best suited to the load and road conditions.

23. *Best performance from a truck ESC system will be obtained from a 6S6M system. That is, each wheel on a three-axle truck is individually sensed and controlled.*

    Individual wheel sensing and control provides the best possible response. Weight transfers within the drive axle group will not lessen the performance because they can be compensated for.

    An EBS combined with a Roll Stability Program (RSP) on a trailer constitutes trailer Electronic Stability Control. Sensing of two axles in a tri-axle group will provide superior ESC performance compared with sensing of one axle only. It will usually be adequate to sense one axle in a bogie-axle group on both a semi-trailer and a dog trailer.

General Recommendations with Electronically-Controlled Braking Systems

24. *For trucks that have an EBS, EBD or ESC, the supply voltage (either 12V or 24V) should be the same as the voltage that the CAN signal bus operates at (either 12V or 24V).*

    Trailer Electronically Controlled Brake Systems (Tr EBS) now require either 24V or multi-volt (i.e. either 12V or 24V) power. There is no current Australian offering that is powered at 12 V only. Therefore, trailer EBS can be supplied at 24 V in all instances.

    Irrespective of the power supply voltage, the electronic controller assumes that the CAN communication bus will operate at the same voltage as the supply level. Therefore, the voltages must be the same if communication is to occur.

    It is common for European and Japanese trucks, which have 24V electrical systems, to have a voltage reducer fitted (24V to 12V) so that the trailer brake controller is powered at 12V. This practice resulted from a now deleted requirement in ADR 35 that the trailer ABS connector be powered at 12 V. In this case, a converter module is necessary to change the truck CAN level from 24V to 12V to enable communication with the trailer.

    North American and Australian trucks have 12 V voltage level. If a step-up converter is used to supply the trailer with 24V power, a 'multi-volt' communication module will be needed on the truck to provide a 24V CAN bus level.

    CAN converter modules are now availble that alter the CAN bus voltage level. For a European or Japanese truck it is important that the converter module is bi-directional; that is passes communication signal from the trailer to the truck as well as vice-versa. European truck EBS may alter the Trailer Response Management level depending upon whether the trailer is communicating via the CAN bus.

25. *The electrical connector keying, circuit position and voltage level should accord with the standard ISO 7638-1 (24V) or -2 (12V).*

    This is important so that operators have confidence that equipment will not be damaged and that communication is possible when conections are made.

    Some truck and trailer suppliers provide dual socket connectors – with 12V and 24V circuits respectively – to allow a fleet with mixed trailer voltages to be connected. This practice is acceptable assuming that each connector has the same CAN and power voltage levels.

    Some EBS suppliers have developed a 'multivolt' trailer EBS plug that has both a 12V and a 24V keyway. This can be used on both a 12V and 24 V truck to supply a multi-volt trailer EBS.

It is not advisable to have two-keyways on a socket connector because of water ingress problems that arise.

26. *The EBD / EBS connector on the towing vehicle should be a socket type.*

    The usual practice is to provide a socket connector at the back of a towing vehicle and a plug connector at the front of the towed vehicle. However, this practice is not specifically mandated in the Australian Design Rules and may not be followed. Whilst variations from the recommendation are acceptable in a closed fleet, it is important that a consistent connector type is used so that casual connection of trucks and trailers is possible.

27. *The trailer EBS / ESC connector should be supplied at the native truck voltage level, unless practical considerations require the voltage to be changed.*

    Voltage converters should not be routinely installed unless a good reason exists for using them. That is, the starting point for voltage consideration whould be the base truck voltage (either 12 V or 24 V). There is no longer any design rule limitation on the voltage level.

    It will be necessary to fit a converter in a mixed fleet that has both 12 V and 24 V trailers. In this instance, it is preferable to standardise on a 24 V supply level, which may require a voltage inverter (step-up unit) on some trucks.

28. *A 24 V supply level is sensible for multi-trailer EBS and ESC applications.*

    A 24 V supply level is sensible for multiple trailer vehicles because supply current draw is lower and therefore smaller voltage drops occur than at the 12V supply level.

    It is unwise to supply three trailer ABS or EBS systems at the 12 V level because the voltage level may be inadequate on the third trailer. Expereicne has shown that two trailers can be satisfactorily suppled at 12 V.

    Generally a 24 V supply level to trailers is prefered because it provides a strong power supply and is suitable for all current trailer EBS susyems marketed in Australia.

29. *The adjustment of wheel-speed sensors should be routinely checked when the brakes are serviced.*

    Wheel speed sensors sometimes get out of adjustment. Resetting is simple and involves using a blunt prod to push the sensor onto the pole ring and then allowing the gap to be reset by spring action. If sensors are out of adjustment the system will not function to full potential.

30. *When wheels are sensed on a tri-axle or quad-axle group, at least two axles should be sensed.*

    ADR 38 can be interpreted to require that at least two axles are sensed on a trailer tri-axle group. It is not a requirement in ADR 35 for trucks with a tri-axle group. Tri-axle drive groups are now available on some truck models. Two axles (at least) should be sensed so that gross wheel lock-up can be protected against. Sensing on one axle only may not achieve this.

31. *Electronic trailer signalling is preferred.*

    Electronic signalling (which occurs via the CAN bus connection) speeds up the brake response on long vehicles and allows status information to be shared between the vehicle parts.

    Vehicles should be configured to have electronic signaling to all the parts that have electronic brake controls. It is undesirable to have a vehicle part in the middle of a multiple combination that cannot relay the electronic signals to following vehicles.

General Air System Recommendation

32. *OEM Vehicle Manufacturers should adopt a clear colour code for pneumatic polyamide brake hoses. A suggested code is:*

Air supply lines:	Red
Service brake control lines:	Blue
Park brake lines:	Green
Service brake actuator lines	Black

Colour coding helps the serviceman trace the air system and will speed up fault-finding and servicing of vehicle brake systems.

33. *Trailer handpiece brake controls should be spring-to-off.*

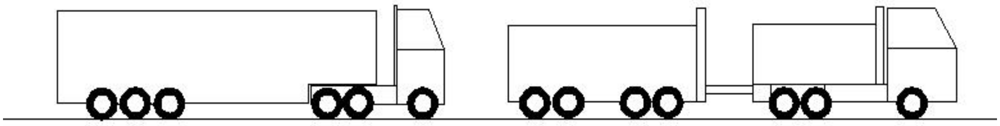
A trailer handpiece that can be left engaged might result in over-heated trailer brakes. Spring-to-off controls provide protection against the trailer brakes being inadvertently left dragging. The trailer brakes should only be applied by a deliberate and sustained control action by the driver.

9 Combinations Likely to Meet the Code's Recommendations

The following three Tables summarize the configurations of brake technologies that for which a high degree of confidence exists that the vehicles will meet the performance standard if they are appropriately set-up.

The set-up should account for the actual characteristics of the towing vehicle. Therefore, an *EBS* truck should be set-up approriately for the trailer(s). A load sensing brake system *(LSB)* should be set-up so that the compatibility characteristics of the towing and towed vehicles are about the same.

Mixtures of brake technologies other than those shown in Tables 2, 3 & 4 might meet the performance standard. This should be proven by calculations (or tests) for the particular vehicle.



Semi-Trailer	Prime Mover	Dog Trailer	Truck
EBS*	EBS	EBS*	EBS
LSB	EBS	LSB	EBS
ABS#	EBS	ABS#	EBS
EBS*	EBD	EBS*	EBD
ABS#	EBD	ABS#	EBD
LSB⇧	ABS#	LSB⇧	ABS#
LSB⇧	LSB⇧	LSB⇧	LSB⇧
ABS#	ABS#	ABS#	ABS#
ABS#	ESC	ABS#	ESC
EBS*	ESC	EBS*	ESC

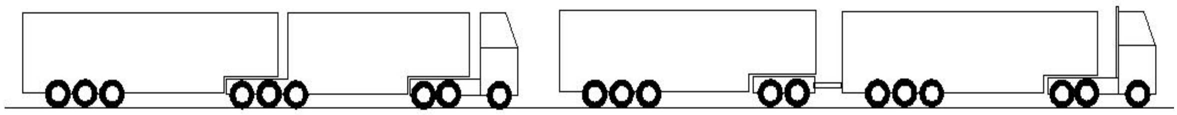
Table 2 Recommended mixtures of brake technologies for single-trailer vehicles.

* In Australia, trailer EBS is coupled with trailer Roll Stability System (RSS). This is assumed.

On new vehicles EBD / EBS / ESC should be specified instead of ABS.

⇧Unladen brake coefficients of the two vehicles should be matched except that an LSB should not be set below 50% (unladen).

Onset (threshold) pressures should be balanced between vehicle parts in a 15 kPa range.



B-Trailer	A-Trailer	Prime Mover	Second Trailer	Dolly Trailer	Semi-Trailer	Prime-Mover
EBS*	EBS*	EBS	EBS*	LSB	EBS*	EBS
LSB	LSB	EBS	LSB	LSB	LSB	EBS
ABS[#]	ABS[#]	EBS	ABS[#]	LSB	ABS[#]	EBS
EBS*	EBS*	ESC	EBS*	EBS	EBS	ESC
EBS*	EBS*	EBD	EBS*	LSB	EBS*	EBD
ABS[#]	ABS[#]	EBD	ABS[#]	LSB	ABS[#]	EBD
LSB⇧	LSB⇧	EBD	LSB⇧	LSB⇧	LSB⇧	EBD
LSB⇧	LSB⇧	ABS^	LSB⇧	LSB⇧	LSB⇧	ABS[#]
LSB⇧	LSB⇧	LSB⇧ + ABS[#] ^	LSB	LSB⇧	LSB⇧	LSB⇧
ABS[#]	ABS[#]	ABS[#] ^	ABS[#]	LSB⇧	ABS[#]	ABS[#]

Table 3 Recommended mixtures of brake technologies for two-trailer vehicles

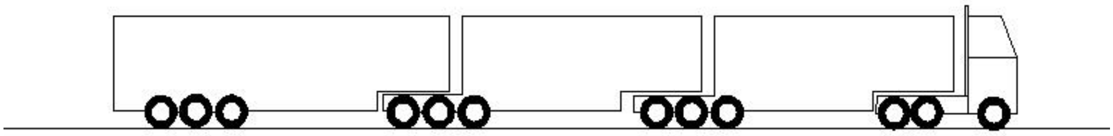
* In Australia, trailer EBS is coupled with trailer Roll Stability Program (RSP). This is assumed.

^ ADR 64 requires that B-double prime movers have an *Antilock* brake function.

On new vehicles EBD / EBS / ESC should be specified instead of ABS.

⇧Unladen brake coefficients of the vehicles should be matched except that an LSB should not be set below 50% (unladen). The LSB on a dolly trailer should be set to 60% (unladen).

Onset (threshold) pressures should be balanced between vehicle parts in a 15 kPa range.



C-Trailer	B-Trailer	A-trailer	Truck
EBS*	EBS*	EBS*	EBS
EBS*	EBS*	EBS*	ESC
ABS#	ABS#	ABS#	EBS
LSB⇧	LSB⇧	LSB⇧	LSB⇧ + ABS# ^
LSB⇧	LSB⇧	LSB⇧	EBS
LSB⇧	LSB⇧	LSB⇧	ABS# ^
ABS#	ABS#	ABS#	ABS# ^

Table 4 Recommended mixtures of brake technologies for a B-Triple vehicle.

* In Australia, trailer EBS is coupled with trailer Roll Stability Program (RSP). This is assumed.

^ ADR 64 requires that B-double prime movers have an *Antilock* brake function. This has been assumed to carry over to B-triple prime-movers.

On new vehicles EBD / EBS / ESC should be specified instead of ABS.

⇧Unladen brake coefficients of the vehicles should be matched except that an LSB should not be set below 50% (unladen). The LSB on a dolly trailer should be set to 60% (unladen).

Onset (threshold) pressures should be balanced between vehicle parts in a 15 kPa range.

10 Glossary

Antilock Brake System (ABS)

Acts to prevent wheel lock up during braking by altering the service brake control level at each controlled wheel.

ABS Platform

A basic *ABS* system to which is added additional functional elements such as *ESC, ACC* or *Brake Assist*.

Adaptive Cruise Control (ACC)

A system that applies the auxiliary brake and if necessary the service brake to increase the separation distance (i.e. the distance between the truck and the vehicle immediately in front) when the cruise control is operating.

Anti Skid Brakes – see ABS

Australian Design Rules

The national standards for new vehicles. The current applicable braking rules are ADRs 35/03 (trucks) and ADR 38/04 (trailers)

Automatic Brake Adjuster (ABA)

A mechanical device that adjusts individual service brakes at each brake application to keep the individual brake in good adjustment. An ABA must be set-up correctly each time the brake linings / pads are changed.

Autonomous Emergency Braking (AEB)

An electronically controlled braking system that automatically applies the service brakes so as to avoid or minimize the impact of a collision. The system uses advanced visual and / or radar techniques to identify a likely collision situation.

Automatic Traction Control (ATC)

A system that acts to prevent drive wheel slipping during tractive effort. It is always available in conjunction with ABS.

Auxiliary brakes

A mechanical or electrical devise that produces retarding action at the drive wheels of a truck that does not involve service brake action. Typically the auxiliary brake action is provided by an:

- engine brake,
- exhaust brake,
- tail-shaft retarder
- transmission retarder
- regenerative braking transmission.

Future developments might involve auxiliary brakes on trailers.

Available tyre-road friction

The ratio of **retardation force / weight force** for a tyre on a road surface at which the tyre is on the point of locking up.

Brake Assist (BA)

A system that manages a severe service brake application so as to achieve optimum stopping distance performance without loss of directional control.

Braking coefficient (longitudinal)

The ratio of the longitudinal retardation force on an axle / weight carried by the axle. The term can also be applied to the total retardation and weight force ratio of a vehicle part. Braking coefficient (longitudinal) is also called the friction utilization.

Braking coefficient (lateral)

The ratio of the lateral (cornering) forces on an axle / weight carried by the axle. The term can also be applied to the total lateral force and weight force ratio of a vehicle part. Braking coefficient (lateral) is also called the cornering coefficient.

Central Tyre Inflation System (CTI or CTIS)

This is an automatic adjustable typre pressure system, usually set by the driver via a dash mounted controller, that provides a lower tyre pressure for lightly loaded tyres and a high tyre pressure for heavily laden tyres.

CAN (Controlled Area Network) bus

An electronic communication bus (wiring system involving three wires) for

communication of information between distributed micro-controllers and sensors on trucks and trailers.

Coupling Force Control (CFC) - Also called Trailer Response Management (TRM)

A system that manages the control signal level to the trailer(s) in order to improve the brake compatibility balance.

Drag Torque Control (DTC)

A system that increases the engine fuelling level to overcome drag on the rear (drive) axles.The auxiliary retarder may also be disabled.

Electronic Brake Distribution (EBD)

An electronic control system that is integrated with either *ABS* or *EBS* that

alters the service brake level between axles on a vehicle in response to the estimated load level. This function is comparable to LSB although the methods of control are different.

Electronic Brake Safety System (EBSS)

An electronic brake control system being marketed in Australia that incorporates *ABS*, *EBD* and electronic trailer signalling. It can have ECS as an option.

EBSS should not be confused with EBS.

Electronic Control Module (ECM)

An electronic unit that implements programmed brake functions in response to signals

and switch positions. The action is implemented electronically via output circuits. ECM for trucks can either be 12V powered (based on North American practice) or 24V powered based on European and Japanese practice.

Electronically (Controlled) Brake System (EBS)

A high-level brake control system that communicates brake control

information between sensors and actuators using electronic CAN communication. *EBS* includes *Coupling Force Control* and electronic signalling to trailers. *EBS* is available on all European trucks and some Japanese trucks. It is not available on North American or Australian manufactured trucks.

Electronic Stability Control (ESC, ESP)

Acts to improve truck trajectory by applying selected brakes, controlling engine

torque and providing wheel lock-up protection. The system monitors the wheel speeds, steering wheel location and lateral acceleration to identify poor or unsafe conditions and to implement a corrective response.

EBS Platform

A basic *EBS* system to which is added additional functional elements such as ESC, ACC and Brake Assist.

Load-Sensing Brakes (LSB – Also Load-Proportioning Brakes or Load-Sensing Valves

A pneumatic control system that reduces the brake control level to one (or more) axle groups on a vehicle by a ratio determined by the load on a sensed axle. The ratio is pre-set and adjustable. On a truck the drive-group brake level is reduced when the load is light.

Lane Departure Warning (LDW) – also Lane Assist

A intelligent system that optically detects the lane markings and warns the driver when the truck moves across a lane marking (or off a sealed pavement) without any driver steering input or trafficator action.

Modulator Valve

A pneumatic valve with electronic control that acts to either allow, block or release service air brake pressure to the service brake actuators.

Modulator Valve - Actuating

A Modulator Valve that has the added capability of delivering air pressure to the service brake actuators under instruction from an ECM.

Retractable (Lift) Axles

A design that causes one or two axles to be lifted when a vehicle is lightly laden. The lifting force is usually pneumatic and the lift control electronic. This system alters the brake distribution on a truck or a trailer.

Roll Stability System (RSS) – also called Roll Stability Program (RSP)

An electronic brkae control system that predicted impending vehicle roll-over and acts to reduce the vehicle speed by applying service brakes and / or the auxiliary brakes on the truck.

Sense-Low Strategy

Installation of wheel sensors onto the wheels that lock-up first on an axle. Other unsensed wheels in the axle group are controlled according to the sensed wheel speeds.

Sense-High Strategy

Installation of wheel sensors onto the wheels that lock-up last on an axle group. Other unsensed wheels in the axle group are controlled according to the sensed wheel speeds.

Trailer Electronically (Controlled) Brake System (TEBS)

A high-level brake control system that communicates brakecontrol information between sensors and actuators using electronic CAN communication.

Trailer Response Management (TRM)

The general name for the management of the brake control level on a trailer.

There are two aspects: firstly, the setting of the trailer signal level at a calculated leveland secondly generation of a CAN bus (electronic) signal that is sent by the truck to the trailer(s).

Trailer Response Signalling (TRS)

Electronic communication of the desired braking level from a truck to the trailer(s) via the Can bus.

Vehicle Stability Program - see ESC

Wheel slip

A measure of the relative speed between a wheel and the vehicle speed. It is an indication of the braking (or tractive) effort that an individual wheel controbutes.

Wheel slip = actual wheel speed / free running wheel speed.

A truck tyre typically locks up at a slip of about 0.15.